

# **MaP Graduate Symposium**

## **featuring the MaP Award 2017**

The 12<sup>th</sup> Annual Gathering of Materials & Processes Researchers at ETH Zürich

**Thursday, 22 June 2017**  
**ETH Zürich Zentrum**

[www.map.ethz.ch/graduate-symposium →](http://www.map.ethz.ch/graduate-symposium)

**Symposium Booklet**

**MANY THANKS TO OUR SPONSORS!**



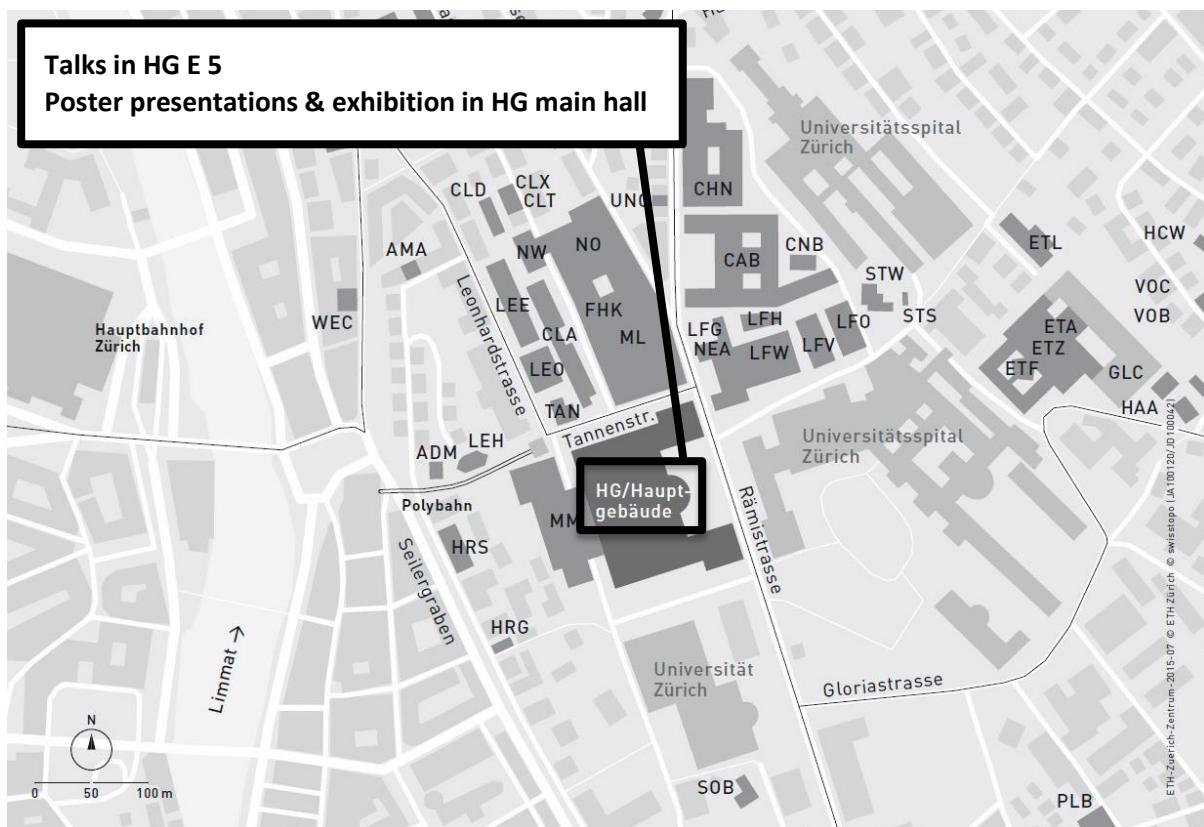
The Chemical Company

**oerlikon  
balzers**

## TABLE OF CONTENTS

PROGRAM.....	4
ABSTRACTS OF TALKS.....	6
ETH SPIN-OFF SPECIAL .....	14
POSTER PRESENTATIONS .....	15
ABSTRACTS OF POSTERS .....	18
LIST OF PARTICIPANTS .....	45
NOTES .....	50

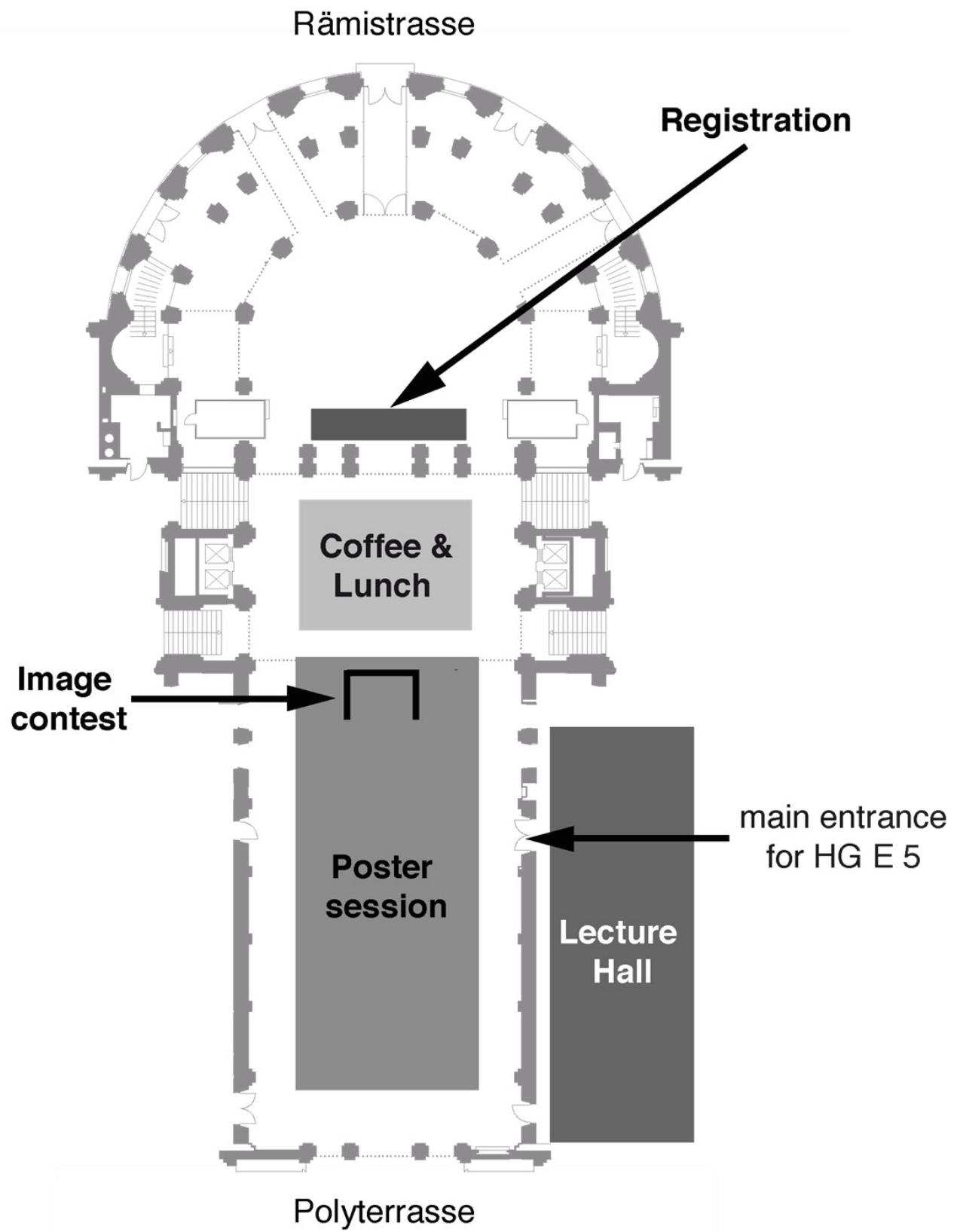
## SITE MAP ETH ZENTRUM



## WLAN ACCESS FOR EXTERNAL GUESTS:

Network: public  
Login: MaPGradSymp  
Password: MaP2017

# HG E-floor



# PROGRAM

08.00	<i>Registration</i>
08.50	<b>Prof. André R. Studart</b> , <i>MaP Director</i> Opening remarks
09.00	<b>Matija Varga</b> , <i>Wearable Computing, D-ITET</i> On-Skin Liquid Metal Tilt Sensor
09.15	<b>Kevin Bircher</b> , <i>Experimental Continuum Mechanics, D-MAVT</i> Microstructure Based Prediction of the Deformation Behavior of Soft Collagenous Membranes
09.30	<b>Kirstin Casdorff</b> , <i>Wood Materials Science, D-BAUG</i> A Closer Look at Plant Cell Walls
09.45	<b>Dr. Maria Ibáñez</b> , <i>Functional Inorganic Materials, D-CHAB</i> Pb-Ag-S-Te Nanocomposites Produced from the Bottom-Up Processing of K <sub>2</sub> Te-Surface Treated PbS-Ag <sub>2</sub> S Heterostructured Nanoparticles
10.00	<b>Michele Zanini</b> , <i>Interfaces, Soft Matter &amp; Assembly, D-MATL</i> Rough Particles at Liquid-Liquid Interfaces: Arrested Adsorption and "Universal" Emulsion Stabilization
10.15	<i>Coffee Break &amp; Poster Session</i>
11.15	<b>Dr. Patrick A. Rühs</b> , <i>Complex Materials, D-MATL</i> Rheology of Living Bioinks Used in 3D Printing
11.30	<b>Leonardo Pierobon</b> , <i>Metal Physics &amp; Technology, D-MATL</i> Skyrmion Lattice Collapse and Defect-Induced Melting
11.45	<b>Agnieszka Ładosz</b> , <i>Transport Processes &amp; Reactions Laboratory, D-MAVT</i> Phase Separation in Microdevices: Separate Droplets from Carrier Fluid by Capillary Forces
12.00	<b>Hen-Wei Huang</b> , <i>Multi-Scale Robotics, D-MAVT</i> Programming Magnetic Anisotropy in Reconfigurable Origami Micromachines
12.15	<i>Lunch &amp; Poster Session</i>

<b>MaP Award 2017</b>	
13.45	<b>Dr. Luca Hirt, Biosensors &amp; Bioelectronics (D-ITET)</b> Electrochemical Surface Patterning and Additive Manufacturing with FluidFM
14.05	<b>Dr. Loredana Protesescu, Functional Inorganic Materials (D-CHAB)</b> Novel Luminescent Colloidal Nanocrystals and Studies on Nanocrystal Surface Chemistry
14.25	<b>Dr. Jessica Schulz, Drug Formulation &amp; Delivery (D-CHAB)</b> Improving Enzymatic Oral Therapies via Site-Specific Polymer Conjugation
14.45	<i>Coffee Break</i>
15.30	<b>Claire Donnelly, Mesoscopic Systems, D-MATL</b> Buried Internal Magnetic Configurations Revealed with Hard X-Ray Magnetic Tomography
15.45	<b>Dr. Sudhir Kumar, Interface &amp; Surface Engineering of Nanomaterials, D-CHAB</b> Colloidal 2D Perovskites for Ultrapure Green Optoelectronics: Synthesis and Applications
16.00	<b>Chiara Vailati, Wood Materials Science, D-BAUG</b> Wood Bilayers for Autonomous Climate Adaptive Building Shells
16.15	<b>Nicholas H. Cohrs, Functional Materials Laboratory, D-CHAB</b> Soft Total Artificial Hearts – a New Approach for Heart Replacements
16.35	Flash Poster Presentations
16.45	Industry Presentations “ETH Spin-Off Special”
17.15	Award Ceremony
17.45	<i>Industry Apéro Riche</i>

# ABSTRACTS OF TALKS

## Session 1: 09.00 – 10.15

### On-Skin Liquid Metal Tilt Sensor

Matija Varga<sup>1</sup>, Collin Ladd<sup>2</sup>, Siyuan Ma<sup>2</sup>, Jim Holbery<sup>2</sup>, and Gerhard Tröster<sup>1</sup>

<sup>1</sup> Wearable Computing, D-ITET, ETH Zurich, <sup>2</sup> Applied Sciences Group, Microsoft Corporation (US)

---

### Microstructure Based Prediction of the Deformation Behavior of Soft Collagenous Membranes

Kevin Bircher<sup>1</sup>, Alexander E. Ehret<sup>1,2</sup>, and Edoardo Mazza<sup>1,2</sup>

<sup>1</sup> Experimental Continuum Mechanics, D-MAVT, ETH Zurich, <sup>2</sup> Mechanical Integrity of Energy Systems, Empa

The mechanical response to biaxial and uniaxial tensile loading of two soft collagenous tissues, human amnion and bovine Glisson's capsule, is analyzed on the length scale of the tissue ( $\sim$ mm) and the collagen fibers ( $\sim$ μm). Microstructural features such as organization and quantity of collagen fibers were used to determine the parameters of a simple discrete fiber network model. The microstructure in human Amnion and bovine Glisson's capsule is fundamentally different, in that for the latter collagen fibers form thick fiber bundles, which is encompassed in the phenomenological model, revealing shear force transmission through the fibrils within the bundles. The discrete network model presents an excellent prediction of the biaxial und uniaxial response of both membranes, while revealing similar progressive fiber reorientation mechanisms in uniaxial loading as experiments from multiphoton microscopy, which is particularly relevant since model parameters were not obtained from a fitting procedure. Finally, simulations of *in-vivo* deformation levels indicate that a large quantity of fibers are in an un-crimped state in physiological loading conditions, and that the crimped fibers generally observed in histological sections are a consequence of tissue contraction after separation from the body.

K. Bircher et al., *Soft Matter* **in press** (2017)

---

### A Closer Look at Plant Cell Walls

Kirstin Casdorff<sup>1,2</sup>, Tobias Keplinger<sup>1,2</sup>, and Ingo Burgert<sup>1,2</sup>

<sup>1</sup> Wood Materials Science, D-BAUG, ETH Zurich, <sup>2</sup> Applied Wood Materials Laboratory, Empa

Wood is a hierarchical material, which macroscopic properties originating from the nanoscale structure and components. There is a lack of applicable characterization techniques on wood in the nanometer range to reveal structure-property relationships beyond SEM, TEM or nanoindentation, although this basic knowledge is crucial to improve wood properties in a controlled and desired fashion. Atomic Force Microscopy (AFM) can push the limit of resolution down to the nanoscale of the cell wall, in terms of imaging the topography and mechanical characterization. For this purpose, a testing protocol has been developed, which allows for characterizing the cell walls mechanically under natural conditions, without embedding the samples.

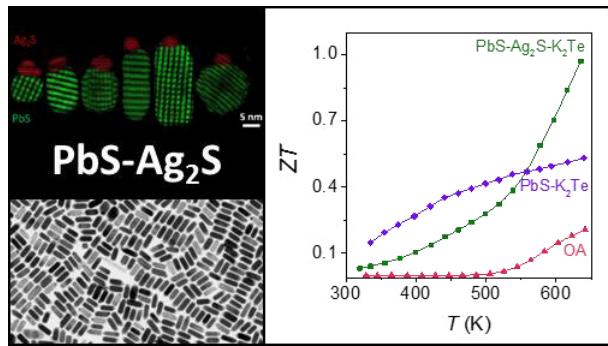
The Quantitative Imaging mode has been successfully applied to natural and modified wood. Thereby, we can differentiate for the first time between the different cell wall layers, namely CML, S<sub>1</sub>, S<sub>2</sub>, S<sub>3</sub> on a spruce cross section on the basis of their mechanical properties. Furthermore, we have visualized the change in micro fibril angle in the transition zone from the S<sub>1</sub> to the S<sub>2</sub> layer by a stiffness gradient, and proven the concept of a concentric lamella structure of the S<sub>2</sub>. In terms of modified wood, we have visualized the buildup of a homogeneous layer by layer polyelectrolyte coating, which can be used for wood surface protection. We could detect the deposition of differently charged layers by their adhesion and gain an understanding of how the processing parameters change the deposition. In terms of wood gluing, primer treated wood surfaces were characterized in detail by studying individual force-distance curves, in order to determine the work of adhesion compared to non-primer treated surfaces. The gained knowledge unravels wood-glue interactions and can help to improve the formulation of adhesives.

## Pb-Ag-S-Te Nanocomposites Produced from the Bottom-Up Processing of K<sub>2</sub>Te-Surface Treated PbS-Ag<sub>2</sub>S Hetero-Structured Nanoparticles

Maria Ibáñez<sup>1,2</sup>, Roger Hasler<sup>1</sup>, Olga Nazarenko<sup>1</sup>, Andreu Cabot<sup>3,4</sup>, and Maksym V. Kovalenko<sup>1,2</sup>

<sup>1</sup> Functional Inorganic Materials, D-CHAB, ETH Zurich, <sup>2</sup> Laboratory for Thin Films & Photovoltaics, Empa, <sup>3</sup> Catalonia Institute for Energy Research – IREC (Spain), <sup>4</sup> Institutó Catalana de Recerca i Estudis Avançats – ICREA (Spain)

Nanocomposites are interesting materials due to the vast range of properties that can emerge from the combination of the particular characteristics of each component together and the huge potential of such type of materials for a large plethora of applications. However, limitations in the control over the nanostructure of solid-state materials are halting or preventing our understanding of structure-property relationships and the development of new materials by design for the target application. Solution processing approaches are attractive due to their cost-efficiency and their compatibility with ultrahigh-throughput deposition techniques. Of particular interest for a precisely engineered nanocomposite are those methodologies that involve the use of nanoparticle/nanocrystals.



Nanocrystals can be envisioned as artificial atoms to build-up materials from. The accurate and precise control of size, shape, crystalline phase and composition of nanocrystals achieved by colloidal synthetic routes allows precisely engineering such artificial atoms. Therefore, a new generation of complex nanocomposites with nanoscale control can be created in which components and functionalities can be defined in a predictable manner. Beyond nanocrystal design, another key player on the building-up process is the nanocrystal surface ligands which control the interaction between the nanocrystals; hence the final properties of the macroscopic material.

Herein, we build-up Pb-Ag-S-Te nanocomposites with potential application in thermoelectric energy conversion. We use Ag<sub>2</sub>S nanocrystals as seeds to grow PbS nanorods, producing therefore PbS-Ag<sub>2</sub>S heterostructures. Additionally, we replace the native organic ligand with K<sub>2</sub>Te, to introduce a p-type dopant (K) and a source of Te for the anion exchange reaction to form the Te-phases. Finally, upon consolidation we produced p-type doped Pb-Ag-S-Te nanocomposites. We further characterize the charge and thermal transport properties of the different obtained materials and demonstrated how such precise engineering in the nanoparticle synthesis and surface treatment allow to tune nanocomposite properties to optimize thermoelectric performance.

## Rough Particles at Liquid-Liquid Interfaces: Arrested Adsorption and "Universal" Emulsion Stabilization

Michele Zanini<sup>1</sup>, Claudia Marschelke<sup>2</sup>, Svetoslav Anachkov<sup>3</sup>, Emanuele Marini<sup>1</sup>, Alla Synytska<sup>2</sup>, and Lucio Isa<sup>1</sup>

<sup>1</sup> Interfaces, Soft Matter & Assembly, D-MATL, ETH Zurich, <sup>2</sup> Department of Polymer Interfaces, Leibniz Institute of Polymer Research in Dresden (Germany), <sup>3</sup> Department of Chemical & Pharmaceutical Engineering, Sofia University (Bulgaria)

Surface heterogeneities, including surface roughness, significantly affect the adsorption<sup>[1-3]</sup>, motion<sup>[4,5]</sup> and interactions<sup>[6-9]</sup> of particles at fluid interfaces. These consequences of surface heterogeneities have been the focus of many studies, but there is still a lack of experimental systematic work where the roughness is tailored over a broad range of length scales and its effect on particle wettability is investigated at the single-particle level. Here, we synthesize a library of all-silica microparticles with uniform surface chemistry, but tuneable surface roughness and study their spontaneous adsorption at oil-water interfaces. Akin to contact-line pinning for macroscopic droplets on structured surfaces<sup>[10]</sup>, we demonstrate that surface roughness strongly pins the particle contact lines and arrests their adsorption in long-lived metastable positions. We also directly show that the interface around each particle is deformed as predicted by the capillary theory<sup>[6,7]</sup>. Finally, pinning imparts tremendous contact angle hysteresis for rough particles adsorbing either from the polar, or the non-polar phase. For large

enough roughness, this can practically invert the particle wettability, irrespective of their chemical nature, e.g. rough hydrophilic particles can behave as hydrophobic ones if adsorbing from the oil. As a unique consequence, the same rough particles can be used as “universal” stabilizers for both water-in-oil and oil-in-water emulsions by just changing the phase in which they are initially dispersed. These results both shed light on fundamental phenomena concerning particle adsorption and indicate new design rules for particle-based emulsifiers.

- [1] Y. Nonomura et al., *J. Phys. Chem. B* **110**, 13124 (2006); [2] D. M. Kaz et al., *Nat Mater* **11**, 138 (2012);  
 [3] A. Wang et al., *Soft Matter* DOI: 10.1039/C6SM01690A (2016); [4] G. Boniello et al., *Nat Mater* **14**, 908 (2015);  
 [5] N. Sharifi-Mood et al., *Soft Matter* **11**, 6768 (2015); [6] D. Stamou et al., *Phys. Rev. E* **62**, 5263 (2000);  
 [7] P. A. Kralchevsky et al., *Langmuir* **17**, 7694 (2001); [8] W. Chen et al., *Phys. Rev. E* **74**, 021406 (2006);  
 [9] W. Chen et al., *Phys. Rev. E* **79**, 041403 (2009); [10] J. F. Joanny et al., *J. Phys. Chem.* **81**, 552 (1984).
- 

## Session 2: 11.15 – 12.15

### Rheology of Living Bioinks Used in 3D Printing

Patrick A. Rühs<sup>1</sup>, Manuel Schaffner<sup>1</sup>, Fergal Coulter<sup>1,2</sup>, Samuel Kilcher<sup>3</sup>, and André R. Studart<sup>1</sup>

<sup>1</sup> Complex Materials, D-MATL, ETH Zurich, <sup>2</sup> School of Mechanical & Materials Engineering, University College Dublin (Ireland), <sup>3</sup> Food Microbiology, D-HEST, ETH Zurich

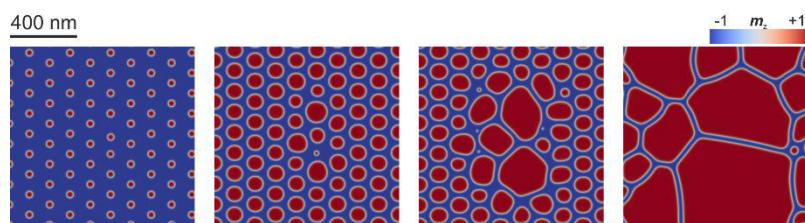
---

### Skyrmion Lattice Collapse and Defect-Induced Melting

Leonardo Pierobon<sup>1</sup>, Christoforos Moutafis<sup>2</sup>, Jörg F. Löfller<sup>1</sup>, and Michalis Charilaou<sup>1</sup>

<sup>1</sup> Metal Physics & Technology, D-MATL, ETH Zurich, <sup>2</sup> School of Computer Science, University of Manchester (UK)

Complex spin textures arise in chiral magnets due to competing interactions. A fascinating example are skyrmions and skyrmion lattices, which are promising for future data-storage technologies<sup>[1]</sup>.



They form as a result of symmetry-breaking-fields, and have been observed<sup>[2]</sup> in bulk crystals (MnSi, FeGe) or at transition metal interfaces (Co/Pt). Their spin winding gives them topological stability because it cannot be unwound

Fig. Defect-induced melting due to a point defect, and the comparison to the ideal lattice.

continuously, i.e. without a phase transition. A way of doing this is by increasing the external magnetic field until the ferromagnetic state is reached. This is largely unexplored, and is the object of our study. We use finite-difference micromagnetic simulations<sup>[3]</sup> to investigate the collapse of skyrmion lattices in ultrathin chiral magnetic films. We have found that there is a first-order phase transition of skyrmion lattice inversion characterized by a transient state in which antiskyrmions form. Furthermore, we have shown that the presence of defects significantly reduces the stability of skyrmion lattices and introduces a different kind of collapse, which we called defect-induced melting (Fig.). These findings provide us with the optimal conditions for the formation of stable skyrmion lattices and head our way to their more successful experimental realization.

- [1] S. S. P. Parkin et al., *Science* **320**, 5873 (2008); [2] S. Mühlbauer et al., *Science* **323**, 915 (2009); [3] A. Vans-teenkiste et al., *AIP Advances* **4**, 107133 (2014)
-

## Phase Separation in Microdevices: Separate Droplets from Carrier Fluid by Capillary Forces

Agnieszka Ładosz and Philipp Rudolf von Rohr

Transport Processes & Reactions Laboratory, D-MAVT, ETH Zurich

Flow of droplets in microchannels

is an excellent technique to obtain large number of well-controlled samples within short time and has found applications in biology, chemistry and life sciences. After completion of the process, the desired product is either captured within discrete slugs of dispersed phase or in carrier fluid embedding those and on-chip

phase separation is needed to recover it. With negligible influence of gravity on microscale ( $Bo \ll 1$ ), surface forces have been used to separate immiscible fluids in so-called capillary phase-separators<sup>[1]</sup>. In such devices, continuous phase exits the main channel through an array of carefully designed narrow channels (capillaries) where dispersed phase cannot enter due to capillary pressure (Fig. a). Despite widespread use, capillary separators are designed and constructed by trial-and-error method. In this work, we describe the mechanism of phase separation in a capillary phase separator and we propose and validate experimentally a model to determine the operating limits of the device (Fig. b). With functioning phase separator, droplets may be separated from the continuous liquid and undergo further processing or analysis.

[1] J. G. Kralj et al., *Lab Chip* **7**, 256 (2007)

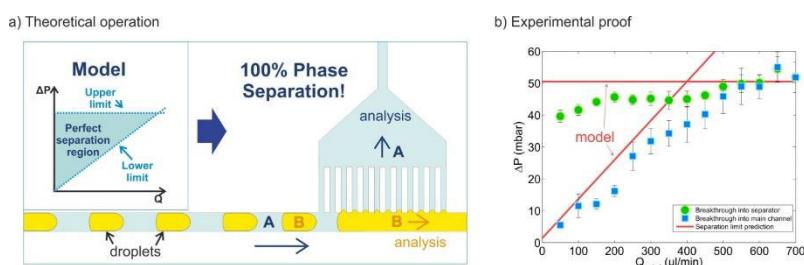


Fig. (a) Device operating at 100% efficiency- both outlets contain pure phases. (b) Experimental (marks) and modelled (solid lines) separation limits.

## Programming Magnetic Anisotropy in Reconfigurable Origami Micromachines

Hen-Wei Huang and Bradley J. Nelson

Multi-Scale Robotics, D-MAVT, ETH Zurich

Hydrogel-based micromachines are widely used in various biomedical applications due to their high swelling, biocompatibility, biodegradability, and stimuli-responses<sup>[1,2]</sup>. Recently, stimuli-responsive hydrogels have been largely employed in multi-layered structures to enable programmable shape transformations that permit on-demand delivery of therapeutic agents, including cell scaffolds<sup>[3]</sup>, microtissue transplantsations<sup>[4]</sup>, and sustained molecular release<sup>[5]</sup>. When these micromachines are equipped with programmable magnetic anisotropy, they are able to navigate in low Reynolds number media by external magnetic fields, which shows the potential in targeted therapies. A bilayered structure allows us to program the shape transformations and magnetic anisotropy independently by aligning magnetic nanoparticles in different layer<sup>[6]</sup> (Fig. a). Reconfigurable micromachines have the ability to change their shapes to alter their locomotion or perform different tasks, as the situation requires. The dexterous locomotion of magnetically driven micromachines relies on proper coordination between the shape and the magnetic anisotropy (Fig. b). In this work, we propose two approaches for programming magnetic anisotropy in reconfigurable micromachines, which are shape variant magnetic anisotropy and shape invariant magnetic anisotropy. The shape variant magnetic anisotropy allows the reconfigurable machines to switch the locomotion mode by changing shape. While the shape invariant magnetic anisotropy permits the reconfigurable micromachines to keep the locomotion mode during the shape changes. Finally, we also study the relationship between the magnetic properties and the reconfigurable morphologies by means of vibrating sample magnetometer.

[1] T. R. Hoare et al., *Polymer (Guildf)*. **49**, 1993 (2008); [2] Y. S. Zhang et al., *Science* **356** (2017); [3] M. Jamal et al., *Adv Heal. Mater* **2**, 1142 (2013); [4] S. Pedron et al., *Adv. Funct. Mater.* **21**, 1624 (2011); [5] S. Fusco et al., *ACS Appl. Mater. Interfaces* **7**, 6803 (2015); [6] H.-W. Huang et al., *Nat Commun* **7** (2016)

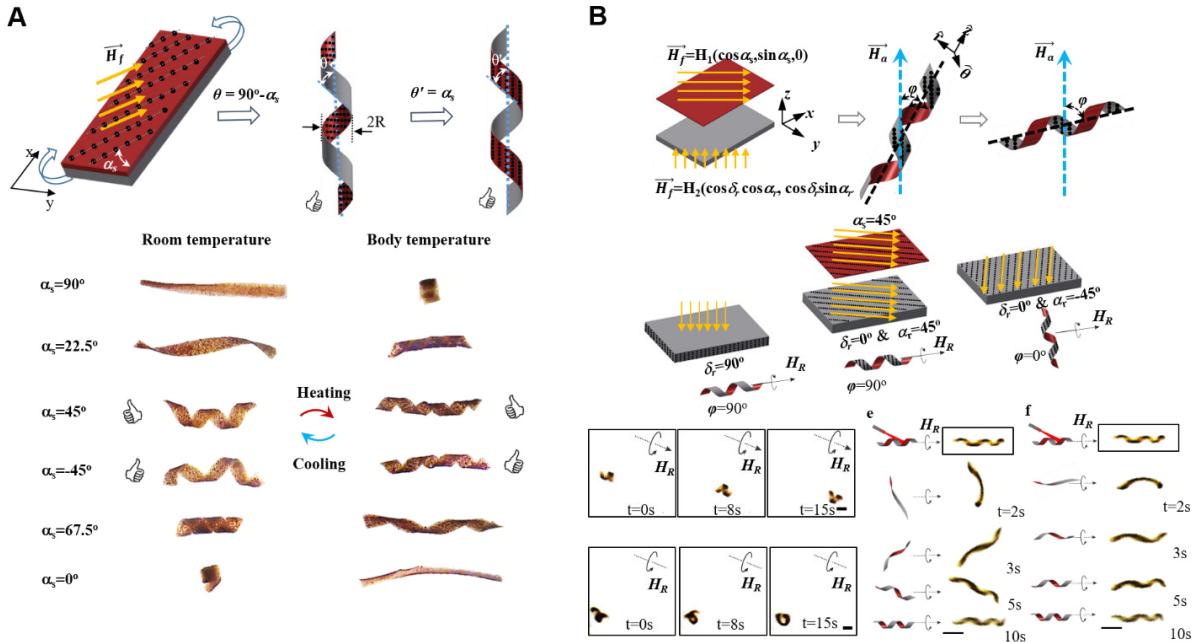


Fig. Programming the shape transformations and magnetic anisotropy in bilayered structures. A) Reconfigurable micromachines with various shapes. B) Reconfigurable micromachines programmed with various magnetic anisotropy show different locomotion modes.

## MaP Award 2017

13.45 – 14.45



### Electrochemical Surface Patterning and Additive Manufacturing with FluidFM

Luca Hirt

Biosensors & Bioelectronics, D-ITET, ETH Zurich

Additive manufacturing, with its advantages such as independence from photo masks, less material waste and freedom in geometry, is being increasingly adopted in the industries. However, the most widespread 3D printing techniques have limited resolution and are not suitable for fabrication on the micro- and nanometer scale. This gap was filled by processes based on 2-photon polymerization with a resolution down to nanometers. For metals however, there is still no established solution for additive manufacturing on such small scales.

In our laboratory, we are working with a unique tool – the FluidFM. This technology uses hollow atomic force microscopy (AFM) cantilevers to create a force-controlled micropipette. Thus, we have a system with the following features: We can precisely position a micropipette with an opening of 300nm, we can dispense liquid using a pressure controller, and we always know the forces acting on the micropipette since it is also an AFM cantilever.

In my thesis, we exploited this unique combination to create an automated metal 3D printer for the micrometer scale. The technique is based on electrodeposition from a metal salt solution which is provided locally from a FluidFM probe. Thus, the FluidFM tip serves as a local source of metal ions which are electroplated in a confined area under the tip. The AFM force feedback allows us to automate the 3D printing: Whenever the growing structure touches the cantilever, this is sensed and the process may be continued at the next desired position. In this way, we can fabricate metallic structures in a direct and mask-free manner.



### Novel Luminescent Colloidal Nanocrystals and Studies on Nanocrystal Surface Chemistry

Loredana Protesescu

*Functional Inorganic Materials, D-CHAB, ETH Zurich*

Enormous progress in synthesis and characterization of monodisperse colloidal semiconductor nanocrystals (NCs, also known as quantum dots) has been made since the discovery of quantum-size-effects almost three decades ago. A particularly difficult challenge in the chemistry of NCs is their detailed structural and chemical analysis of NC surfaces on atomistic level, limiting further progress in rational synthesis of such entities. An atomically precise image of the NC surface was not entirely discussed. Therefore, building the atomistic picture of ligand-capped NCs requires a powerful combination of modern experimental tools and atomistic modelling. In this study, several experimental techniques ( $^1\text{H}$  NMR spectroscopy, solution and solid-state  $^{119}\text{Sn}$  NMR spectroscopy, far-infrared and X-ray absorption spectroscopies and elemental analysis) were combined with atomistic simulations at density functional theory level in order to understand the surface chemistry of CdSe NCs, covered with organic ligands and with thiostannate ligands. Another challenge in this field is to identify and develop nano-scale materials that exhibit novel properties or outstanding characteristics. From visible range to far infrared, we developed new materials such as perovskite halide nanocrystals with superior photophysical quality previously achievable only with Cd-chalcogenides of complex compositions and morphologies such as core-shell CdSe/CdS NCs. The compelling combination of enhanced optical properties, inexpensiveness, lower than for Cd-based counterparts toxicity, and chemical robustness makes CsPbX<sub>3</sub> NCs appealing for optoelectronic applications, particularly for blue and green spectral regions, where typical metal chalcogenide-based QDs suffer from photodegradation. Moreover, we extend our expertise towards mid-infrared and we developed a procedure to obtain stable infrared emitters based on lead chalcogenide quantum dots.



### Improving Enzymatic Oral Therapies via Site-Specific Polymer Conjugation

Jessica Schulz

*Drug Formulation & Delivery, D-CHAB, ETH Zurich*

One of the most promising avenues for treating celiac disease is the administration of exogenous enzymes that can rapidly degrade immunotoxic gluten peptides *in situ*. Prolyl endopeptidases (PEPs) are proline-specific enzymes which, in contrast to human luminal enzymes, effectively cleave and hence detoxify gluten peptides. While promising, this approach is limited by the relative lability of the enzymes under the harsh conditions encountered in the gastro-intestinal (GI) tract. A possible strategy to overcome this problem involves conjugation of appropriate polymers to PEPs. The objective of this project was to synthesize and characterize polymer–PEP conjugates in which the polymer was introduced site-specifically at engineered cysteine residues without destroying enzymatic activity.

Cysteine residues were site-specifically incorporated on the surface of PEPs derived from *Myxococcus xanthus* (MX). The modified enzymes were conjugated with methoxypolyethylene glycole (mPEG 5,000 and 40,000 Da) and poly(amidoamine) (PAMAM G3) *via* the cysteine residues. *In vitro* activity of the PEP conjugates was analyzed, and the stability was tested in simulated GI fluids. An immunogenic-like sequence of gluten, labeled with a fluorescent dye and a corresponding quencher, and the conjugated PEPs were orally administered to rats. Upon cleavage fluorescent emission was detected and quantified with an *in vivo* imaging system to examine PEP's ability to cleave the peptide.

The mutated PEPs and polymer conjugates showed similar activity compared to the wild-type enzyme. The stability under GI conditions was significantly enhanced with increasing number of polymers attached. Our results also showed that the longer mPEG had a higher stabilization effect than the shorter polymer both *in vitro* and *in vivo*.

Site-specifically modified PEPs provide a tool for investigating the impact of polymer conjugation on enzyme stability in the GI tract. Based on its stabilizing effect, the directed conjugation of 40 kDa-PEG to PEPs may represent a simple and promising option to improve the performance of these enzymes in the treatment of celiac disease.

## Session 3: 15.30 – 16.30

### Buried Internal Magnetic Configurations Revealed with Hard X-Ray Magnetic Tomography

Claire Donnelly<sup>1,2</sup>, Manuel Guizar-Sicairos<sup>2</sup>, Valerio Scagnoli<sup>1,2</sup>, Sebastian Gliga<sup>3</sup>, Mirko Holler<sup>2</sup>, Jörg Raabe<sup>2</sup>, and Laura J. Heyderman<sup>1,2</sup>

<sup>1</sup> Mesoscopic Systems, D-MATL, ETH Zurich, <sup>2</sup> Laboratory for Micro & Nanotechnology, PSI, <sup>3</sup> School of Physics & Astronomy, University of Glasgow (United Kingdom)

Three dimensional magnetic systems promise significant opportunities for applications, providing higher density devices and new functionality associated with greater degrees of freedom. Over the past years we have worked towards both the fabrication and characterisation of three dimensional magnetic structures. In particular we have fabricated an artificial magnetic buckyball and performed a detailed characterisation of the structural and elemental properties<sup>[1]</sup>. For the determination of the magnetic configuration in a three dimensional system, we have developed hard X-ray mag-

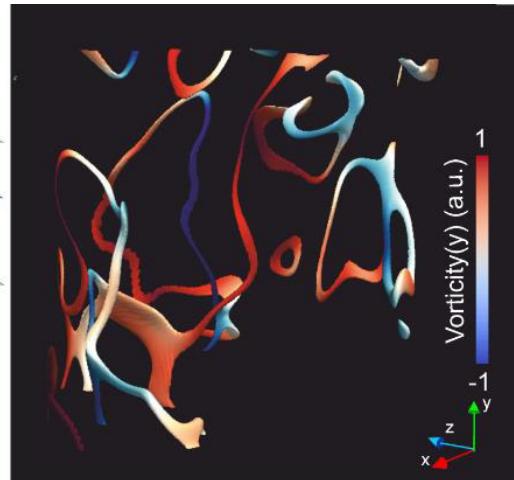
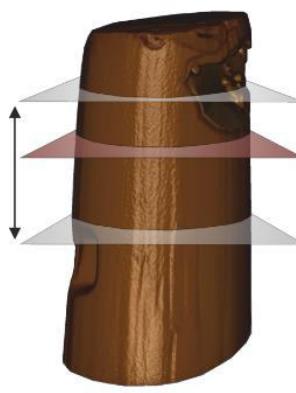


Fig. The internal magnetic configuration of a section of a 5  $\mu\text{m}$ -diameter GdCo<sub>2</sub> pillar (left) is determined using hard X-ray magnetic tomography. (right) The internal network of the cores of intersecting magnetic structures including magnetic vortices (red and blue) and antivortices (white), coloured by their vorticity, is given.

netic imaging at the nanoscale<sup>[2]</sup>, and combined this with a new iterative reconstruction algorithm to achieve hard X-ray magnetic tomography<sup>[3]</sup>. In a first demonstration, we determine the three dimensional magnetic nanostructure within the bulk of a soft magnetic micropillar, observing a complex magnetic configuration consisting of vortices and antivortices that form cross-tie and vortex walls<sup>[3]</sup>. With its high penetration depth, hard X-ray magnetic tomography opens the possibility for the elucidation of complex three dimensional magnetic structures for a range of extended magnetic systems with high spatial resolution.

- [1] C. Donnelly et al., *Phys. Rev. Lett.* **114**, 115501 (2015); [2] C. Donnelly et al., *Phys. Rev. B* **94**, 064421 (2016);  
[3] C. Donnelly et al., **under revision**

### Colloidal 2D Perovskites for Ultrapure Green Optoelectronics: Synthesis and Applications

Sudhir Kumar, Jakub Jagielski, and Chih-Jen Shih

Interface & Surface Engineering of Nanomaterials, D-CHAB, ETH Zurich

## Wood Bilayers for Autonomous Climate Adaptive Building Shells

Chiara Vailati<sup>1,2</sup>, Markus Rüggeberg<sup>1,2</sup>, and Ingo Burgert<sup>1,2</sup>

<sup>1</sup> *Wood Materials Science, D-BAUG, ETH Zurich*, <sup>2</sup> *Applied Wood Materials Laboratory, Empa*

Environmental and economic requirements put increasing pressure on the building industry concerning energy efficient and sustainable construction. Climate adaptive building shells (CABS) may well provide significant energy savings and improve the indoor environmental quality of buildings. Nowadays, the responsiveness of CABS commonly relies on extrinsic control and motorized systems based on thermal or optical stimuli. This leads to rather complex systems. In our project, we aim at developing a novel CABS system, which is based on smart wooden actuators. Wood undergoes reversible anisotropic dimensional changes due to the uptake and loss of water when exposed to changes of relative humidity. By using bilayer elements with perpendicular fiber orientation, the dimensional changes result into reversible bending movements.

In nature, deformations of plant organs and tissues such as pine cones, orchid seed pods and wheat awns are based on this mechanism. Due to the hygroscopic properties of the tissues, they react to the change of the relative humidity by bending or twisting (depending on the tissue fiber disposition). In a CABS system, such wooden actuators would respond to and take the energy for the movement from the daily change in relative humidity, which is driven by the sun.

While the behavior of wooden bilayers has been characterized, upscaling and matching the required amplitude and rate of shape change of such wooden actuators for CABS is still an issue. I will present material adapted design principles for tackling these challenges. By enlarging the surface to volume ratio of the bilayers and by coupling of two bilayer elements (Patent: EP 16184786.8) through a lever arm configuration, amplitude and rate of shape change can be amplified compared to the simple bilayer element. The final goal is the implementation of such coupled wooden bilayer systems in autonomous humidity-driven shading systems for climate adaptive building facades.

---

## Soft Total Artificial Hearts – a New Approach for Heart Replacements

Nicholas H. Cohrs<sup>1</sup>, A. Xavier Kohll<sup>1</sup>, Anastasios Petrou<sup>2</sup>, Christoph Starck<sup>3</sup>, Mirko Meboldt<sup>2</sup>, Volkmar Falk<sup>3</sup>, and Wendelin J. Stark<sup>1</sup>

<sup>1</sup> *Functional Materials Laboratory, D-CHAB, ETH Zurich*, <sup>2</sup> *Product Development, D-MAVT, ETH Zurich*,

<sup>3</sup> *Department of Cardiothoracic & Vascular Surgery, Deutsches Herzzentrum Berlin (Germany)*

Currently most implanted artificial hearts are so called Ventricular Assist Devices (VAD), which support and relieve the weakened heart. In principle, these VADs are very basic pumps, which produce a continuous blood flow, rather than a physiological pulsatile one. This seems intrinsically wrong and unhealthy, as the consequences of missing blood flow pulsatility remain unknown. In great contrast to the current focus on VAD technologies, we develop an artificial heart, which imitates the human heart in its resemblance, mechanical properties and way of pumping (i.e. by squeezing the blood). Using a 3D-printed mold and a lost-wax casting technique, it is possible to manufacture a soft total artificial heart (sTAH), which is made of one single silicone elastomer monoblock and, in contrast to existing VADs, is completely soft. Evaluation of the sTAH against physiological pre- and afterloads of the human circulatory system revealed a physiological pressure waveform, which is very similar to the one of the human heart. An aortic pulse pressure of 35 mmHg was reached, which is to our knowledge the most physiological pulse pressure, compared to any other artificial heart. Against a physiological afterload, the sTAH reaches a left ventricular flow of 2.2 L/min with a systolic/diastolic pressure of 71 to 36 mmHg. Certainly, these values are not sufficient to allow implantation into animals or even patients. However, vast improvements are feasible by using alternative elastomeric materials, optimization of the pneumatic drive and optimization of the chamber geometry.

Adapted from: N. H. Cohrs et al., *Artif. Org.* doi:10.1111/aor.12956, accepted for publication

---

## ETH SPIN-OFF SPECIAL



[www.bluact.com](http://www.bluact.com)

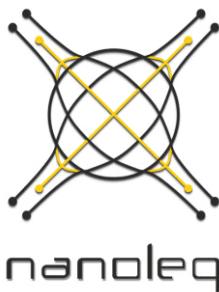
Dr. Sreenath Bolisetty, CEO

Prof. Raffaele Mezzenga, Scientific Advisor



[www.haelixa.com](http://www.haelixa.com)

Gediminas Mikutis, CTO



[www.nanoleq.com](http://www.nanoleq.com)

Dr. Vincent Martinez, CEO

Dr. Luca Hirt, CTO



[www.novamem.com](http://www.novamem.com)

Dr. Christoph Kellenberger, CEO

Dr. Michael Loepfe, CTO



[www.scrona.ch](http://www.scrona.ch)

Dr. Patrick Galliker, CEO



Custom microstructures and microfluidics  
for lab-on-a-chip research.

[www.wunderlichips.ch](http://www.wunderlichips.ch)

Dr. Dirk Van Swaay, CEO

# POSTER PRESENTATIONS

Name	Poster Title	Affiliation	Poster No.
Noha <b>Abdel Wahab</b>	Effect of Au Size on Catalyst Activity for Low Temperature Water-Gas Shift Reaction in Idealized and Realistic Reaction Conditions	Particle Technology Laboratory, D-MAVT	29
Alexandra <b>Alicke</b>	Arresting Bubble Dissolution by Interfacial Rheology Design	Soft Materials, D-MATL	10
Lauriane <b>Alison</b>	Stabilization of Food-Grade Oil-In-Water Emulsions by Chitosan-Modified Nanoparticles at Different pHs	Complex Materials, D-MATL	11
Vidyasagar <b>Ananthan</b>	Understanding Electromechanical Microstructure Evolution in Ferroelectric Ceramics	Mechanics & Materials, D-MAVT	53
Mario <b>Arcari</b>	Liquid Crystal Phase Transitions in Amyloid Fiber Nematic and Cholesteric Tactoids	Food & Soft Materials, D-HEST	21
Lucas <b>Armbrecht</b>	Magnetic Labeling for Selective Cell Capture and Single-Cell Analysis on a Microfluidic Platform	Bioanalytics Group, D-BSSE	19
Paul <b>Baade</b>	Orientation Distributions of Platelet Shaped Graphite Particles in LIB Anodes	Nanoelectronics, D-ITET	43
Björn J. <b>Bachmann</b>	A Novel Bioreactor for the Evaluation of Endothelialized Elastomer Membranes under (Supra)Physiological Stretch and Flow for Application in Ventricular Assist Devices (VADs)	Thermodynamics in Emerging Technologies, D-MAVT	27
Fabio L. <b>Bargardi</b>	Bio-Inspired Self-Shaping Ceramics	Complex Materials, D-MATL	8
Peter <b>Benedek</b>	Low Temperature Hydrothermal Synthesis of Battery-Grade LiFePO <sub>4</sub> Platelet Particles	Nanoelectronics, D-ITET	47
Nicolas <b>Bologna</b>	Stair-Rod Dislocation Cores Acting as Nano-Channels for Carrier Mono-Dimensional Transport in GaAs Nanowires	Advanced Materials & Surfaces, Empa	48
Federica <b>Boscaro</b>	Chemical Solutions for Environmentally Friendly Cements in Switzerland	Physical Chemistry of Building Materials, D-BAUG	58
Raphael <b>Brechbühler</b>	Surface Plasmon Polariton Self-Interference of Electric and Magnetic Dipoles in Front of Plasmonic Reflectors	Optical Materials Engineering, D-MAVT	40
Martina <b>Cihova</b>	Impact of Heat-Treatment Induced Microstructural Changes on the Properties of Biodegradable Mg-Zn-Ca-Lean Alloys	Metal Physics & Technology, D-MATL	5
Gabriele <b>Colombo</b>	High Speed Confocal Imaging of Sheared Colloidal Gels	Soft Materials, D-MATL	13
Eva <b>De Leo</b>	Polarization-Resolved Spectral Multiplexing Using Multi-Resonant Plasmonic Antennas	Optical Materials Engineering, D-MAVT	42
Luca <b>Del Carro</b>	All-Copper Interconnects for Electronic Chips Formed by Low-Temperature Dip Transfer	Complex Materials, D-MATL / IBM Research	20
Céline <b>Del Don</b>	Investigation of Permeation through Model Membranes on a Microfluidic Device by Fluorescence Correlation Spectroscopy	Bioanalytics Group, D-BSSE	25
Thibault <b>Demoulin</b>	Drawing Coloured Patterns in Concrete	Physical Chemistry of Building Materials, D-BAUG	55

<b>Felicitas R. Flohr</b>	Micro-3D Printing for the Fabrication of a Biomimetic Model of Functional Osteocytes	Bone Biomechanics, D-HEST	22
<b>Reza Ghanbari</b>	Diffusion of Polymers through Periodic Networks of Lipid-Based Nanochannel	Food & Soft Materials, D-HEST	18
<b>Madeleine Grossman</b>	Interfacial Strength in Nacre-Like Polymer-Matrix Composites	Complex Materials, D-MATL	12
<b>Christoph P. Guntlin</b>	Synthesis of Nanocrystalline Iron(III) Trifluoride from Molecular Precursors and its Li- and Na-Ion Storage Properties	Functional Inorganic Materials, D-CHAB / Empa	37
<b>Fabian Haag</b>	Bulk Metallic Glass Casting: Insights into Critical Cooling Using High-Speed IR Monitoring and Fast DSC	Metal Physics & Technology, D-MATL	3
<b>Michael Hausmann</b>	3D Printing of Cellulose Reinforced Composites	Complex Materials, D-MATL / Empa	7
<b>Alexander Hernandez</b>	Ultra-Flat and Structured Template Stripped Metal-Organic Halide Perovskites	Optical Materials Engineering, D-MAVT	41
<b>Marie Hoes</b>	Charge Compensating Double Doped Ceria for Improved Redox Performance of Solar Thermochemical H <sub>2</sub> O/CO <sub>2</sub> Splitting Cycles	Renewable Energy Carriers, D-MAVT	31
<b>Julia Kompalla</b>	Breath Formaldehyde Sensing with Small Sensor Arrays for Lung Cancer Detection	Particle Technology Laboratory, D-MAVT	33
<b>Sanja Kostic</b>	Towards the Development of a Novel Adhesion System between Wood Timber and Concrete: Investigation of the Wood-Glue-Concrete-Interface	Wood Materials Science, D-BAUG	60
<b>Ralph Z. Lange</b>	A Two-Dimensional Polymer with Crystalline Order	Polymer Chemistry, D-MATL	9
<b>Gaston O. Larrazábal</b>	Magic at the Interface: A Microfabrication Process for Model Oxide-On-Metal Electrodes for Electrocatalytic CO <sub>2</sub> Reduction	Advanced Catalysis Engineering, D-CHAB	35
<b>Wei-Chih Liao</b>	Local Connectivity and Confining Environments of Sn-Sites in Sn-Chabazites Are Distinguishable Using DNP-NMR	Surface & Interfacial Chemistry, D-CHAB	26
<b>Tsung-Han Lin</b>	Low Temperature Wet Conformal Metal Silicide Deposition for Transistor Technology through an Organometallic Approach	Interface & Surface Engineering of Nanomaterials, D-CHAB	36
<b>Ratan K. Mishra</b>	All-Atom Models of Tobermorite 11 Å and 14 Å – Benchmarks for Realistic Modelling of C-S-H	Physical Chemistry of Building Materials, D-BAUG	52
<b>Ahmad Moghimikheirabadi</b>	Multiscale Coarse Graining of Nonionic Surfactants Adsorbed at Fluid-Fluid Interfaces	Polymer Physics, D-MATL	2
<b>Aniket S. Mule</b>	Growth Control of CdSe Nanoplatelets Using New Organoselenium Precursors	Optical Materials Engineering, D-MAVT	44
<b>Olga Nazarenko</b>	Single Crystals of Caesium-Formamidinium Lead Halide Perovskites: Phase Stability and Gamma Dosimetry	Functional Inorganic Materials, D-CHAB / Empa	38
<b>Alessandro Ofner</b>	Glass Step Emulsification for the Production of Functional Materials	Complex Materials, D-MATL	16
<b>Philipp Okle</b>	Evolution of Solid State Dewetting of Two-Phase Thin Films	Nanometallurgy, D-MATL	1
<b>Laura Piveteau</b>	The Study of Colloidal Nanocrystals with Dynamic Nuclear Polarization NMR Spectroscopy	Functional Inorganic Materials, D-CHAB / Empa	34
<b>Sara T. R. Velasquez</b>	Powder-Based Processing of Highly-Loaded Platelet-Reinforced Composites	Complex Materials, D-MATL	15

Alain <b>Reiser</b>	Microscale Metal Additive Manufacturing	Nanometallurgy, D-MATL	6
Lex <b>Reiter</b>	Slipforming with Flexible Formwork - Inline Measurement and Control	Physical Chemistry of Building Materials, D-BAUG	56
Aline F. <b>Renz</b>	Porous Electrodes for Soft and Stretchable Microelectrode Arrays	Biosensors & Bioelectronics, D-ITET	23
Jan-Georg <b>Rosenboom</b>	Polyethylene Furanoate (PEF) as a Substitute for PET from 100% Renewable Resource-Based Cyclic Oligomers	Chemical Reaction & Separation Engineering, D-CHAB	14
Aurelio A. <b>Rossinelli</b>	High-Temperature Growth of Thick-Shell CdSe/CdS Core/Shell Nanoplatelets	Optical Materials Engineering, D-MAVT	46
Daniel <b>Sanz Pont</b>	Ultra High Performance Thermally Insulating Aerogel Mortars	Physical Chemistry of Building Materials, D-BAUG	59
Dominik <b>Schildknecht</b>	Monte Carlo Renormalization Group Study of Dipolar Coupled XY Spins	Mesoscopic Systems, D-MATL / PSI	49
Yannick R. F. <b>Schmid</b>	Peroxidase-Encapsulating Liposomes: Characterization and Microfluidic Application	Bioanalytics Group, D-BSSE	17
Stéphanie <b>Schon</b>	Easy Cholesterol Monitoring from Breath: Selective Isoprene Detection with Ti-Doped ZnO Sensors	Particle Technology Laboratory, D-MAVT	32
Natalia <b>Smatsi</b>	Molecular Dynamics Simulation of Gas Diffusion in Zeolites	Particle Technology Laboratory, D-MAVT	54
Paolo <b>Testa</b>	Magneto-Mechanical Metamaterial	Mesoscopic Systems, D-MATL / PSI	4
Tian <b>Tian</b>	Room-Temperature Growth of Superhydrophobic Semiconductor Nanowires on Arbitrary Substrates	Interface & Surface Engineering of Nanomaterials, D-CHAB	39
Maria <b>Tou</b>	Continuous Solar-Driven Thermolysis of CO <sub>2</sub> into CO and O <sub>2</sub> with an Isothermal Ceria Membrane Reactor	Renewable Energy Carriers, D-MAVT	28
Daniel-Alexander <b>Türk</b>	Integrated Lightweight Structures with Additive Manufacturing and Carbon Fiber-Reinforced Polymers	Product Development Group, D-MAVT	57
Abbas D. <b>Tutcuoglu</b>	Multiscale Modelling of Texture Evolution and Discontinuous Dynamic Recrystallization of HCP Metals in Thermo-Mechanical Processing	Mechanics & Materials, D-MAVT	50
Viola Valentina <b>Vogler-Neuling</b>	Solution Processing of BaTiO <sub>3</sub> Nanoparticles for Nonlinear Photonic Applications	Optical Nanomaterial Group, D-PHYS	45
Ji-Wook <b>Yoon</b>	Highly Sensitive Ethanol Gas Sensor Using Interconnected Trimodally Porous SnO <sub>2</sub> Nanospheres	Particle Technology Laboratory, D-MAVT	30
Ning <b>Zhang</b>	Integrated Mechanical and Electrical Biosensors for Multifunctional Heart-On-A-Chip Platform	Biosensors & Bioelectronics, D-ITET	24
Joel <b>Zuercher</b>	Modelling of Nascent and Mature Soot Optical Properties	Particle Technology Laboratory, D-MAVT	51

# ABSTRACTS OF POSTERS

## 1 Evolution of Solid State Dewetting of Two-Phase Thin Films

Philipp Okle and Ralph Spolenak

Nanometallurgy, D-MATL, ETH Zurich

Solid state dewetting is a diffusion driven surface energy minimization process. While wetted thin films are thermodynamically metastable, dewetted particles ("islands") are stable. When going from a solid solution phase to a two-phase region, the order of the phases within an island can be predicted by the different interfacial energies.

DC Magnetron sputtered thin films with thicknesses between 20-80 nm were thermally dewetted by rapid thermal annealing (RTA) at UHV conditions at various temperatures below  $T_m$  for different times. The films were sputtered as two layers or co-sputtered on a ceramic substrate. Several metallic multi-phase systems were studied, e.g. Au/Ni, Ag/Cu, Ag/Ni.

Upon annealing in a two-phase regime reallocation of A atoms in B and vice versa as well as void growth, preferably at phase boundaries and triple junctions were observed. Samples showed a grain growth of one of the two elements in the system directly at the retraction edge, followed by a regime some 100 nm from the edge where high diffusion activities between A and B atoms were detected due to the lack of one species caused by the mentioned grain growth<sup>[1,2]</sup>.

Atom probe tomography and FIB tomography is employed at a retracting edge of the metallic films in order to find the interfacial and triple junction excess during the thermal treatment.

[1] A. Herz, *Journal of Applied Physics* **116**, 044307 (2014); [2] X. Cen, *Acta Materialia* **119**, 167 (2016)

---

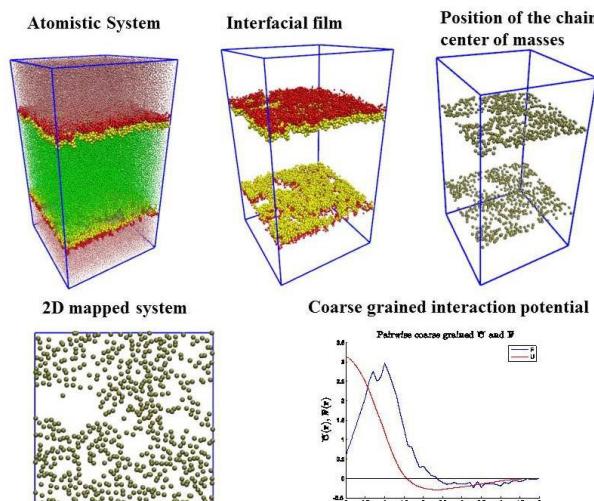
## 2 Multiscale Coarse Graining of Nonionic Surfactants Adsorbed at Fluid-Fluid Interfaces

Ahmad Moghimikheirabadi<sup>1</sup>, Leonard M. C. Sagis<sup>1,2</sup>, Patrick Ilg<sup>3</sup>, and Hans Christian Öttinger<sup>1</sup>

<sup>1</sup> Polymer Physics, D-MATL, ETH Zurich, <sup>2</sup> Food Physics Group, Wageningen University (Netherlands),

<sup>3</sup> School of Mathematical & Physical Sciences, University of Reading (UK)

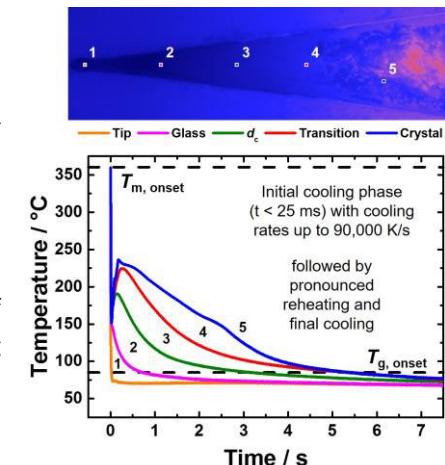
Molecular Dynamics (MD) simulations are performed for the "atomistic" systems which consist of two immiscible mono atomic fluids (W and O particles) and linear diblock copolymers ( $H_5T_5$  molecules). Using trajectories obtained from "atomistic" simulations and applying the force matching scheme, the effective coarse grained pairwise force field for the adsorbed block copolymers is calculated, assuming a flat fluid-fluid interface with a zero thickness i.e. two dimensional (2D) interface. These effective force fields are then used to perform 2D MD simulation of the "coarse grained block copolymers" at the interface at the same surface concentration as 3D "atomistic" simulations. There is a good agreement between surfactant-surfactant pair correlation functions and surface pressure-area isotherms obtained from fully atomistic simulations and their 2D coarse grained counterparts. We have investigated the effects of block copolymer segment-segment interactions and surface concentration on the coarse grained force fields. Our simulation results depict that by changing segment-segment interactions, the effective coarse grained force field can show attractive features. These force fields can then be used to investigate possible 2D phase diagrams of the adsorbed interfacial film.



### **3 Bulk Metallic Glass Casting: Insights into Critical Cooling Using High-Speed IR Monitoring and Fast DSC**

Fabian Haag, Güven Kurtuldu, and Jörg F. Löffler  
Metal Physics & Technology, D-MATL, ETH Zurich

Processing of bulk metallic glasses (BMGs) is limited by the temperature interval in which the alloys are in their so-called supercooled liquid range. Frequently, BMGs are characterized by their critical cooling rate. Although this value gives information about the processability of glass-former melts, it does not represent the actual cooling behavior when (complex) molds are filled by the molten alloy. We have designed a novel setup for quantitative recording the cooling upon casting using a high-speed infrared camera. Here, we want to introduce the method, show its prerequisites, and discuss its potential for detailed analyses of mold casting. Using low-T<sub>g</sub> Au-based BMGs, we plot local cooling curves for fully amorphous, partly amorphous and crystallized regions of cast parts. The proposed technique allows for investigating individual cooling history by fast DSC (FDSC). We find accurate correlation with time-temperature-transformation diagrams, continuous-cooling-transformation diagrams and quantitative agreement between the IR results and FDSC.



### **4 Magneto-Mechanical Metamaterial**

Paolo Testa<sup>1</sup>, Jizhai Cui<sup>1</sup>, Robert Style<sup>2</sup>, Peter Derlet<sup>3</sup>, Eric Dufresne<sup>2</sup>, and Laura J. Heyderman<sup>1</sup>

<sup>1</sup> Mesoscopic Systems, D-MATL, ETH Zurich & PSI, <sup>2</sup> Soft & Living Materials, D-MATL, ETH Zurich,

<sup>3</sup> Condensed Matter Theory Group, PSI

Artificially designed arrays of nanostructures with a microstructure at sub-micrometer length scales can exhibit unique functionality, especially when built from a combination of different classes of materials. We present an overview of a novel magneto-mechanical metamaterial, where the coupling between nanoscale magnets embedded in a soft polymer matrix is exploited to control its mechanical properties. In addition, we elaborate on the possible applications unlocked by this new system. Different approaches to the realization of such a material using lithography<sup>[1]</sup>, 3D laser lithography<sup>[2]</sup> and nanoparticle dispersions<sup>[3]</sup> are expanded upon. Finally, we present the most recent results involving fabrication and characterization of magneto-mechanical properties of our proposed metamaterial.

[1] C. Iss et al., *Sci. Rep.* **7**, 1 (2017); [2] L. R. Meza et al., *Proc. Natl. Acad. Sci. U.S.A.* **112**, 37 (2015); [3] G. Filipcsei et al., *Adv. Polym. Sci.* **206**, 1 (2007)

### **5 Impact of Heat-Treatment Induced Microstructural Changes on the Properties of Biodegradable Mg–Zn–Ca–Lean Alloys**

Martina Cihova<sup>1</sup>, Kai von Petersdorff-Campen<sup>1</sup>, Robin Schäublin<sup>1,2</sup>, Patrik Schmutz<sup>3</sup>, Peter J. Uggowitzer<sup>1</sup>, and Jörg F. Löffler<sup>1</sup>

<sup>1</sup> Metal Physics & Technology, D-MATL, ETH Zurich, <sup>2</sup> ScopeM, ETH Zurich, <sup>3</sup> Laboratory of Joining Technologies & Corrosion, Empa

### **6 Microscale Metal Additive Manufacturing**

Alain Reiser, Ramon Frey, Vladimir Voitech, Jeffrey M. Wheeler, and Ralph Spolenak  
Nanometallurgy, D-MATL, ETH Zurich

Additive manufacturing (AM) is transforming the way we design and fabricate structures on many scales. A main driving force of this movement is the ability of AM to overcome traditional geometrical constraints imposed by subtractive manufacturing techniques. Because such geometric design restrictions become increasingly limiting

at small length scales, microscale AM has the potential to expand the capabilities of microfabrication significantly.

Here, we review the variety of novel microscale AM techniques currently available for fabricating metal structures<sup>[1]</sup> and touch on the resulting materials properties of structures printed with these techniques. Furthermore, we present electrochemical approaches to microscale AM and summarize some of our recent work. This includes the development of a new electrochemical AM technique based on strongly spatially-confined reduction of metal ions using nanosecond pulse plating. Additionally, we show possible methods for achieving voxel-by-voxel control of the printed materials' microstructure and thus the local properties within the structure. This highlights a unique ability of electrochemical AM, which could enable the printing of complex geometries with locally tailored microstructures.

[1] A. Reiser et al., *Adv. Mater.* **2016** *04211*, 1604211 (2017)

## 7 3D Printing of Cellulose Reinforced Composites

Michael Hausmann<sup>1,2</sup>, Gilberto Siqueira<sup>1</sup>, Dimitri Kokkinis<sup>2</sup>, Rafael Libanori<sup>2</sup>, Tanja Zimmermann<sup>1</sup>, and André R. Studart<sup>2</sup>

<sup>1</sup> Applied Wood Materials Laboratory, Empa, <sup>2</sup> Complex Materials, D-MATL, ETH Zurich

Cellulose is an abundant biomaterial that can be used as reinforcing elements in a wide range of polymer composites at different length scales, ranging from macro (natural fibers) through micro (micro-fibrillated fibers) down to nano scale (nanocrystals). Because of the high surface-to-volume ratio and the high density of available primary hydroxyl groups on their surfaces, cellulose nanocrystals are highly prone to surface functionalization, which increases their chemical compatibility with different polymer matrices. Developing techniques to control the orientation and spatial distribution of these nanocrystals can allow us to fabricate composites with tunable mechanical properties. In this work, we investigated how direct-ink writing can be explored to assemble complex cellulose-based materials with controlled orientation and spatial distribution of nanocrystals. By varying the concentration of reinforcing nanocrystals, high degree of alignment and improved mechanical properties were obtained, paving the way for the fabrication of high-performance materials with renewable sources of reinforcing elements using additive manufacturing techniques.

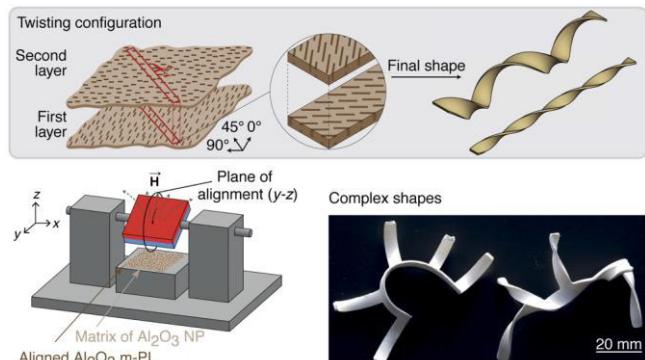
## 8 Bio-Inspired Self-Shaping Ceramics

Fabio L. Bargardi, Hortense Le Ferrand, Rafael Libanori, and André R. Studart

Complex Materials, D-MATL, ETH Zurich

Shaping ceramics into complex and intricate geometries is often a cost-intensive process. Inspired by self-folding mechanisms in nature, we show that self-shaping can be implemented in ceramics by programming the material's microstructure to undergo local anisotropic shrinkage during sintering. The shape change is controlled during the fabrication of bio-inspired bilayers by magnetically aligning functionalized alumina platelets in a liquid ceramic suspension and subsequently consolidation through an enzyme-catalysed reaction. Bending, twisting or combinations of these two basic movements can be successfully programmed into the microstructure of alumina compacts to obtain a myriad of unusual geometries and complex shapes. Simplicity, low-waste and universality of this bottom-up shaping method makes it attractive for many applications where conventional top-down manufacturing is not accessible.

F. L. Bargardi et al., *Nat. Commun.* **7**, 13912 (2016)

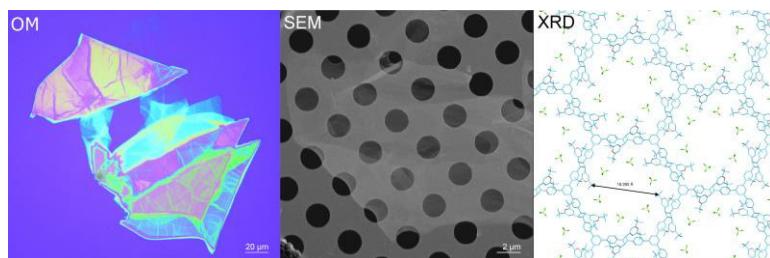


## 9 A Two-Dimensional Polymer with Crystalline Order

Ralph Z. Lange<sup>1</sup>, Gregor Hofer<sup>1,2</sup>, Thomas Weber<sup>2</sup>, Nils Jürgensen<sup>3,4</sup>, Haoyuan Qi<sup>5</sup>, Uli Lemmer<sup>4</sup>, Gerardo Hernandez-Sosa<sup>3,4</sup>, Ute Kaiser<sup>5</sup>, and A. Dieter Schlüter<sup>1</sup>

<sup>1</sup> Polymer Chemistry, D-MATL, ETH Zurich, <sup>2</sup> X-Ray Platform, D-MATL, ETH Zurich, <sup>3</sup> InnovationLab Heidelberg (Germany), <sup>4</sup> Light Technology Institute, Karlsruhe Institute of Technology (Germany), <sup>5</sup> Electron Microscopy Group of Materials Science, University of Ulm (Germany)

There is ample research on inorganic two dimensional materials, revolving loosely around the groundbreaking work of Geim und Novoselov on graphene<sup>[1]</sup>. In comparison, knowledge on organic two-dimensional polymers (2DP)<sup>[2]</sup> is limited.



We here report the convenient, inexpensive and large scale synthesis of a pyrylium based novel monomer for the synthesis of a 2DP<sup>[3]</sup>. Our approach makes use of pre-organizing monomers by growing of single crystals. This method renders highly ordered polymers that enables structure elucidation with single crystals XRD and TEM. Benefits comprise:

- Easy accessibility (35 g prepared after single runs of a 4-step synthesis)
- Crystals grow in sizes of up to 5 mm
- Single and multi layers of polymer by liquid-phase exfoliation within a few days

The 2DP may be regarded as a positively charged, planar and crystalline honeycomb-mesh. The negative counter-ions are supposed to encase the sheet from both sides. Properties of these organic materials are intrinsically different from their inorganic 2D counterparts, e.g. pores are rather large (16 – 28 Å) and the polymerization reaction is reversible at elevated temperatures (>150 °C). Therefore, post-modifications under mild conditions are conceivable.

- [1] K. S. Novoselov et al., *Science* **306**, 666 (2004); [2] P. Payamyar et al., *Chem. Commun.* **52**, 18 (2016);  
[3] R. Z. Lange et al., *J. Am. Chem. Soc.* **139**, 2053 (2017)

---

## 10 Arresting Bubble Dissolution by Interfacial Rheology Design

Peter J. Beltramo<sup>1</sup>, Alexandra Aliche<sup>1</sup>, Manish Gupta<sup>2</sup>, and Jan Vermant<sup>1</sup>

<sup>1</sup> Soft Materials, D-MATL, ETH Zurich, <sup>2</sup> Department of Chemical Engineering, KU Leuven (Belgium)

Tuning the interparticle interaction potential in bulk suspensions has long been a strategy to engineer the desired properties, such as flow behavior, rheology, and structure, of colloidal suspensions. In this work<sup>[1]</sup>, we apply this paradigm to interfacial materials, specifically particle-stabilized bubbles, and a strategy to halt dissolution in particle coated air bubbles in water based on interfacial rheology design is presented. Whereas previously a dense monolayer was believed to be required for such an “armored bubble” to resist dissolution, in fact engineering a two-dimensional yield stress interface suffices to achieve such performance at sub-monolayer particle coverages. We use a suite of interfacial rheology techniques to characterize the behavior of spherical PS-PVP particles at an air-water interface as a function of surface coverage. Spherical bubbles with varying particle coverages are made and their resistance to dissolution evaluated using a microfluidic technique. Whereas a bare bubble only has a single pressure at which a given radius is stable, we find a range of pressures over which bubble dissolution is arrested for armored bubbles. The link between interfacial rheology and macroscopic collapse of ~100 µm bubbles coated with ~1 µm PS-PVP particles is presented and discussed. The results imply a generic design rationale that can be applied to successfully inhibit coarsening in a multitude of foam and emulsion applications.

- [1] P. J. Beltramo et al., *under revision*
-

## **11 Stabilization of Food-Grade Oil-In-Water Emulsions by Chitosan-Modified Nanoparticles at Different pHs**

Lauriane Alison<sup>1</sup>, Ahmet F. Demirörs<sup>1</sup>, E. Tervoort<sup>1</sup>, A. Teleki<sup>2</sup>, and André R. Studart<sup>1</sup>

<sup>1</sup> *Complex Materials, D-MATL, ETH Zurich, <sup>2</sup> Drug Delivery, Uppsala University (Sweden)*

Particle-stabilized emulsions are desired in the food industry due to their long-term stability and surfactant-free character. In this work, a novel edible stabilizer has been demonstrated to produce ultrastable oil-in-water emulsions consisting of micron-sized droplets via high-pressure homogenization<sup>[1]</sup>. Here, stabilizer particles are produced by modifying non-covalently silica nanoparticles with a weak polyelectrolyte, chitosan. Chitosan modification increases the particle hydrophobicity, thus enhancing particle adsorption at the oil-water interface. The adsorption of chitosan to silica nanoparticles is reversible and strongly depends on the pH of the continuous phase, which significantly influences the emulsion stability. Confocal microscopy, cryo-scanning electron microscopy, diffusing wave spectroscopy, and bulk and interfacial rheology are used to shed light on different stabilization mechanisms. We have found that particle modification at different pHs lead to emulsions with distinct microstructures and macroscopic behaviors. This provides a versatile system that can result in either network or Pickering stabilization by simply tuning the pH. Furthermore, we have demonstrated that pH changes performed at different stages during emulsification do not affect the final product, which is industrially important due to potential practicalities such flexibility may provide.

[1] L. Alison et al., *Langmuir* **32**, 13446 (2016)

---

## **12 Interfacial Strength in Nacre-Like Polymer-Matrix Composites**

Madeleine Grossman, Florian Bouville, Kunal Masania, Rafael Libanori, and André R. Studart

*Complex Materials, D-MATL, ETH Zurich*

The rational design of composites with high strength, modulus and fracture toughness is a major challenge in materials science. Fracture toughness requires inelastic deformation and ductile response but the molecular origins of strength conflict with ductility<sup>[1]</sup>. Yet, nature works around this inherent conflict, creating composites with hierarchical meso-structures that are stiff in their pristine state but become inelastic after damage. Nacre, aka mother of pearl, materializes this concept by arranging mineral platelets and bio-polymers layers like bricks and mortar. During damage, energy is dissipated over a large volume by shearing the interfaces between platelets throughout a process zone. Therefore, optimal strength and morphology of these platelet-platelet interfaces are considered to be key to nacre's functionality.

In this work, we use our Vacuum Assisted Magnetic Alignment (VAMA) technique to generate nacre-like mineral scaffolds with varying interfacial strength<sup>[2]</sup>. By hot-pressing titania-coated alumina microplatelets at variable pressures and temperatures, we are able to exploit the significant difference in sintering between these two phases; creating size controlled titania contacts between platelets at temperatures well below the alumina sintering point. Scanning this design space, we have developed a phase diagram for scaffold density as a function of sintering temperature and pressure. Infiltration of these scaffolds with commercial epoxy produces nacre like composites.

In isodensity composites with 60% mineral content, we observe a linear increase in flexural strength, from 180 MPa to 350 MPa, as the interfacial titania contact area increases. However, at 350 MPa, the observed strength reaches a plateau and the failure behavior transitions from a platelet pull-out to a platelet fracture mode, indicating that interfacial shear forces have become larger than the strength of the individual platelets.

[1] R. O. Ritchie, *Nature Materials* **10**, 817 (2011); [2] M. Grossman et al., *Adv. Mat.* **29**, 8 (2017)

---

## **13 High Speed Confocal Imaging of Sheared Colloidal Gels**

Gabriele Colombo and Jan Vermant

*Soft Materials, D-MATL, ETH Zurich*

Colloidal gels are an important class of soft materials with a wide range of technological applications, exploiting the combination of solid-like rest structure and liquefaction under mechanical stress of these thixotropic mate

rials. Even though such complex flow behavior is widespread in a number of consumer products and industrially relevant systems, the changes in microstructure underlying thixotropy remain poorly understood. Recent scaling arguments propose a dependence of the mechanical properties of gels under flow on subpopulations of rigid, isostatic clusters of closely packed particles. Such a scaling does not rely on fractal geometry or glassy dynamics, which only take into account ensemble averaged descriptors and are therefore insensitive to highly localized events, which may determine the rheological response.

In this work, we intend to test these ideas of cluster rigidity and evaluate the microstructural basis of thixotropy, varying the packing behavior in model colloidal gels by changing the particle aspect ratio slightly. The experimental approach relies on the quantitative study of the gel microstructure using high-speed confocal microscopy. Microscopic studies under flow are performed using a stress controlled rheometer with a home-made shear cell for counter-rotation of the lower plate, allowing single particles to be located and tracked for long times at the stagnation plane. The stress is directly measured, so that the link between microscopic observations and nonlinear rheology can be established.

We also intend to clarify the role of microstructural anisotropy under flow, resulting in the butterfly scattering patterns observed for colloidal gels. Recent simulation approaches also show the emergence of large structural elements in the vorticity direction of flow, whose relevance for the rheological properties of gels was recently shown by two-dimensional oscillatory measurements on a model thixotropic gel.

---

#### **14 Polyethylene Furanoate (PEF) as a Substitute for PET from 100% Renewable Resource-Based Cyclic Oligomers**

Jan-Georg Rosenboom, Peter Fleckenstein, Giuseppe Storti, and Massimo Morbidelli

*Chemical Reaction & Separation Engineering, D-CHAB, ETH Zurich*

Ring-opening polymerization (ROP) can be an alternative process to synthesize polyethylene furanoate (PEF), which may polyethylene terephthalate (PET) with a more sustainable and superior material. Recent efforts and first commercial scale production were invariably based on polycondensation, which requires condensation by-product removal and thus several days to reach commercially relevant molecular weights<sup>[1,2]</sup>. Cyclic PEF monomers (cyOEF) do not have endgroups and thus render byproduct removal unnecessary, which enables ROP as a living chain-growth mechanism to deliver high conversion to PEF within minutes.

CyOEF can be derived from 100% renewables-based building blocks furandicarboxylic acid and ethylene glycol via depolymerization of short PEF oligomers in aromatic solvents to yield >90% cyOEF within 4 hours. Maximization of material turnover as well as minimization of waste is possible by full recycling of unconverted linear and solvents. Purification of cyOEF from residual linear via silica gel adsorption to yield >99% cycles was found essential for ROP to deliver 1) sufficiently high molecular weights, 2) reproducible reaction control and 3) colorless products.

PEF was then obtained in yields of >95% and bottle-grade molecular weights ( $M_w \sim 60'000$  g/mol) within less than 30 min<sup>[3]</sup>. The cyclic oligomers exhibit a distribution of ring sizes, where the individual species show melting points ranging from 270 to 370°C and different reactivity. Successful conversion of each observed cyclic species from dimer to heptamer was achieved well below their melting point using 230–280°C with tin-catalysts and inert plasticizers. The resulting PEF shows advantageous thermal, stress and gas diffusion properties compared with PET, which can be explained with a higher molecular rotational energy barrier of the furanic species. Scale-up to larger (kilogram) volumes, processing towards actual bottles and the search for alternative solvents is ongoing.

[1] M. Gomes et al., *J. Polym. Sci. A: Polym. Chem.* **49**, 3759 (2011); [2] L. Sipos et al., *ACS Symposium Series* **1105**, Smith(Ed.), 1-11 (2012); [3] J.-G. Rosenboom et al., *Macromol Chem and Phys* **218**, 1600436 (2017)

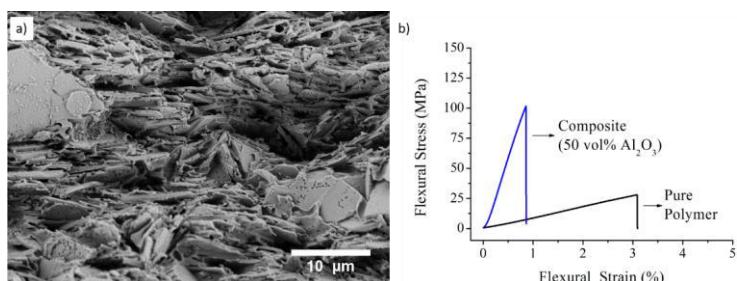
---

#### **15 Powder-Based Processing of Highly-Loaded Platelet-Reinforced Composites**

Sara T. R. Velasquez, Justin Ulbrich, Marco R. Binelli, Kunal Masania, Rafael Libanori, and André R. Studart

*Complex Materials, D-MATL, ETH Zurich*

Conventional processes commonly used for the fabrication of composites with high volume fraction of reinforcing elements usually require the infiltration of monomers that are subsequently consolidated into a continuous polymer matrix. Such infiltration step often leads to long processing times and limits the choices of materials that can be used as soft continuous matrices. In this work, we present a new infiltration-



*Fig. a)* SEM image showing the fractured surface of a composite containing 50 vol% of reinforcing ceramic platelets. *b)* Representative stress-strain curves comparing the mechanical performance in flexural mode for the pure polymer matrix and the composite with 50 vol% of reinforcing ceramic platelets.

less route in which a co-suspension of organic/inorganic powders is assembled through vacuum-assisted magnetic alignment and the resulting composite consolidated by uniaxial hot pressing<sup>[1]</sup>. Composites with up to 50% in volume of aligned reinforcing platelets could be easily processed using this method (Fig. a). As illustrated in Fig. b, the incorporation of reinforcing platelets within the composite material enhanced the flexural modulus and flexural strength by 14-fold and 3-fold as compared to the pure polymer. As expected, the strain at rupture decreased from 3.0% to 0.8% upon addition of ceramic platelets. These results demonstrate the potential of using infiltration-less routes to enable the fabrication of high-performance platelet-reinforced composites with high volume fraction of reinforcing ceramic phase and polymer matrices that are difficult to be infiltrated using conventional methods.

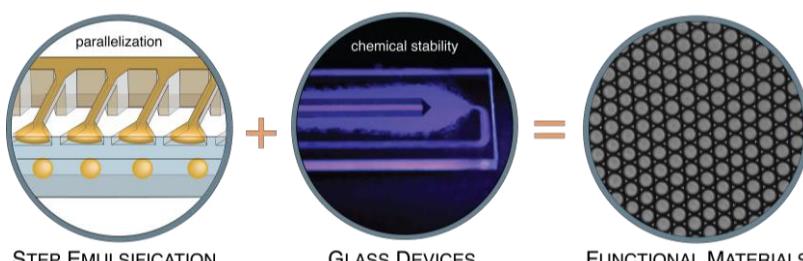
[1] M. Grossman et al., *Adv. Mat.* **29**, 8 (2017)

## 16 Glass Step Emulsification for the Production of Functional Materials

Alessandro Ofner<sup>1</sup>, David G. Moore<sup>1</sup>, Patrick A. Rühs<sup>1</sup>, Pascal Schwendimann<sup>1</sup>, Maximilian Eggersdorfer<sup>2</sup>, Esther Amstad<sup>3</sup>, David A. Weitz<sup>2</sup>, and André R. Studart<sup>1</sup>

<sup>1</sup> Complex Materials, D-MATL, ETH Zurich, <sup>2</sup> Department of Physics & School of Engineering & Applied Sciences, Harvard University (USA), <sup>3</sup> Institute of Materials, EPFL

High-volume production of mono-disperse droplets is of importance for industrial applications due to increased emulsion stability, precise control over droplet volumes, and the formation of periodic arranged structures. So far, parallelized microfluidic devices are limited by either their complicated channel geometry or by their chemically or thermally unstable embedding material<sup>[1,2]</sup>. This study<sup>[3]</sup> shows a scalable microfluidic step emulsification chip that enables production of mono-disperse emulsions at a throughput of up to 25 mL/min a glass device with 364 linearly parallelized droplet makers. The chemical and thermal stability of such a glass device allows for the preparation of a broad variety of functional particles and microdroplets by using any desired solvent together with nanoparticles, polymers, and hydrogels. Moreover, the microfluidic device can be stringently cleaned for nearly unlimited use and permits the alternating production of oil-in-water and water-in-oil emulsions. The combined high throughput, chemical and thermal stability offered by our device enables production of monodisperse functional materials for large-scale applications.



[1] M. Eggersdorfer et al., *Lab Chip* **17**, 936 (2017); [2] Amstad et al., *Lab Chip* **16**, 4163 (2016); [3] A. Ofner et al., *Macromol. Chem. Phys.* **1600472** (2016)

## 17 Peroxidase-Encapsulating Liposomes: Characterization and Microfluidic Application

Yannick R. F. Schmid<sup>1</sup>, Ya Zhang<sup>2,3</sup>, Sandra Luginbühl<sup>2</sup>, Qiang Wang<sup>3</sup>, Petra S. Dittrich<sup>1</sup>, and Peter Walde<sup>2</sup>

<sup>1</sup> Bioanalytics Group, D-BSSE, ETH Zurich, <sup>2</sup> Polymer Chemistry, D-MATL, ETH Zurich, <sup>3</sup> Key Laboratory of Science & Technology of Eco-Textile, Jiangnan University (China)

Horseradish peroxidase (HRP) is a well-known heme-containing enzyme. In the presence of hydrogen peroxide HRP promotes the oxidation of a variety of substrates and is therefore widely used in different applications including bioanalytics, organic synthesis, and wastewater treatment. This makes HRP an interesting candidate for liposomal encapsulation. Liposomes (lipid vesicles) allow the study of membrane-dependent events and biomolecules, e.g. solute permeation or ligand binding to membrane bound receptors. Loading and storage of biomolecules such as enzymes, here HRP, is crucial for many applications that use liposomes.

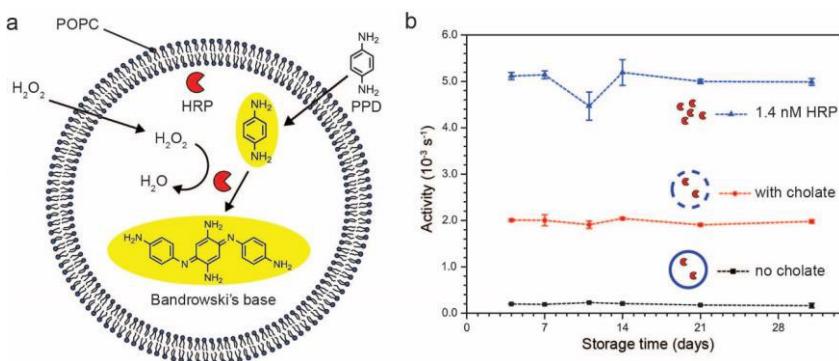


Fig. a) Scheme of HRP-encapsulating liposomes. PPD can diffuse through the lipid membrane to access the encapsulated HRP and react, in the presence of hydrogen peroxide ( $H_2O_2$ ) to Bandrowski's base. b) HRP-containing liposomes were stored at 4 °C for one month. The activity was measured during this period using ABTS<sup>2-</sup> with (red circles) and without (black squares) cholate to monitor the enzyme activity and the membrane leakiness, respectively. Cholate lysed the lipid membrane and made the encapsulated HRP accessible for ABTS<sup>2-</sup>. Without cholate ABTS<sup>2-</sup> could only reach the HRP through leaky membranes. As a control, pure HRP was measured (blue triangles), see ref [1].

Here, we prepared horseradish peroxidase-encapsulating liposomes from POPC (= 1-palmitoyl-2-oleoyl-sn-glycero-3-phosphocholine) by extrusion with an average size of 180 nm in diameter. We applied two spectrophotometric assays to quantify the HRP activity and the liposome stability. HRP activity was measured by following the oxidation of *p*-phenylenediamine which permeated almost unhindered through the lipid membrane (Fig. a). Conversely, ABTS<sup>2-</sup> (2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonate)) was used as membrane impermeable HRP substrate. Thus, the oxidation of ABTS<sup>2-</sup> indicated leaky membranes. The HRP-encapsulating POPC vesicles were stable for at least 31 days with no significant loss of enzyme activity (Fig. b)<sup>[1]</sup>. In these cases, HRP enclosed in the aqueous interior of liposomes might act as sensitive reporter for hydrogen peroxide.

[1] Y. Zhang et al., *Anal. Chem.* **89**, 5484 (2017)

## 18 Diffusion of Polymers through Periodic Networks of Lipid-Based Nanochannel

Reza Ghanbari<sup>1</sup>, Salvatore Assenza<sup>1</sup>, Abhijit Saha<sup>2</sup>, and Raffaele Mezzenga<sup>1</sup>

<sup>1</sup> Food & Soft Materials, D-HEST, ETH Zurich, <sup>2</sup> Department of Chemistry, University of Washington (USA)

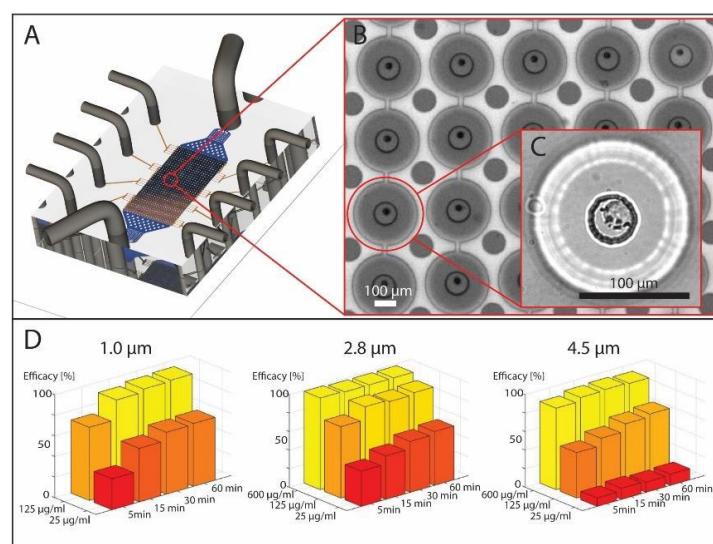
## 19 Magnetic Labeling for Selective Cell Capture and Single-Cell Analysis on a Microfluidic Platform

Lucas Armbrecht, Felix Kurth, and Petra S. Dittrich

Bioanalytics Group, D-BSSE, ETH Zurich

New microfluidic tools facilitate the analysis of biological processes on the single-cell level in the past years<sup>[1]</sup>. In addition, several methods for the selective capture of individual cells based on size, surface markers, mechanical properties, etc. have been introduced<sup>[2]</sup>, which are of great interest for the isolation of rare cells like circulating tumor cells<sup>[3,4]</sup>. However, the combination of selective cell capture and analysis on the same microfluidic device remains difficult.

To address this challenge, we developed a method for localized capture of magnetically labeled cells on a microfluidic chip. We used anti EpCAM-coated magnetic beads which bind to epithelial specific cell surface markers with high selectivity. Then, we characterized the binding efficiency to MCF-7 breast cancer cells in detail by variations of bead size, concentration, and incubation time. High binding efficiencies above 90% were found and subsequently, labeled cells were successfully captured on our microfluidic platform. In 612 individual single cell traps, each being surrounded by a tiny valve, the cells are isolated in volumes of less than 100 pL. This allows us to combine selective cell capture and single-cell analysis through immunoassays on a single microfluidic chip<sup>[5]</sup>



*Fig. Selective labeling and capture of single MCF-7 cells on a microfluidic chip.* A) The device has a footprint of  $20 \times 28 \text{ mm}^2$  and holds eight sets of pressure valves (side ports) and a fluidic inlet and outlet. B) The pressure valves are used to actuate doughnut-shaped valves that confine 612 individual microchambers. C) Due to the selectivity of magnetic bead binding, the cells of interest are captured in the central magnetic trap. D) The efficiency of the binding process is dependent on labeling time and bead concentration.

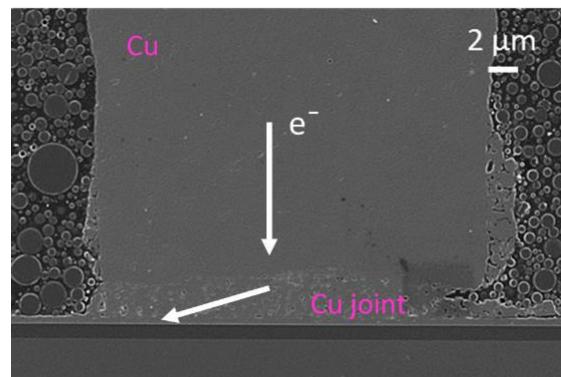
- [1] L. Armbrecht et al., *Anal. Chem.* **89**, 2 (2017); [2] Y. Chen et al., *Lab Chip* **14**, 626 (2014); [3] C. Shields et al., *Lab Chip* **16**, 3833 (2016); [4] A. Sarioglu et al., *Nat. Methods* **12**, 1 (2015); [5] K. Eyer et al., *Anal. Chem.* **85**, 3280 (2013)

## 20 All-Copper Interconnects for Electronic Chips Formed by Low-Temperature Dip Transfer

Luca Del Carro<sup>1,2</sup>, Jonas Zürcher<sup>2</sup>, Sebastian Gerke<sup>2</sup>, and Thomas Brunschwiler<sup>2</sup>

<sup>1</sup> Complex Materials, D-MATL, ETH Zurich, <sup>2</sup> IBM Research Zurich

Flip-chip interconnects made entirely from copper are needed to overcome the intrinsic limits of solder-based interconnects and match the demand for increased current densities in microelectronic chips<sup>[1]</sup>. To this end, dip-based all-copper interconnects are a promising approach to form electrical interconnects by sintering copper nanoparticles between the copper pillar and pad<sup>[2]</sup>. However, the remnant porosity of the copper joint formed between the pillar and the pad limits the performance of this technology. Moreover, the applicability of this technology in the printed circuit board (PCB) industry is endangered by thermo-mechanical stresses that arise during the sintering and by the unknown compatibility with standard finishing layers used to prevent the oxidation of the copper.



This work reports three main advances in dip-based all-copper interconnect technology. First, a reduction in the porosity level of the copper joint is obtained by application of pressure during the bonding. Second, a decrease of the bonding temperature to 160 °C is achieved. Third, the compatibility of this technology with standard finishing layers is demonstrated.

- [1] Ghaffarian et al., *Facta universitatis-series: Electronics and Energetics* **29.4**, (2016); [2] J. Zürcher et al., *Electronic Components and Technology Conference (ECTC)*, (2016)

## 21 Liquid Crystal Phase Transitions in Amyloid Fiber Nematic and Cholesteric Tactoids

Mario Arcari, Gustav Nyström, and Raffaele Mezzenga

Food & Soft Materials, D-HEST, ETH Zurich

Chirality is ubiquitous in nature and plays crucial roles in biology, medicine, physics and materials science. Understanding and controlling chirality is therefore an important research challenge with broad implications in fundamental and applied sciences. Unlike other classes of chiral colloids, such as nanocellulose or filamentous viruses, amyloid fibrils form nematic phases but appear to miss their twisted form in the phase diagram, the so-called cholesteric or chiral nematic phases, and this despite a well-defined chirality at the single fibril level. Here we report the discovery of cholesteric phases in amyloid fibrils, by using  $\beta$ -lactoglobulin fibrils suitably shortened by shear stresses. The physical behavior of this new class of cholesteric materials exhibits unprecedented structural complexity, with confinement-driven ordering transitions between at least three types of nematic and cholesteric tactoids. We use energy functional theory to rationalize these results and demonstrate a chirality inversion upon increasing hierarchical levels, from the left-handed amyloids to the right-handed cholesteric droplets. These findings significantly deepen our understanding of chiral nematic phases and may pave the way to their optimal use in soft nanotechnology, nanomaterials templating and self-assembly.

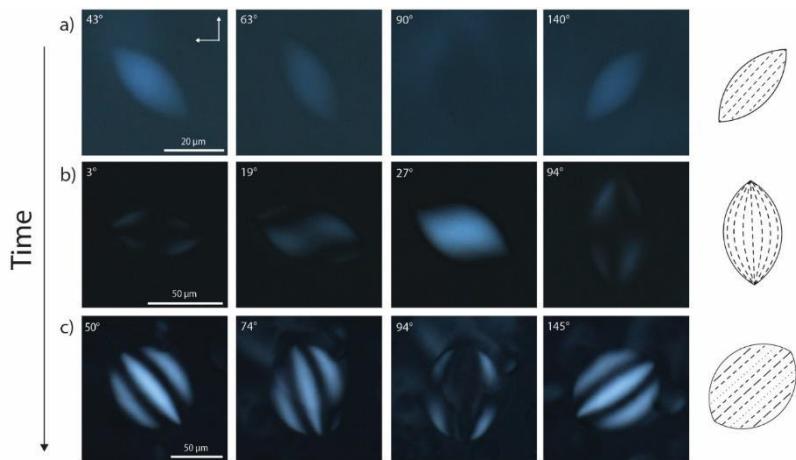


Fig. Nematic and cholesteric phases of amyloid fibrils as observed by rotating the sample in the plane between fixed crossed polarizers. a) The smallest nematic tactoids nucleated from the isotropic phase have a homogeneous nematic field, leading to extinction upon rotation to an angle parallel with one of the linear polarizers. b) As the tactoids grow with time they convert to a bipolar nematic orientation, with no extinction features. c) With further increase in size the tactoids switch to a cholesteric ordering of the amyloid fibrils.

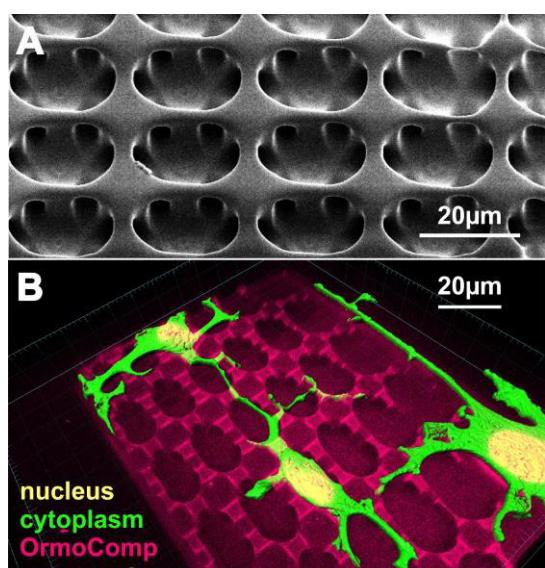
## 22 Micro-3D Printing for the Fabrication of a Biomimetic Model of Functional Osteocytes

Felicitas R. Flohr and Ralph Müller

Bone Biomechanics, D-HEST, ETH Zurich

Osteocytes are considered as the professional mechanosensory cells in bone. *In vivo*, these cells are tightly confined in the lacuno-canicular network (LCN) surrounded by the stiff bone matrix. While this 3D environment is a crucial aspect in osteocytic mechanosensing, its influence remains poorly understood due to the lack of suitable experimental systems.

In order to study functional osteocytes *in vitro* in a biomimetic 3D environment, we fabricated structures mimicking the LCN by two-photon polymerization with the Nanoscribe Professional GT (Nanoscribe, Germany) using OrmoComp®, an inorganic–organic hybrid polymer (micro resist technology, Germany) (Fig. A, scanning electron micrograph). With a collagen I coating, these structures allow for the culture of osteocytic IDG-SW3 cells for over 3 days. By



live-cell fluorescence microscopy, we observed that osteocytes grow inside cavities and extended multiple processes through channels, leading to cell-cell-contacts (Fig. B, 3D visualization of confocal fluorescence micrograph). Using time-lapsed imaging, we were able to follow cellular dynamics for several hours.

We believe that this system opens up new avenues for research in osteocyte mechanobiology: The flexibility of the micro-3D printing approach allows for tight control over the geometry of the cellular environment while numerous functional readouts are amenable through live-cell fluorescence microscopic observation.

---

## 23 Porous Electrodes for Soft and Stretchable Microelectrode Arrays

Aline F. Renz<sup>1</sup>, Klas Tybrandt<sup>2</sup>, Greta Thompson-Steckel<sup>1</sup>, and Janos Vörös<sup>1</sup>

<sup>1</sup> Biosensors & Bioelectronics, D-ITET, ETH Zurich, <sup>2</sup> Department of Science & Technology, University of Linköping (Sweden)

While traditional electronic devices are fabricated as rigid and planar structures, the new generation of biomedical devices needs to be soft, flexible and biocompatible in order to adapt to the curvilinear shapes of the human body. These features are combined in polydimethylsiloxane (PDMS), a stretchable and biocompatible elastomer, currently used in soft and stretchable electronics. It already has shown to be a suitable material for several biomedical applications as brain recordings, cardiac recordings and epidermal sensors<sup>[1,2]</sup>.

We developed a fast fabrication process, which allows us to produce a fully functional structure of up to several dozen electrodes within a day. The filter technique developed by Tybrandt et al. was adapted using a photolithography-patterned membrane, to assure limited material waste<sup>[3]</sup>.

The produced soft microelectrode array (MEA) consists of biocompatible conductive nanomaterials, which are embedded in PDMS. The microelectrodes consist of porous pillars containing conductive nanoparticles. This leads to a decreased impedance due to the gain in electrode surface area and stable stimulation when compared to other stretchable microelectrodes. This is especially important for frequencies below 1 kHz, when measuring on a single cell level. The electrode grid as well as the electrodes themselves can be freely defined with desired shapes, heights and sizes, opening new possibilities in stretchable electronics.

Our fabricated MEAs perfectly adapt to their surroundings, improving the cell-electrode interface of 3D cell cultures *in vitro* for stimulation and recording of electrical excitable cells. Additionally, they are currently tested *in vivo* for long-term measurements, demonstrating the broad field of applications possible with this technique and electrodes.

[1] C. Towne et al., *PLoS One* **8**, e72691 (2013); [2] I. R. Minev et al., *Science* **347**, 159 (2015); [3] K. Tybrandt et al., *Small* **12**, 180 (2016)

---

## 24 Integrated Mechanical and Electrical Biosensors for Multifunctional Heart-On-A-Chip Platform

Ning Zhang<sup>1,2</sup>, Flurin Stauffer<sup>2</sup>, Aline F. Renz<sup>2</sup>, Hana Han<sup>2</sup>, Benjamin R. Simona<sup>3</sup>, Ning-Ping Huang<sup>1</sup>, and Janos Vörös<sup>2</sup>

<sup>1</sup> State Key Laboratory of Bioelectronics, Southeast University (China), <sup>2</sup> Biosensors & Bioelectronics, D-ITET, ETH Zurich, <sup>3</sup> Ectica Technologies AG (Switzerland)

Heart is one of the important organs which is a muscular pump responsible for continuously providing efficient blood transport throughout the whole body. In order to fabricate heart-on-a-chip system (biomimetic tissues) that recapitulate the function of *in vivo* organ, it is very important to quantitatively characterize the relevant structure and performance that define normal physiological function. Measurements of physical features and functional parameters, such as beating rate, beating force (related to systolic and diastolic pressure), cardiac pacing, electrical propagation speed, etc. can be used to assess the degree to which engineered tissues faithfully mimic the native heart. To approach more dynamic and multifunctional heart artificial interfaces, here, we report an integrated platform that combines mechanical force sensing with electrical stimulation and recording of the myocardium in one unit and allows for measuring in a continual and dynamic manner. Specifically, we applied a fast and efficient method based on wax pattern assisted filtration to embed the mechanical and electrical sensors in a flexible PDMS platform for *in situ* monitoring the myocardium including recording cardiomyocyte

beating rate and force. Also, we could locally stimulate and pace the cells which is potentially interesting for the maturing of the cardiomyocytes. More importantly, this platform with different sensors has a potential to be applied in drug screening for *in situ* monitoring the biophysical parameters of the heart tissue.

---

## **25 Investigation of Permeation through Model Membranes on a Microfluidic Device by Fluorescence Correlation Spectroscopy**

Céline Del Don, Simon Bachler, and Petra S. Dittrich

*Bioanalytics Group, D-BSSE, ETH Zurich*

Peptides are highly relevant as drug candidates. Hydrophobicity and charge are key properties to their function and can be tailored by changing the amino acid sequence. Peptides can interact in various ways with cell membranes such as partitioning and accumulating in the membrane, or permeation across the membrane, but a prediction is difficult.

The aim of this project is to obtain a more detailed understanding of the permeation process. Therefore, we study interactions between fluorescently labeled peptides and membranes. Ultimately, this method will help to screen for possible peptide candidates, and may also be employed as a test method for potential harmful, cell-lysing molecules.

We employ giant unilamellar vesicles (GUVs) of various composition as model membrane and follow the permeation of molecules from outside to inside of the vesicle. To achieve a fast fluid exchange and hence, a high temporal resolution, we immobilize the GUVs on a microfluidic platform with (up to 60) integrated vesicle traps<sup>[1,2]</sup>. Next, we supply short, fluorescently labeled peptides that possess the ability to cross natural cell membranes as well as artificial membranes, enabling also cargo transportation into cells<sup>[3]</sup>. Permeation of the fluorescently labeled peptides into GUVs is characterized with fluorescence correlation spectroscopy (FCS). FCS is a sensitive single-molecule method, which can be used to obtain molecular information, such as diffusion coefficient, and average intra- and extra-vesicular concentrations.

The results indicate that the composition of the membrane influences the permeability of the tested cell-penetrating peptides. Translocation of the short peptides was observed in GUVs composed of anionic or negative curvature inducing lipids. In comparison, no translocation was observed in GUVs composed of neutral lipids.

In conclusion, FCS combined with microfluidic trap arrays constitute a valuable platform for drug or toxin screening with model membranes and can be used likewise for cell studies.

- [1] K. Eyer et al., *Anal. Chem.* **85** (12), 3280 (2013); [2] T. Robinson et al., *Biomicrofluidics* **7** (4), 44105 (2013);  
[3] C. Ciobanaru et al., *Biophys. J.* **99** (1), 153 (2010)

---

## **26 Local Connectivity and Confining Environments of Sn-Sites in Sn-Chabazites Are Distinguishable Using DNP-NMR**

Wei-Chih Liao<sup>1</sup>, Jamie W. Harris<sup>2</sup>, John R. Di Iorio<sup>2</sup>, Alisa M. Henry<sup>2</sup>, Ta-Chung Ong<sup>1</sup>, Aleix Comes-Vives<sup>1</sup>, Rajamani Gounder<sup>2</sup>, and Christophe Copéret<sup>1</sup>

<sup>1</sup> *Surface & Interfacial Chemistry, D-CHAB, ETH Zurich*, <sup>2</sup> *School of Chemical Engineering, Purdue University*

Chabazite molecular sieves with isomorphously substituted framework Sn heteroatoms (Sn-CHA) constitute model stannosilicate zeolites comprising a single crystallographically unique tetrahedral-site (T-site). The predominant incorporation of isolated Sn sites within framework positions was assessed from UV-Visible absorption edge energies (>4.1 eV), four-coordinate Sn centers measured after dehydration by X-ray absorption spectroscopy (XAS) and <sup>119</sup>Sn dynamic nuclear polarization nuclear magnetic resonance (DNP NMR), and Lewis acid site fractions of nearly unity quantified by ammonia and acetonitrile titration. Aqueous-phase glucose-fructose isomerization turnover rates on Sn-CHA (per extracrystalline framework site) were similar to rates on an amorphous stannosilicate, while intermolecular Meerwein-Ponndorf-Verley propionaldehyde reduction and Oppenauer ethanol oxidation (MPVO) reactions confirm that Sn sites confined within micropores behave as Lewis acids capable of catalyzing intermolecular hydride shift steps.

The increased sensitivity afforded by DNP NMR enabled performing 2D  $^{119}\text{Sn}$  cross polarization magic angle turning (CPMAT) NMR experiments, which allows the detection of different sites having the same isotropic chemical shift but different chemical shift anisotropy (CSA) parameters, an unexpected result considering the presence of single T-site in CHA framework. By using pyridine as a probe molecule, which is too large to enter the pore of CHA framework, the Sn sites within mesoporous voids and at extracrystalline surfaces can be selectively detected by IR and  $^{15}\text{N}/^{119}\text{Sn}$  DNP enhanced NMR. Experimentally measured  $^{119}\text{Sn}$  NMR CSA parameters were compared to values estimated using density functional theory (DFT), supporting the presence of defect-open and closed Sn sites in dehydrated samples, which evolves into hydrated defect-open and hydrolyzed-open sites respectively upon hydration. These findings highlight the characterization of local structures of active sites in Sn zeolites enabled by DNP NMR with the aid of DFT calculations, and the crucial role of the confining environment in zeolitic porous framework in Lewis acid promoted reactions.

---

**27 A Novel Bioreactor for the Evaluation of Endothelialized Elastomer Membranes under (Supra)Physiological Stretch and Flow for Application in Ventricular Assist Devices (VADs)**

Björn J. Bachmann<sup>1</sup>, Laura Bernardi<sup>2</sup>, Christian Loosli<sup>3</sup>, Julian Marscheski<sup>1</sup>, Michela Perrini<sup>2,4</sup>, Martin Ehrbar<sup>4</sup>, Paolo Ermanni<sup>3</sup>, Dimos Poulikakos<sup>1</sup>, Aldo Ferrari<sup>1</sup>, and Edoardo Mazza<sup>2,5</sup>

<sup>1</sup> *Thermodynamics in Emerging Technologies, D-MAVT, ETH Zurich*, <sup>2</sup> *Experimental Continuum Mechanics, D-MAVT, ETH Zurich*, <sup>3</sup> *Composite Materials & Adaptive Structures, D-MAVT, ETH Zurich*, <sup>4</sup> *Department of Obstetrics, University Hospital Zurich*, <sup>5</sup> *Mechanical Integrity of Energy Systems, Empa*

The generation of a living protective layer at the luminal surface of cardiovascular devices, composed of an autologous functional endothelium, represents the ideal solution to life-threatening, implant-related complications in cardiovascular patients. The initial evaluation of engineering strategies fostering endothelial cell adhesion and proliferation as well as the long-term tissue homeostasis requires *in vitro* testing in environmental model systems able to recapitulate the hemodynamic conditions experienced at the blood-to-device interface of implants as well as the substrate deformation. Here, we introduce the design and validation of a novel bioreactor system which enables the long-term conditioning of human endothelial cells interacting with artificial materials under dynamic combinations of flow-generated wall shear stress and wall deformation. The wall shear stress and wall deformation values obtained encompass both the physiological and supraphysiological range. They are determined through separate actuation systems which are controlled based on validated computational models. In addition, we demonstrate the good optical conductivity of the system permitting online monitoring of cell activities through live-cell imaging as well as standard biochemical post-processing. Altogether, the bioreactor system defines an unprecedented testing hub for potential strategies toward the endothelialization or re-endothelialization of target substrates.

B. J. Machmann et al., *Sci. Rep.* (2016)

---

**28 Continuous Solar-Driven Thermolysis of CO<sub>2</sub> into CO and O<sub>2</sub> with an Isothermal Ceria Membrane Reactor**

Maria Tou, Ronald Michalsky, and Aldo Steinfield

*Renewable Energy Carriers, D-MAVT, ETH Zurich*

Splitting CO<sub>2</sub> with a thermochemical redox cycle utilizes the entire solar spectrum and provides an attractive path to the synthesis of solar fuels at high rates and efficiencies. However, irreversible energy losses and severe material stresses are inherent to the temperature/pressure-swing operation commonly applied between the reduction and oxidation steps. Here, we experimentally demonstrate for the first time the continuous splitting of CO<sub>2</sub> into separate streams of CO and O<sub>2</sub> under steady-state isothermal/isobaric conditions. This benchmark demonstration was accomplished with a solar-driven ceria membrane reactor conducting oxygen ions and vacancies driven by the oxygen chemical potential gradient across the membrane. Guided by the limitations imposed by thermodynamic equilibrium of CO<sub>2</sub> thermolysis, we operated the solar reactor at 1600°C and 3x10<sup>-6</sup> bar partial pressure of O<sub>2</sub> under 3500 suns radiation, yielding total selectivity of CO<sub>2</sub> to CO and O<sub>2</sub> with a

steady-state conversion rate of  $0.024 \mu\text{mol s}^{-1}$  per  $\text{cm}^2$  of membrane. The dynamics of the oxygen vacancy exchange across the membrane, tracked by gas chromatography and X-ray photoelectron spectroscopy, further validated stable fuel production.

---

**29 Effect of Au Size on Catalyst Activity for Low Temperature Water-Gas Shift Reaction in Idealized and Realistic Reaction Conditions**

Noha Abdel Wahab, Kakeru Fujiwara, and Sotiris E. Pratsinis

*Particle Technology Laboratory, D-MAVT, ETH Zurich*

Au size on  $\text{CeO}_2$  and  $\text{TiO}_2$  supports was controlled by varying the Au content (0.05–0.56 wt.%) using flame-spray pyrolysis (FSP). The Au size effect on low temperature water-gas shift (WGS) reaction ( $\text{CO} + \text{H}_2\text{O} \Rightarrow \text{H}_2 + \text{CO}_2$ ) was investigated at  $250^\circ\text{C}$  in 10% CO and 3%  $\text{H}_2\text{O}$  and in reformate gas mixture (11% CO, 26%  $\text{H}_2\text{O}$ , 26%  $\text{H}_2$ , 7%  $\text{CO}_2$ ). At 15 mL/min of 10% CO and 3%  $\text{H}_2\text{O}$  (balance He), the  $\text{H}_2$  production rate of 0.56 wt.% of Au on  $\text{TiO}_2$  and  $\text{CeO}_2$  are comparable. However, with decreasing Au content, the  $\text{H}_2$  production rate per Au (in mol) of Au/ $\text{TiO}_2$  gradually decreases while that of Au/ $\text{CeO}_2$  increases. Notably, in a reformate gas mixture (11% CO, 26%  $\text{H}_2\text{O}$ , 26%  $\text{H}_2$ , 7%  $\text{CO}_2$ ), the  $\text{H}_2$  production rate per Au (in mol) of Au/ $\text{CeO}_2$  increases with increasing Au loading up till 0.28 wt.% and decreases with further increase in Au loading. At the optimal Au loading (0.28 wt.%), the  $\text{H}_2$  production rate ( $0.23 \text{ mol}_{\text{H}_2}/\text{s/mol}_{\text{Au}}$ ) is comparable with atomically dispersed Au catalysts reported in literature. The activation energy in both reaction conditions (40–45 kJ/mol) are comparable and consistent with literature. Thus, the difference in optimal Au loading is not due to a different reaction pathway.

---

**30 Highly Sensitive Ethanol Gas Sensor Using Interconnected Trimodally Porous  $\text{SnO}_2$  Nanospheres**

Ji-Wook Yoon<sup>1</sup>, Seung Ho Choi<sup>2</sup>, Jun-Sik Kim<sup>3</sup>, Ho Won Jang<sup>4</sup>, Yun Chan Kang<sup>2</sup>, and Jong-Heun Lee<sup>3</sup>

<sup>1</sup> *Particle Technology Laboratory, D-MAVT, ETH Zurich*, <sup>2</sup> *Nano Electronic Materials Laboratory, Korea University*,

<sup>3</sup> *Functional Nano Materials Laboratory, Korea University*, <sup>4</sup> *Oxide Nanostructures & Nanoelectronics Laboratory, Seoul National University*

Porous nanostructures have been vigorously investigated for their rapid mass transport of chemical reactants to their surface followed by high gas response. In this study, we successfully synthesized dense (D-), bimodally porous (2M-) and trimodally porous (3M-)  $\text{SnO}_2$  nanospheres using Multi-Walled Carbon Nanotube (MWCNT), Polystyrene (PS) spheres with various sizes as templates by ultrasonic spray pyrolysis and studied their gas responses to ethanol. Precursor solution containing tin oxalate, MWCNT, PS spheres were used to prepare 3M- $\text{SnO}_2$  spheres (pore sizes  $\approx 3, 20, 100 \text{ nm}$ ) and it showed excessively high response to 5 ppm ethanol ( $S = 316.5$  at  $400^\circ\text{C}$ ). These results show the enhanced gas accessibility through interconnection of trimodal pores in 3M- $\text{SnO}_2$  sensors compared to 2M- $\text{SnO}_2$  sensors by introducing one-dimensional pores via MWCNT template.

---

**31 Charge Compensating Double Doped Ceria for Improved Redox Performance of Solar Thermochemical  $\text{H}_2\text{O}/\text{CO}_2$  Splitting Cycles**

Marie Hoes, Christopher Muhich, and Aldo Steinfeld

*Renewable Energy Carriers, D-MAVT, ETH Zurich*

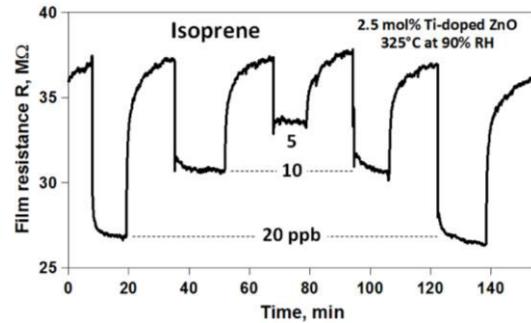
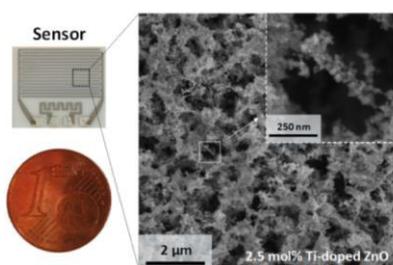
Solar-driven thermochemical redox cycles utilizing nonstoichiometric metal oxides are considered for splitting  $\text{H}_2\text{O}$  and  $\text{CO}_2$  to produce  $\text{H}_2$  and CO (syngas), the precursor of synthetic liquid hydrocarbon fuels. Charge compensating double doped ceria was fabricated using 3+ and 5+ dopants, namely  $\text{Ce}_{0.9}\text{A}_{0.05}\text{Nb}_{0.05}\text{O}_2$  (A=Y, La, Sc). These materials, along with  $\text{Ce}_x\text{La}_{(1-x)/2}\text{Nb}_{(1-x)/2}\text{O}_2$  ( $x=0.75, 0.95$ ), were investigated by thermodynamic characterization and compared to pure and Hf doped ceria. Oxygen nonstoichiometry was measured by thermogravimetric analysis in the temperature range  $T = 1173\text{--}1773 \text{ K}$  and oxygen partial pressure range  $p_{\text{O}_2} = 10^{-15}\text{--}10^{-1} \text{ atm}$ . At a given  $T$  and  $p_{\text{O}_2}$ , the reduction extent of the double doped materials is between that of  $\text{Ce}_{0.9}\text{Hf}_{0.1}\text{O}_2$  and pure ceria as predicted by DFT calculations, with increasing values for decreasing dopant concentrations. We found that the experimental data is accurately described by a defect model based on a combined point and cluster defect. Thermodynamic properties, namely the partial molar enthalpy and entropy were extracted from the

defect model. The calculated partial molar enthalpy of the charge compensating double doped materials is within the range of 360-410 kJ/mol and varies based on composition and dopant concentration. These novel redox materials can be tuned for improved redox performance of solar thermochemical H<sub>2</sub>O/CO<sub>2</sub> splitting cycles.

### 32 Easy Cholesterol Monitoring from Breath: Selective Isoprene Detection with Ti-Doped ZnO Sensors

Andreas T. Güntner, Stéphanie Schon, Nicolay J. Pineau, Donovan Chie, Frank Krumeich, and Sotiris E. Pratsinis  
Particle Technology Laboratory, D-MAVT, ETH Zurich

Approximately 39% of the world population suffers from high blood cholesterol levels that might be responsible for 2.6 million estimated deaths per year<sup>[1]</sup>. Breath isoprene is a promising



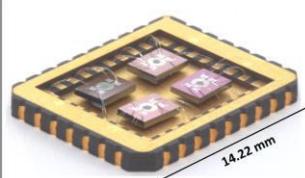
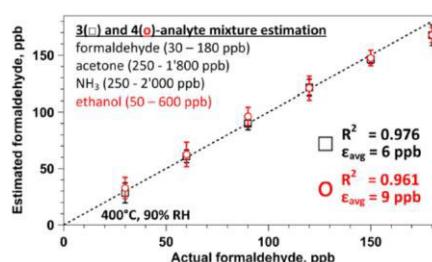
marker for non-invasive monitoring of blood cholesterol-lowering therapy. Here, we present for the first time an *isoprene-selective* sensor consisting of chemo-resistive Ti-doped ZnO nanoparticles<sup>[2]</sup>. Stable Ti-doped ZnO solid solutions are synthesized by flame spray pyrolysis and directly deposited onto sensor substrates forming highly porous films. At an optimized Ti content (2.5 mol%), the resulting sensing films detect isoprene concentrations down to 5 ppb with high signal-to-noise ratio ( $> 10$ ) at breath-realistic conditions (90 % relative humidity). Furthermore, this sensor showed superior isoprene selectivity towards acetone, NH<sub>3</sub> and ethanol while featuring fast response times (< 1 min) suitable for real-time breath analysis. As a result, an inexpensive isoprene sensor is presented that can be incorporated readily into portable devices for blood cholesterol-monitoring<sup>[3]</sup>.

[1] WHO, *Global Health Observatory (GHO) data* (2015); [2] A. T. Güntner et al., *J. Mater Chem. B* **4**, 5358 (2016);  
[3] M. Righettoni et al., *J. Breath Res.* **9**, 047101 (2015)

### 33 Breath Formaldehyde Sensing with Small Sensor Arrays for Lung Cancer Detection

Andreas T. Güntner<sup>1</sup>, Julia Kompalla<sup>1</sup>, Vitaly Koren<sup>1</sup>, Kiran Chikkadi<sup>2</sup>, Marco Righettoni<sup>1</sup>, and Sotiris E. Pratsinis<sup>1</sup>  
<sup>1</sup> Particle Technology Laboratory, D-MAVT, ETH Zurich, <sup>2</sup> Micro & Nanosystems, D-MAVT, ETH Zurich

The early diagnosis of lung cancer could significantly improve medical therapy reducing mortality rates. A promising breath markers for early lung cancer detection is formaldehyde (FA)<sup>[1]</sup>. Especially needed are portable FA analyzers for rapid screening of a widespread pop-



ulation. Here, we present a microsensor array for selective breath FA detection consisting of four differently doped and nanostructured SnO<sub>2</sub> films. The sensor substrates are silicon wafer-based and fabricated by state-of-the-art micro-processing technology resulting in an extremely compact design with low power consumption (500 mW) at operational condition. Rapid flame aerosol synthesis is applied to pattern highly porous and nanostructured SnO<sub>2</sub> sensing films (500 μm in diameter) on these substrates. The resulting sensors are highly sensitivity and can detect FA down to 5 ppb (SNR > 30) at breath-realistic 90% relative humidity. Even in breath-simulating gas-mixtures (with interfering acetone, NH<sub>3</sub> and ethanol concentrations), FA can be detected selectively with an average error of  $\leq 9$  ppb. These arrays can be integrated into portable electronic devices (e.g. smart phone).

[1] D. Fuchs et al., *Int. J. Cancer* **126**, 2663 (2010); [2] A. T. Güntner et al, *ACS Sensors* **1**, 528 (2016)

### 34 The Study of Colloidal Nanocrystals with Dynamic Nuclear Polarization NMR Spectroscopy

Laura Piveteau<sup>1,2</sup>, Ta-Chung Ong<sup>3</sup>, Aaron J. Rossini<sup>4</sup>, Brennan J. Walder<sup>4</sup>, Lyndon Emsley<sup>4</sup>, Christophe Copéret<sup>3</sup>, and Maksym V. Kovalenko<sup>1,2</sup>

<sup>1</sup> Functional Inorganic Materials, D-CHAB, ETH Zurich, <sup>2</sup> Laboratory for Thin Films & Photovoltaics, Empa,

<sup>3</sup> Surface & Interfacial Chemistry, D-CHAB, ETH Zurich, <sup>4</sup> Institute of Chemical Sciences & Engineering, EPFL

Nuclear magnetic resonance (NMR) is one of the most powerful analytical techniques to characterize molecules (solution NMR) and materials (solid-state NMR), including colloidal or powdered nanocrystals (NCs). However, NMR is suffering of inherently poor sensitivity, especially when it comes to isotopes other than <sup>1</sup>H, <sup>13</sup>C, <sup>19</sup>F and <sup>31</sup>P, rendering most NC materials difficult or not accessible by NMR.

We have presented in earlier work that dynamic nuclear polarization (DNP) is an efficient enhancement technique for NMR signal from NCs, especially for surface-located species, which are particularly low abundant compared to the NC-core atoms<sup>[1]</sup>. We developed a novel, universally applicable, extremely simple and inexpensive methodology for sample preparation to overcome the low signal intensity<sup>[2]</sup>. Further, we found 2D-spectroscopy to be an elegant tool to overcome the difficulties of spectra interpretation, by visualizing interactions<sup>[2]</sup> (Fig.) or by increasing resolution through the isolation of line broadening effects<sup>[3]</sup>.

NMR therefore permits to selectively study NC-core, NC-surface or capping ligands, may they be of organic or inorganic nature. Additionally, atomistic-level insights into nature and distribution of species present in NCs can be obtained. Their composition, chemical dynamics and electronic structure can be studied, which are inaccessible through any other known single analytical technique.

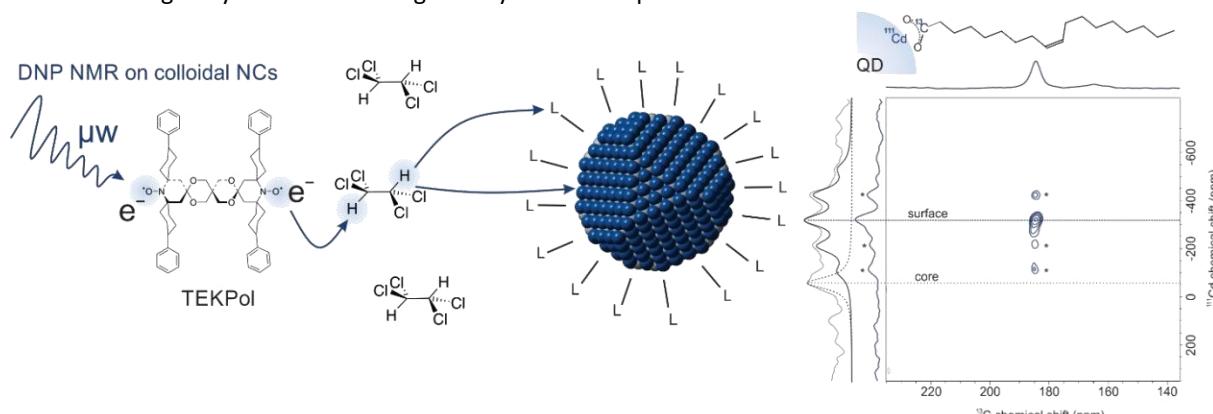


Fig. (left) Polarization transfer mechanism of DNP-NMR, (right) D-HMQC-R3 spectrum displaying connectivity of the oleate ligand to the surface cadmium species.

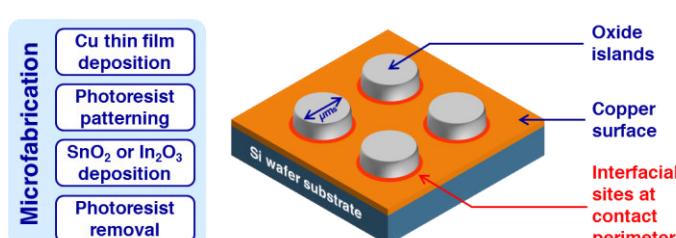
- [1] L. Protesescu et al., *ACS Nano* **8**, 2639 (2014); [2] L. Piveteau et al., *J. Am. Chem. Soc.* **137**, 13964 (2015); [3] L. Piveteau et al., *in preparation* (2017)

### 35 Magic at the Interface: A Microfabrication Process for Model Oxide-On-Metal Electrodes for Electrocatalytic CO<sub>2</sub> Reduction

Gaston O. Larrazábal, Tatsuya Shinagawa, Antonio J. Martín, and Javier Pérez-Ramírez

Advanced Catalysis Engineering, D-CHAB, ETH Zurich

Combining the electrochemical reduction of CO<sub>2</sub> (eCO<sub>2</sub>RR) with carbon-neutral energy sources is a potentially sustainable strategy for recycling carbon emissions. In particular, reducing CO<sub>2</sub> to CO would provide a versatile building block for the production of liquid fuels and plastics. However, the application of



this reaction requires the development of more efficient electrocatalysts<sup>[1]</sup>. Cu-In and Cu-Sn catalysts have shown high selectivity for CO evolution at moderate overpotentials, but their further development requires the

rationalization of the synergistic effect observed in these multicomponent systems. Oxidic species that are stable under reaction conditions are crucial to the eCO<sub>2</sub>RR over bulk In and Sn electrodes<sup>[2,3]</sup>, and recent findings indicate that the presence of In(OH)<sub>3</sub> plays a pivotal role in maintaining a high selectivity for CO over Cu-In catalysts<sup>[4]</sup>. Consequently, we hypothesize that bifunctional sites located at the interfaces between Cu surfaces and In and Sn (hydr)oxides are particularly favorable for CO evolution. To investigate this hypothesis, we have developed a photolithography-based process for creating model electrodes with “oxide islands” on a Cu surface. By quantitatively relating the catalytic performance of the electrodes to their microstructural geometry, we aim to shed light on the role of interfacial sites in the reduction of CO<sub>2</sub> to CO.

- [1] A. J. Martín et al. *Green Chem.* **17**, 5114 (2015); [2] A. Dutta et al. *ACS Catal.* **5(12)**, 7498 (2015); [3] Z. M. Detweiler et al. *Langmuir* **30(25)**, 7593 (2014); [4] G. O. Larrazábal et al. *ACS Catal.* **6(9)**, 6265 (2016)

---

### **36 Low Temperature Wet Conformal Metal Silicide Deposition for Transistor Technology through an Organometallic Approach**

Tsung-Han Lin<sup>1</sup>, Tigran Margossian<sup>1</sup>, Michele De Marchi<sup>2</sup>, Maxime Thammasack<sup>2</sup>, Sudhir Kumar<sup>3</sup>, Chih-Jen Shih<sup>3</sup>, Giovanni De Michelis<sup>2</sup>, David Baudouin<sup>1</sup>, Pierre-Emmanuel Gaillardon<sup>4</sup>, and Christophe Copéret<sup>1</sup>

<sup>1</sup> Surface & Interfacial Chemistry, D-CHAB, ETH Zurich, <sup>2</sup> Integrated Systems Laboratory, EPFL,

<sup>3</sup> Interface & Surface Engineering of Nanomaterials, D-CHAB, ETH Zurich, <sup>4</sup> Electrical & Computer Engineering Department, University of Utah (USA)

The formation of metal silicides, which are indispensable materials involved in the fabrication of all field effect transistors to reduce the contact resistance of the source and drain regions<sup>[1]</sup>, has been identified as one of the most critical steps in current fabrication process flows<sup>[2]</sup>. Among all the existing metal silicides, cobalt silicide (CoSi<sub>x</sub>) has advantages for its low resistivity, its material compatibility, and its good stability<sup>[3]</sup>. However, the transition towards devices using advanced 3D geometries makes it challenging to form homogeneous silicides using classical silicidation processes based on sputtering. Therefore, a one-pot wet chemical approach<sup>[4]</sup> has been proposed to synthesize the metal silicide layer onto silicon wafer exhibiting applicable electric properties and allowing a homogenous coverage of 3D-structure device. A 20-nm Co-rich layer on Si (100) wafer was observed by electron microscopy (STEM-EDS), a layer that according to preliminary XAS results on the Si(0) model indicated to be CoSi<sub>x</sub>. XPS spectroscopy showed a small amount of carbon contamination, which is similar to what is found for the pristine Si wafer (< 9%). Then, high temperature vacuum-treatment ( $\sim 10^{-5}$  mbar) leads to layer having conductive behavior (Ohmic behavior) with a lower resistivity ( $\rho = 116 \mu\Omega\cdot\text{cm}$ ) measured by 4-point probe measurement confirming the presence of Cobalt silicide. In addition to forming the silicide layer onto the flat Si (100) surface, the method was applied to 3D-patterned wafers, in which the TEM results showed that a promising step coverage ratio could be obtained. This work shows that the homogeneous CoSi<sub>x</sub> layer can be deposited via wet organometallic approach at ambient temperature and that, after thermal vacuum-treatment, it exhibits an Ohmic behavior with a low resistivity, thus creating an alternative possibility for modern 3D-transistor fabrication.

- [1] H. Zhang et al., *2015 IITC/MAM*, May; IEEE: 187 (2015); [2] Y.-C. Chou et al., *Nano Lett.* **15**, 4121 (2015); [3] K. Bernal-Ramos et al., *Chem. Mater.* **27**, 4943 (2015); [4] T.-H. Lin et al., *ACS Appl. Mater. Interfaces* **9**, 4948 (2017)

---

### **37 Synthesis of Nanocrystalline Iron(III) Trifluoride from Molecular Precursors and Its Li- and Na-Ion Storage Properties**

Christoph P. Guntlin<sup>1,2</sup>, Tanja Zünd<sup>1,2</sup>, Michael Wörle<sup>1</sup>, Kostiantyn V. Kravchyk<sup>1,2</sup>, Maryna I. Bodnarchuk<sup>2</sup>, and Maksym V. Kovalenko<sup>1,2</sup>

<sup>1</sup> Functional Inorganic Materials, D-CHAB, ETH Zurich, <sup>2</sup> Laboratory for Thin Films & Photovoltaics, Empa

The performance demands placed on batteries for the use in electrical mobility and portable devices are enormous. Cathode materials remain a bottleneck for the further increase on energy density. A promising candidate

compound featuring low cost and high natural abundance is iron trifluoride ( $\text{FeF}_3$ ). It has been demonstrated that  $\text{FeF}_3$  intercalates lithium with near theoretical capacity of 237 mAh/g<sup>[1]</sup>, also with promising rate capability<sup>[2]</sup>. However, there remains a strong need to develop low-cost synthesis methods for this material in a nanoscale form, needed for maximizing the performance. Herein, we show a new synthesis for nanocrystalline  $\text{FeF}_3$  based on a thermal decomposition of an organic precursor. Such inexpensive  $\text{FeF}_3$  can be charged and discharged in a lithium half-cell at a reversible capacity of 155 mAh/g within 1 min (10 A/g) or even faster. After 100 cycles, a capacity retention of 88 % has been achieved. In a sodium-ion half-cell, a capacity of 160 mAh/g at a current rate of 0.2 A/g could be measured<sup>[3]</sup>.

- [1] J. Liu et al., *J. Mater. Chem. A* **1**, 1969 (2013); [2] D. L. Ma et al., *Energy Environ Sci*, **5**, 8538 (2012);  
[3] C. P. Guntlin et al., *J. Mater. Chem. A* **5**, 7383 (2017)

---

**38 Single Crystals of Caesium-Formamidinium Lead Halide Perovskites: Phase Stability and Gamma Dosimetry**

Olga Nazarenko<sup>1,2</sup>, Sergii Yakunin<sup>1,2</sup>, Viktoriia Morad<sup>1</sup>, Ihor Cherniukh<sup>1</sup>, and Maksym V. Kovalenko<sup>1,2</sup>

<sup>1</sup> *Functional Inorganic Materials, D-CHAB, ETH Zurich*, <sup>2</sup> *Laboratory for Thin Films & Photovoltaics, Empa*

---

**39 Room-Temperature Growth of Superhydrophobic Semiconductor Nanowires on Arbitrary Substrates**

Tian Tian<sup>1</sup>, Chander Shekhar Sharma<sup>2</sup>, Navanshu Ahuja<sup>1</sup>, Dimos Poulikakos<sup>2</sup>, and Chih-Jen Shih<sup>1</sup>

<sup>1</sup> *Interface & Surface Engineering of Nanomaterials, D-CHAB, ETH Zurich*, <sup>2</sup> *Thermodynamics in Emerging Technologies, D-MAVT, ETH Zurich*

The fabrication of functional nanowires is crucial in nanophotonics, nanoelectronics and functional surface technologies. Here we present a room-temperature growth method of semiconducting copper perfluorophthalocyanine (F16CuPc) nanowires on graphene by low pressure evaporation. We show that the growth of nanowires is attributed to the orientation of F16CuPc molecules on graphene. Owing to the fluoro-rich nature of such semiconducting molecule, the F16CuPc nanowires on graphene exhibit superhydrophobicity, in combination with the Cassie-Baxter wetting state of its nanostructures. Due to the versatility of graphene transferring technology, we present that the nanowires can be grown on arbitrary substrates, including copper,  $\text{SiO}_2$ , and wood, with uniform hydrophobicity. The semiconducting nanowires, in combination with the gate-tunable conductivity of graphene, is also capable for fabricating vertical field effect transistors.

---

**40 Surface Plasmon Polariton Self-Interference of Electric and Magnetic Dipoles in Front of Plasmonic Reflectors**

Raphael Brechbühler<sup>1</sup>, Freddy Rabouw<sup>1</sup>, Patrik Rohner<sup>2</sup>, Boris Le Feber<sup>1</sup>, Dimos Poulikakos<sup>2</sup>, and David J. Norris<sup>1</sup>

<sup>1</sup> *Optical Materials Engineering, D-MAVT, ETH Zurich*, <sup>2</sup> *Thermodynamics in Emerging Technologies, D-MAVT, ETH Zurich*

---

**41 Ultra-Flat and Structured Template Stripped Metal-Organic Halide Perovskites**

Alexander Hernandez Oendra, Eva De Leo, Aurelio A. Rossinelli, Andreas Riedinger, David J. Norris, and

Ferry Prins

*Optical Materials Engineering, D-MAVT, ETH Zurich*

Metal-organic halide perovskites benefit from unique material properties such as continuous band gap tunability, high carrier mobility, low non-radiative carrier recombination rates, and potential inexpensive fabrication methodologies. Thanks to these advantages, perovskite thin film devices are interesting candidates for photovoltaic and light emitting technologies. To facilitate the integration of perovskite thin films into such optoelectronic device architectures, there is a growing need for simple and efficient fabrication methods.

Here we present a template stripping technique to produce ultra-flat and flexible Perovskite thin films. We combine careful surface engineering of silicon templates with a one-step spin-coating procedure to produce high-quality  $\text{CH}_3\text{NH}_3\text{PbX}_3$  ( $X = \text{I}, \text{Br}$ ) perovskite thin films. These films can be mechanically cleaved from the silicon template using a polymer adhesive backing to expose the ultra-flat perovskite surfaces. We will demonstrate

how we can use the flatness and flexibility of these films to provide new processing strategies based on dry-interfacing. Moreover, we will show that our method can produce structured Perovskite surfaces with sub-micron resolution when using pre-patterned silicon templates.

## 42 Polarization-Resolved Spectral Multiplexing Using Multi-Resonant Plasmonic Antennas

Eva De Leo, Ario Cocina, Preksha Tiwari, Lisa Poulikakos, Patricia Marqués Gallego, Boris le Feber, David J. Norris, and Ferry Prins

*Optical Materials Engineering, D-MAVT, ETH Zurich*

Plasmonic antennas are able to confine electromagnetic fields at the nanoscale as well as shape the far-field pattern of coupled emitters. Specifically, careful design of these nanostructures allows enhanced in- and out-coupling of light for targeted wavelengths or propagation directions. Moreover, the ability to control both the polarization-dependent response of the plasmonic antenna and the polarization state of the outgoing light, offers an effective strategy to manipulate electromagnetic fields<sup>[1,2]</sup>. Thanks to these properties, optical nanoantennas represent a powerful tool in a wide range of applications including optical imaging, light harvesting, and sensing<sup>[3]</sup>. One of the most successful examples of plasmonic antennas are the so-called bull's eye apertures<sup>[4-6]</sup>. Using concentric circular grooves around a central subwavelength hole, these single-resonant structures provide spectrally selective and directional transmission of light<sup>[4,5]</sup>. Here, inspired by these structures, we introduce a new class of plasmonic bull's eye antennas, consisting of concentric polygons<sup>[7]</sup>. In contrast to the traditional circular bull's eyes, our polygonal bull's eyes can accommodate multiple resonances by introducing variations in the periodicity along the different axes of the structure. Moreover, the resonant color associated with each axis will acquire a unique linear polarization imposed by the axis orientation. We experimentally demonstrate that the resonance wavelengths of our structures can indeed be directly mapped to the transmitted polarization. From these observations, that we support with far-field simulations, we will work toward polarimetric applications that may enable increased sensitivity and selectivity in plasmonic sensing.

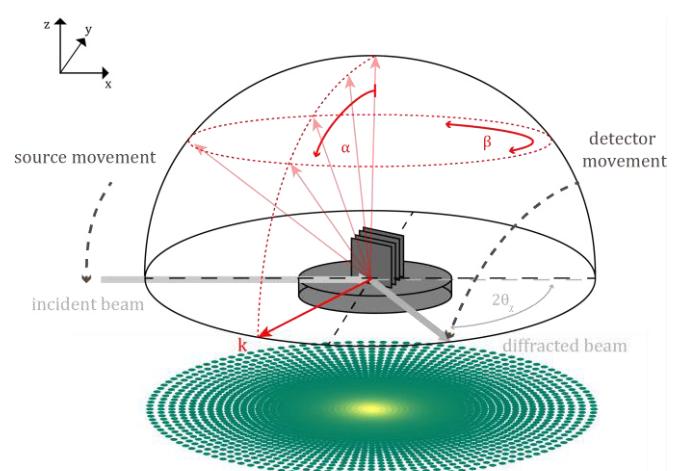
- [1] L. Novotny et al., *Nature Photonics* **5**, 83 (2011); [2] C. Osorio et al., *Scientific Reports* **5**, 9966 (2015);
- [3] F. Afshinmanesh et al., *Nanophotonics* **1**, 125 (2012); [4] H. J. Lezec et al., *Science* **297**, 820 (2002);
- [5] J. Schuller et al., *Nature Materials* **9**, 193 (2010); [6] S. Han et al., *Phys. Rev. Lett.* **104**, 043901 (2010); [7] E. De Leo et al., **in preparation** (2017)

## 43 Orientation Distributions of Platelet Shaped Graphite Particles in LIB Anodes

Paul Baade, Martin Ebner, and Vanessa Wood

*Nanoelectronics, D-ITET, ETH Zurich*

Platelet-shaped graphites are often used as an active material in lithium ion battery anodes. Because of their anisotropic shape, the orientation distributions of the particles play an important role in optimizing battery performance. Current techniques to quantify orientation distributions have drawbacks: scanning electron microscopy (SEM) cross-section images are destructive, time consuming and present ambiguities due to their 2D nature. X-ray tomography is data intensive and may not be readily available to a large number of users. We present x-ray diffraction-based texture measurements as a rapid, quantitative, non-invasive method to characterize the orientation of graphite flakes in battery anodes. Pole figures, which are a way of representing a preferred orientation of lattice planes, are collected from x-ray diffraction



*Fig. Experiment setup of in-plane texture measurements. The resulting pole figure is shown in green/yellow as a projection.*

with laboratory equipment in as little as 30 min. The overall grain distribution, which is directly measured, is modeled as a convolution of a grain orientation distribution within a single particle and a particle orientation distribution. The March model is used to describe the individual contributions and to derive a degree of preferred orientation.

#### **44 Growth Control of CdSe Nanoplatelets Using New Organoselenium Precursors**

Aniket S. Mule<sup>1</sup>, Andreas Riedinger<sup>1,2</sup>, Philippe N. Knüsel<sup>1</sup>, Florian D. Ott<sup>1</sup>, Aurelio A. Rossinelli<sup>1</sup>, and David J. Norris<sup>1</sup>

<sup>1</sup> Optical Materials Engineering, D-MAVT, ETH Zurich, <sup>2</sup> Max Planck Institute for Polymer Research in Mainz (Germany)

Semiconductor nanoplatelets are quasi-2D materials having atomically precise thickness which therefore gives rise to spectrally pure fluorescence. Recently we demonstrated the synthesis of Nanoplatelets by heating blends of cadmium carboxylate and elemental selenium<sup>[1]</sup>. The simplicity of this synthetic route allowed us to explore the underlying chemistry and understand the reaction pathway to form these nanoplatelets. We performed in-situ thermogravimetric measurements coupled with mass spectroscopy and realised the reduction pathway of selenium to diacyl selenides which eventually lead to formation of nanoplatelets. With this knowledge, we synthesised a series of diacyl selenides with a tailored reactivity towards cadmium carboxylates. A previously established protocol was further modified to get rid of the chromatographic techniques and was scaled up 20 times to produce diacyl selenides at a gram scale with a purity of >90%. We demonstrate for first time the control over thickness of CdSe nanoplatelets through reactivity of the precursor<sup>[2]</sup>. Such precursors could be exploited in nanocrystal (NC) or quantum dot (QD) syntheses, where elemental Se or S is often combined with metal carboxylates and can serve as a good alternative to thiourea or selenourea which might have a detrimental impact on NC synthesis due to the metal binding affinity of sulfo/thiocarbamide groups. With the enhanced reactivity of such precursor, we were also able to demonstrate the synthesis of nanoplatelets at temperatures as low as 100°C resulting in a more controlled growth of platelets.

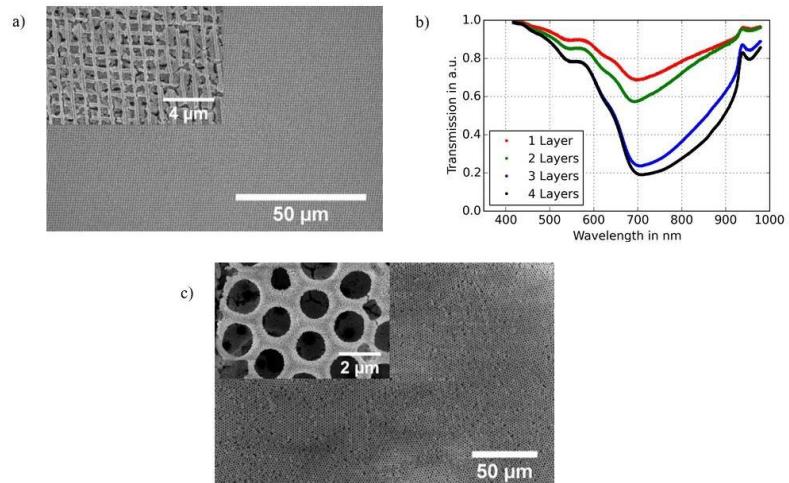
[1] A. Riedinger et al., *Nat. Mater.*, 10.1038/nmat4889 (2017); [2] A. Riedinger et al., **in preparation** (2017)

#### **45 Solution Processing of BaTiO<sub>3</sub> Nanoparticles for Nonlinear Photonic Applications**

Viola Valentina Vogler-Neuling<sup>1</sup>, Nicholas R. Hendricks<sup>2</sup>, Barbara Schneider<sup>1</sup>, Victor Chausse<sup>1</sup>, and Rachel Grange<sup>1</sup>

<sup>1</sup> Optical Nanomaterial Group, D-PHYS, ETH Zurich, <sup>2</sup> CSEM Neuchâtel (Switzerland)

The perovskite barium titanate (Ba-TiO<sub>3</sub>) offers huge potentials for a variety of applications reaching from electro-optical modulators in integrated photonic devices<sup>[1]</sup> over flat optical components to biological applications exploiting barium titanate's linear and nonlinear optical properties at the nanoscale<sup>[2]</sup>. Fabrication of perovskite based nonlinear materials is often challenging due to an inherent high etch resistance<sup>[3]</sup>. Therefore, we demonstrate two fast and low-cost solution based processing methods for barium titanate (Soft Nanoimprint Lithography and Evaporation Induced Self-Assembly) which are easily implementable on industrial scales. With use of these methods, we realized 3D woodpile photonic crystal structures



*Fig. a) SEM pictures of a 3D photonic crystal woodpile structure b) Linear response from one to four woodpile layers measured in transmission. There is a clear formation of a band gap at 700 nm with increasing amount of layers. c) SEM pictures of inverse opal structure.*

(Fig. a) exhibiting an incomplete band gap at 700 nm (Fig. b) and inverse opal structures (Fig. c). Future challenges are related to roughness, refractive index contrasts in the nanoparticle sol-gel layers and random phase matching of the individual particles.

[1] S. Abel et al., *Advanced Photonics* (2013); [2] F. Timpu et al., *ACS Photonics* **4**, 76 (2017); [3] S. Dizain et al., *Appl. Phys. Lett.* **103**, 051117 (2013)

---

#### **46 High-Temperature Growth of Thick-Shell CdSe/CdS Core/Shell Nanoplatelets**

Aurelio A. Rossinelli<sup>1</sup>, Andreas Riedinger<sup>1,2</sup>, Patricia Marqués Gallego<sup>1</sup>, Philippe N. Knüsel<sup>1</sup>, and David J. Norris<sup>1</sup>

<sup>1</sup> *Optical Materials Engineering, D-MAVT, ETH Zurich*, <sup>2</sup> *Max Planck Institute for Polymer Research, Mainz (Germany)*

Colloidal nanoplatelets (NPLs) are quasi-two-dimensional nanocrystals with atomically precise thicknesses. As a result of their well controlled geometry, CdE (E=Se, S, Te) NPLs show much narrower absorption and emission linewidths than quantum dots.<sup>[1]</sup> These properties make NPLs very interesting candidates for optical and optoelectronic applications where spectrally pure emission is desired. However, to optimize the optical properties and improve photo- and chemical stability, they need to be coated with a shell of an appropriate material.

Due to their two-dimensional geometry, nanoplatelets are thermodynamically much less stable at elevated temperatures than quantum dots.<sup>[2]</sup> This makes the development of a coating protocol significantly more difficult as it has to ensure that the nanoplatelets do not undergo etching or ripening during the process. As a result, only a very limited number of synthetic routes have been developed to coat nanoplatelets with a shell, and most of them involve multiple reaction steps.<sup>[3,4]</sup>

Herein, we present a new method for obtaining CdSe/CdS core/shell NPLs in which the shell is added at high temperature. To develop such a protocol, we first aimed to minimize the etching of the core NPLs during shell growth. We were then able to synthesize high-quality monodisperse CdSe/CdS core/shell NPLs with narrow emission linewidths, high QYs, and uniform shell thicknesses. Such samples exhibit significant spectral shifts in emission from 515 nm for CdSe NPL cores to 670 nm for the core/shell NPLs.

[1] S. Ithurria et al., *Nat. Mater.* **10**, 936 (2011); [2] A. Riedinger et al., *arXiv:1605.06553* (2016); [3] S. Ithurria et al., *J. Am. Chem. Soc.* **134**, 18585 (2012); [4] B. Mahler et al., *J. Am. Chem. Soc.* **134**, 18591 (2012)

---

#### **47 Low Temperature Hydrothermal Synthesis of Battery-Grade LiFePO<sub>4</sub> Platelet Particles**

Peter Benedek, Nils Wenzler, Maksym Yarema, and Vanessa Wood

*Nanoelectronics, D-ITET, ETH Zurich*

LiFePO<sub>4</sub> (LFP) is a commercially-used cathode material in lithium ion batteries that offers high rate capability and relatively low toxicity compared to cobalt-containing systems. LFP crystalizes in an olivine-type structure with a highly stable FePO<sub>4</sub> backbone and one-dimensional lithium channels along which the main Li ion diffusion occurs. In these channels, single defects of Fe can hinder Li ions. Therefore, it is crucial to both reduce the Li channel length and keep the antisite defect concentration low. Hydrothermal syntheses of LFP platelet particles have been shown to be very promising to fulfill both of these conditions; however, typically hydrothermal reactor temperatures must exceed 150°C, which means very high energy consumption and high reactor overpressures, making it unlikely for commercial use.

Here, we report a hydrothermal reaction of LFP at only 115°C, for which reactor overpressure is only 1 bar. Combining Fourier Transform Infrared spectroscopy with X-ray diffraction and Scanning electron microscopy, we can track changes of particle morphology and defect concentration from different samples and optimize them with surfactants and improved reaction conditions. We obtain LFP particles with a specific discharge capacity of over 150mAh/g at a C/10 rate maintaining 130mAh/g at a rate of 1C. A detailed energy analysis from mine to ready-to-use cathode material shows us that applying our approach, we reduce the energy consumption by 30% and become compatible with solid state synthesis approaches.

---

## 48 Stair-Rod Dislocation Cores Acting as Nano-Channels for Carrier Mono-Dimensional Transport in GaAs Nanowires

Nicolas Bologna<sup>1,2</sup>, Piyush Agrawal<sup>1,3</sup>, Marco Campanini<sup>1</sup>, Moritz Knödler<sup>2</sup>, Luca Francaviglia<sup>4</sup>, Anna Fontcuberta i Morral<sup>4</sup>, Marta D. Rossell<sup>1,2</sup>, Rolf Erni<sup>1</sup>, and Daniele Passerone<sup>3</sup>

<sup>1</sup> Advanced Materials & Surfaces, Empa, <sup>2</sup> IBM Research Zurich, <sup>3</sup> Nanotech@Surfaces Laboratory, Empa,

<sup>4</sup> Laboratoire des Matériaux Semiconducteurs, EPFL

III-V semiconductor nanowires are low dimensional compounds receiving an increasing interest from the research community thanks to their superior physical properties. Compared to silicon, their higher electron mobility combined with bandgap engineering results in perfectly suited materials for electronic devices. Furthermore, the nanowire geometry offers, besides novel architecture possibilities, a larger gap for critical dimensions below which misfit dislocations can be reduced, allowing a more optimal growth. However, other types of defects can be present in the crystals, e.g. partial dislocations and stacking faults, acting as traps able to affect the performance of the device by inducing non-radiative recombination of the carriers. For this reason, the structure and influence of such imperfections have been deeply studied in the last decade.

In the present work, we investigated, by means of aberration-corrected STEM, the atomic structure of {111}-oriented v-shaped intrinsic stacking faults merging together into two different stair-rod dislocations in gallium arsenide NWs. Atomic-scale elemental mapping obtained by energy dispersive x-ray spectroscopy (EDS) allowed us to determine unambiguously the nature of the single gallium and arsenic columns at the dislocation cores. A 3D atomic model was built and its validity verified with Stem\_Cell software by comparing the strain distribution of the experimental data. Concordantly, both simulated and experimental data show quantitatively comparable strain. The same model was then implemented in density functional theory calculations to analyze the effect induced on the band gap and the density of states (DOS). A decrease in the gap from 1.15 eV (bulk) to 0.65 eV (defect) was observed. Furthermore, a shift of highly localized DOS from the valence band of the gallium core to the conduction band of the arsenic core was reported along the intrinsic stacking fault. This suggests the possibility to obtain nano-channels able to transport electrons and holes through the entire nanowire for novel electronic applications.

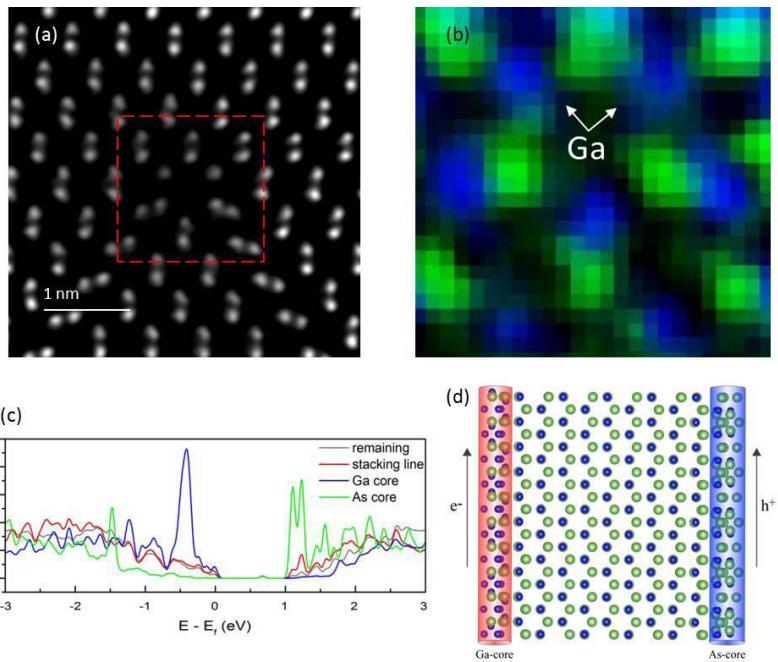


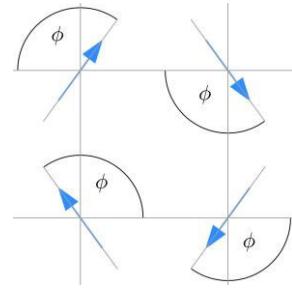
Fig. (a) Atomic-resolution HAADF-STEM micrograph showing the dislocation core as the result of the merging of two differently inclined intrinsic stacking faults. (b) Atomically-resolved EDX elemental map to identify the single unpaired atomic columns. (c) Density of states simulation highlighting the localized states in the valence and conduction band for the gallium and arsenic core, respectively. A lower energy gap (0.65 eV) with respect to the bulk crystal (1.2 eV) is also observable. (d) Graphical representation illustrating how the two type of dislocation cores, extending along the whole nanowire, can act as preferential nano-channels for electron and holes within the gallium and arsenic core, respectively.

## 49 Monte Carlo Renormalization Group Study of Dipolar Coupled XY Spins

Dominik Schildknecht<sup>1,2,3</sup>, Laura J. Heyderman<sup>2,3</sup>, and Peter Derlet<sup>2</sup>

<sup>1</sup> Condensed Matter Theory, PSI, <sup>2</sup> Mesoscopic Systems, D-MATL, ETH Zurich, <sup>2</sup> Laboratory for Micro- & Nanotechnology, PSI

In contrast to well-known models such as the Heisenberg model, which just incorporate the notion of the nearest neighbour, the anisotropic dipolar interaction directly depends on the geometry of the lattice and therefore its symmetries. These symmetries should be reflected by the properties of a possible phase transition in that system. To study these effects we employ the Monte Carlo Renormalization Group technique since this method can provide precise estimates of the critical exponents. We will show our latest results for the 2D XY dipolar interacting square lattice and other related systems.




---

## **50 Multiscale Modelling of Texture Evolution and Discontinuous Dynamic Recrystallization of HCP Metals in Thermo-Mechanical Processing**

Abbas D. Tutcuoglu<sup>1,2</sup>, Vidyasagar<sup>1,2</sup>, Kaushik Bhattacharya<sup>3</sup>, and Dennis M. Kochmann<sup>1,2</sup>

<sup>1</sup> *Mechanics & Materials, D-MAVT, ETH Zurich, <sup>2</sup> GALCIT, California Institute of Technology (USA),*

<sup>3</sup> *Department of Mechanical Engineering, California Institute of Technology (USA)*

With the recent advent of magnesium alloys endowed with significantly improved flammability properties compared to their pure counterpart as well as relaxed regulations in the automotive and aerospace industry, the interest in integrating magnesium has experienced a significant increase. In view of the diversity of applications and variety of requirements on macroscopic properties, a fundamental understanding of the dependence of the latter on the underlying microstructure is of paramount importance. Amongst the myriad of factors affecting the desired tailoring of macroscopic properties, optimal grain size control through thermo-mechanical processes such as equal channel angular extrusion (ECAE) is indispensable in achieving the desired yield strength and creep performance. Numerous models provide the means to simulate the two major mechanisms underlying the microstructural evolution under plastic deformation, namely, texture evolution and recrystallization, but are generally confined to small strains or face-centered cubic (fcc) metals. However, both the presence of twinning in hexagonal close-packed (hcp) metals as well as the inherently large deformations in ECAE demand for new alternatives. The model we present affords the solution to the microscopic initial boundary value problem (IBVP) for a representative volume element (RVE) based on the Fast Fourier Transform (FFT). The time evolution of internal variables throughout the RVE is performed on the basis of a variational constitutive model for slip-twinning interactions in finite deformation kinematics<sup>[1,2]</sup>. We apply the model to simulate texture evolution in pure Mg and present an extension to capture discontinuous dynamic recrystallization (DDRX) during severe plastic deformation. The results from a diffuse interface phase-field and a sharp interface stochastic Monte-Carlo approach are compared to a computationally inexpensive Taylor model and the influence of both manufacturing conditions as well as the initial microstructures on the final state are presented.

[1] Y. Chang et al., *Int. J. Plast.* **73**, 39 (2015); [2] M. Ortiz et al., *Computer Methods in Applied Mechanics and Engineering* **171**, 419 (1999)

---

## **51 Modelling of Nascent and Mature Soot Optical Properties**

Joel Zuercher, Georgios A. Kelesidis, and Sotiris E. Pratsinis

*Particle Technology Laboratory, D-MAVT, ETH Zurich*

Soot optical properties are typically approximated with the well-known and relatively easy-to-use Mie theory for spheres, neglecting the fractal-like nature of soot. The Rayleigh-Debye-Gans (RDG) theory for agglomerates consisting of primary particles in point contact has been applied alternatively, resulting in better agreement with optical measurements<sup>[1]</sup>. However, it is unable to resolve the effect of overlapping soot primary particles typically observed in microscopic images of soot. The robust Discrete Dipole Approximation (DDA) has been validated against RDG for the case of agglomerates<sup>[2]</sup> and can also be used for aggregates of chemically-bonded primary particles.

Here, the Discrete Element Model (DEM) for agglomeration and surface growth by acetylene pyrolysis in the absence of oxidation<sup>[3]</sup> is used to derive the evolution from nascent to mature soot morphology, quantified by

the fractal dimension,  $D_f$ , and mass-mobility exponent,  $D_{fm}$ . The good agreement found between the DEM-derived  $D_f$  and  $D_{fm}$  evolutions and microscopy<sup>[4]</sup> and mass-mobility measurements<sup>[5,6]</sup>, respectively, indicates that the present DEM for agglomeration and surface growth accurately captures the transition from nascent to mature soot morphology by agglomeration and surface growth, before oxidation takes over.

The DEM-derived soot aggregate optical properties are quantified by the absorption,  $C_{abs}$ , and extinction cross-sections,  $C_{ext}$ , calculated by DDA and compared to those of agglomerates having monodisperse primary particles. The DDA calculations for agglomerates are validated against those of [2]. Nascent soot aggregates formed in the early stages of soot formation, when surface growth is dominant, have to 86 % larger  $C_{ext}$  and  $C_{abs}$  for mass,  $m = 0.002$  fg compared to agglomerates formed at the same residence time in the absence of surface growth. At longer residence times, however, when surface growth has stopped and mature soot grows primarily by agglomeration, the difference between aggregates and agglomerates decreases to about 1 % for both  $C_{ext}$  and  $C_{abs}$ . The DEM-derived mature soot  $C_{ext}$  obtained as function of the incident light wavelength is in fair agreement with Laser Induced Incadescence measurements from diesel engines<sup>[7]</sup>. The ratio of  $C_{abs}$  estimated at 532 nm over that estimated at 1064 nm is 1.79, in excellent agreement with the asymptotic ratio of 1.8 measured from mature soot aggregates in diffusion flames<sup>[8]</sup>.

- [1] M. Loepfe et al., AUBE14 (2014); [2] L. Liu et al., *J. Quant. Spectrosc. Radiat. Transfer* **109**, 2656 (2008); [3] G. A. Kelesidis et al., *Proc. Combust. Inst.* **36**, 29 (2017); [4] M. Schenk et al., *PhysChemPhys* **14**, 3248 (2013); [5] J. Rissler et al., *Aerosol Sci. Technol.* **47**, 792 (2013); [6] J. Yon et al., *J. Aerosol Sci.* **87**, 28 (2015); [7] J. Yon et al., *Appl. Phys. B* **104**, 253 (2011); [8] L. Y. Xerxes et al., *J. Aerosol Sci.* **75**, 43 (2014)

---

## 52 All-Atom Models of Tobermorite 11 Å and 14 Å – Benchmarks for Realistic Modelling of C-S-H

Tariq Jamil<sup>1</sup>, Ratan K. Mishra<sup>2</sup>, Robert J. Flatt<sup>2</sup>, and Hendrik Heinz<sup>1</sup>

<sup>1</sup> Chemical & Biological Engineering Department, University of Colorado Boulder (USA), <sup>2</sup> Physical Chemistry of Building Materials, D-BAUG, ETH Zurich

Calcium silicate hydrate is the main binding phase in cementitious materials. Its accurate atomic-scale models and force fields are crucial in the development of a greener construction industry. Tobermorite 11 Å and 14 Å minerals are known to be the closest crystalline structural analogs for calcium silicate hydrate (C-S-H). Therefore, dependable tobermorite models can serve as a benchmark for C-S-H, which exhibits complex poorly crystalline structures and variable surface chemistry at solid-liquid interfaces and for which nanoscale details are difficult to obtain from experiments. The Interface force field describes models that reproduce covalent versus ionic bonding and surface properties in agreement with experiment in contrast to other models. A new version of tobermorite parameters with extensive validation is presented in this study. Atomic charges of calcium ions of 1.5e in the intra-layer region and 1.7e in the partially hydrated inter-layer region were found to best describe chemical bonding. The lattice parameters of both minerals deviate less than 0.5% on average from X-ray data. The surface energy of tobermorite 14 Å ( $405 \pm 10$  mJ/m<sup>2</sup> least for 001 facet) agrees with available experimental measurements for C-S-H ( $\text{Ca}_3\text{Si}_2\text{O}_7 \cdot 2\text{H}_2\text{O}$ ) of  $386 \pm 20$  mJ/m<sup>2</sup>, whereas other models lead to deviations over 50%. The computed bulk moduli of tobermorite 11 Å and 14 Å are  $71 \pm 2$  GPa and  $45 \pm 1$  GPa, respectively, matching experiment within the uncertainty. Parameters developed using the INTERFACE approach (IFF) are consistent with other important cement phases such as CH, C<sub>3</sub>S, C<sub>3</sub>A, CaO, water, and polymers. This platform is therefore helpful in defining full scale atomistic models of C-S-H multiphase mixtures with local and global morphologies. Brief applications to understand conformations and working mechanisms of polycarboxylate ether superplasticizers in comparison to experiment are demonstrated using these models.

---

## 53 Understanding Electromechanical Microstructure Evolution in Ferroelectric Ceramics

Vidyasagar Ananthan<sup>1,2</sup>, Wei-Lin Tan<sup>2</sup>, and Dennis Kochmann<sup>1,2</sup>

<sup>1</sup> Mechanics & Materials, D-MAVT, ETH Zurich, <sup>2</sup> GALCIT, California Institute of Technology (USA)

Ferroelectric ceramics exhibit electromechanical coupling below the Curie temperature and can be used in large deformation actuators, energy harvesting devices and advanced computer chips. However, to this end, the non-

linear electromechanical response of bulk polycrystalline ferroelectrics, arising from nanoscale and microscale influences, is not yet well understood. Experimental observations indicate the formation of electric domain patterns at the sub-polycrystalline length scale. The evolution and motion of these domain walls appear to dictate the macroscopic electromechanical properties. In this work, theoretical and computational predictions of the evolution of ferroelectric domains in BaTiO<sub>3</sub> and PZT-5A are presented. Pattern formation from random initial states, together with macroscopic electric cycling and strain hysteresis curves are shown and discussed. The results of computational simulations using spectral phase field techniques, and Density Functional Theory derived energetic potentials, are subsequently compared to in-house experimental results (for PZT-5A) to show convincing agreement.

---

#### 54 Molecular Dynamics Simulation of Gas Diffusion in Zeolites

Natalia Smatsi, Nikolaos Lempesis, Vlasios Mavrantzas, and Sotiris E. Pratsinis

Particle Technology Laboratory, D-MAVT, ETH Zurich

In Particle Technology Laboratory, novel devices for the selective sensing of small gas molecules, that serve as health markers in breath, are currently designed and developed<sup>[1]</sup>. A key component of these breath sensors are thin zeolite membranes of all silica or Al-doped frameworks. To get a deeper understanding of the mechanism of response of these sensors to selected compounds, in addition to experimental studies, we employ atomistic molecular dynamics (MD) simulations to model the permeability of selected gases through all-silica MFI zeolites. We rely on detailed forcefields which we validate on the basis of the comparison of the corresponding MD predictions, for several physical properties of the zeolite framework (density, XRD pattern, thermal expansion coefficient), against experimental data. We will report results from these simulations and we will discuss how they are compared with other simulation data in the literature, as well as, experimental measurements. Particular emphasis will be given to the adsorption (or not) of these gases in the pores of the zeolite and their diffusive behaviour through the three different types of pores (straight, zig-zag, sinusoidal) in silicalite-1, and its dependence on temperature.

[1] A. T. Güntner et al., *Sens Actuator B Chem.* **223**, 266 (2016)

---

#### 55 Drawing Coloured Patterns in Concrete

Thibault Demoulin<sup>1</sup>, Ena Lloret-Fritsch<sup>1</sup>, Lex Reiter<sup>1</sup>, Anna Szabo<sup>2</sup>, Fabio Scotto<sup>2</sup>, Timothy Wangler<sup>1</sup>, Fabio Gramazio<sup>2</sup>, Matthias Kohler<sup>2</sup>, and Robert J. Flatt<sup>1</sup>

<sup>1</sup> Physical Chemistry of Building Materials, D-BAUG, ETH Zurich, <sup>2</sup> Institute of Technology in Architecture, D-ARCH, ETH Zurich

The process of Smart Dynamic Casting, developed in the framework of the NCCR Digital Fabrication project, offers the unique possibility of engraving concrete before it hardens. Patterns and grooves can be made and filled with other materials during the casting process, for aesthetic or functional purposes. This work presents the inclusion of coloured patterns in the concrete. The material used for these patterns is a mix of natural sandstone and acrylic resin, used for more than 40 years in the repair of built heritage. The wide variety of colours of local sandstones gives access to a large range of colours for the patterns. Moreover, the mechanical properties of this material make it adequate for use as inlays in the concrete. The mechanisms that control the compatibility with the concrete substrate have recently been uncovered: the viscoelastic relaxation of the polymer associated with a relatively low glass transition temperature, in the range of temperatures found on-site, allows a fast relaxation of the stresses that originate from differential expansion. Together with the process of Smart Dynamic Casting, this material adds another dimension to the manufacturing of concrete.



## **56 Slipforming with Flexible Formwork – Inline Measurement and Control**

Ena Lloret-Fritsch<sup>1</sup>, Lex Reiter<sup>2</sup>, Timothy Wangler<sup>2</sup>, Fabio Gramazio<sup>1</sup>, Matthias Kohler<sup>1</sup>, and Robert J. Flatt<sup>2</sup>

<sup>1</sup> Institute of Technology in Architecture, D-ARCH, ETH Zurich, <sup>2</sup> Physical Chemistry of Building Materials, D-BAUG, ETH Zurich

Smart Dynamic Casting (SDC) – a robotic prefabrication method for non-standard concrete structures – has emerged from shaping concrete with a rigid formwork into an almost fully automated system enabling the production of concrete structures with variable cross-section and geometries using flexible actuated formworks. The flexible formwork systems have yielded full scale prototypes (up to 3 meters in height) that vary in shape, volume and thickness, and show that the SDC design space can be significantly expanded, far beyond what has been achieved in previous studies.

Two different shaping methods were applied. The first method shapes the material locally, at the exit of the formwork, only allowing a minimal gradient of deformation. The second method shapes the material globally, across the whole height of formwork, allowing for significant variation in cross section.

Regardless of whether the deformation occurs locally or globally, any deformation modifies the load on the concrete at the exit of the formwork, thus requiring continuous inline measurements and automated feedback loops. A recent successful approach combines formwork pressure and friction measurements to define the lower and upper strength limits of the shaping window, thereby enabling more robust control of the process.

Together, these advances bring the SDC system another step closer to the main objective of the research, which is to develop a fully automated system that enables efficient production of load bearing structures in a continuous digital chain.

---

## **57 Integrated Lightweight Structures with Additive Manufacturing and Carbon Fiber-Reinforced Polymers**

Daniel-Alexander Türk and Mirko Meboldt

Product Development, D-MAVT, ETH Zurich

The combination of Additive Manufacturing (AM) with Carbon Fiber-Reinforced Polymers (CFRP) is a combination of strengths for the development of highly integrated lightweight structures. This goal of this research is to establish design and processing knowledge for the successful implementation of the combination of technologies.

In this research, an autoclave prepreg layup process is used: Hat-stiffeners with structural cores made by AM are over-laminated with CFRP and cured in an autoclave. The stiffeners are subjected to three-point bending testing to evaluate the mechanical performance in terms of breaking load and stiffness. AM is used to tailor the mechanical properties of the core to the load. Design approaches include AM honeycombs, and load oriented trusses. The designs are compared to a state-of-the Art foam core reference. AM-CFRP stiffeners exhibit a significantly increased breaking load and bending stiffness, while the stress peaks could be reduced.

The results confirm the mechanical competitiveness of AM-CFRP for the production of individualized, high-performance structures with complex geometries. Case studies from robotics and aerospace highlight the potentials with weight savings amounting up to 54%, and part count and assembly step reduction of up to 50%, compared to state-of-the-art designs.

---

## **58 Chemical Solutions for Environmentally Friendly Cements in Switzerland**

Federica Boscaro<sup>1</sup>, Marta Palacios<sup>1,2</sup>, Nilanjon Naskar<sup>1</sup>, Delphine Marchon<sup>1</sup>, and Robert J. Flatt<sup>1</sup>

<sup>1</sup> Physical Chemistry of Building Materials, D-BAUG, ETH Zurich, <sup>2</sup> Eduardo Torroja Institute for Construction Science, CSIC in Madrid (Spain)

Concrete is the most used material in the world and it accounts for about 5-8% of CO<sub>2</sub> emissions. Lowering the clinker content by using supplementary cementitious materials (SCMs) is a successful solution to reduce the embodied energy and the carbon footprint of Portland cement. Nevertheless, the main drawback is the limited mechanical strength at early ages. Our project is focused on the formulation of new low clinker concrete that consider the local availability of raw materials in Switzerland. Specifically, a blended cement composed by 50%

of Portland cement and 50% of SCMs such as limestone, burnt oil shale and slag, is studied. Two different types of admixtures are used to reach a higher early strength. Accelerators, as NaOH and Na<sub>2</sub>SO<sub>4</sub>, are incorporated in order to increase the early reactivity of the binder. Comb-copolymer superplasticizers are added to decrease the water content maintaining a high fluidity. Nevertheless, strong incompatibilities between these two types of admixtures, due to competitive adsorption, have been proved by previous studies. Marchon et al.<sup>[1]</sup> developed a criterion that allows to select the PCEs with a molecular structure compatible with alkaline systems. In this work, the compatibility between the two types of admixtures on the fluidity, the hydration kinetics and the mechanical strength has been studied on pastes, mortars and concrete.

Results have proved the compatibility between these accelerators and comb-copolymers with a high adsorption equilibrium constant. Furthermore, the addition of Ca(NO<sub>3</sub>)<sub>2</sub> favors the adsorption of the comb-copolymer leading to a further decrease of the yield stress. A methacrylic-based PCE has been selected for the production of low clinker concrete as it offers the best properties in terms of fluidity, hydration kinetics and compressive strength up to 90 days.

[1] D. Marchon et al., *Soft Matter* **9**, 10719 (2013)

---

#### **59 Ultra High Performance Thermally Insulating Aerogel Mortars**

Daniel Sanz Pont and Robert J. Flatt

*Physical Chemistry of Building Materials, D-BAUG, ETH Zurich*

Ultra high performance thermally insulating mortars can be achieved by the incorporation aerogel granules into a cementitious matrix via polymer surfactants. The application of such mortars deeply depends on the mechanical properties that can be achieved, as having an ultra-low thermal conductivity compromises the final mortar's strength<sup>[1]</sup>. In this sense, specific material processing can enhance both mechanical and thermal insulating properties making them suitable for building applications. Additionally, in combination with Ultra-High strength concrete, constructive elements such as sandwich panels for highly thermal insulating prefabricated walls can be obtained.

[1] D. Sanz et al., *Materials & Structures* **49.9**, 3647 (2016)

---

#### **60 Towards the Development of a Novel Adhesion System between Wood Timber and Concrete: Investigation of the Wood-Glue-Concrete-Interface**

Sanja Kostic<sup>1,2</sup>, Vivian Merk<sup>1,2</sup>, John K. Berg<sup>1,2</sup>, Philip Hass<sup>1,2</sup>, Ingo Burgert<sup>1,2</sup>, and Etienne Cabane<sup>1,2</sup>

<sup>1</sup> *Wood Materials Science, D-BAUG, ETH Zurich*, <sup>2</sup> *Applied Wood Materials Laboratory, Empa*

Timber-concrete composite structures require rigid, strong, but also ductile connections to optimize their performance. Up to now, the preferred connection systems have been mainly based on metal fasteners or slots in the wood. Within the scope of this project, an alternative technology based on a fully glued connection is proposed, and a wood pre-treatment is applied in order to enhance the compatibility and the adhesion properties at the interface between beech wood and concrete. The wood surface is functionalised with a xerogel obtained by means of a sol-gel process, and consisting of layers of silane nanofilms bearing different functional groups aiming for a chemical interaction with the glue itself. By the use of various chemical analytical methods, we aim to show that the functionalities attached to the wood surface contribute to the epoxy curing and therefore an additional chemical connection will be established in addition to mechanical interlocking due to glue penetration. In terms of mechanical properties, 3-point and 4-point bending tests, as well as push-out experiments reveal the effectiveness of the modification in terms of bending strength, shear resistance and ductile behaviour of the composites.

---

# LIST OF PARTICIPANTS

- Abdala Paula Macarena, Dr.**, Energy Science & Engineering, D-MAVT, ETH Zurich, [abdala@ethz.ch](mailto:abdala@ethz.ch)
- AbdelWahab Noha**, Particle Technology Laboratory, D-MAVT, ETH Zurich, [anoha@student.ethz.ch](mailto:anoha@student.ethz.ch)
- Abrishamkar Afshin**, Biochemical Engineering, D-CHAB, ETH Zurich, [afshin.abrishamkar@chem.ethz.ch](mailto:afshin.abrishamkar@chem.ethz.ch)
- Aellen Marianne**, Optical Materials Engineering, D-MAVT, ETH Zurich, [maellen@ethz.ch](mailto:maellen@ethz.ch)
- Akan Mehmet Tolga**, Complex Materials, D-MATL, ETH Zurich, [makan@student.ethz.ch](mailto:makan@student.ethz.ch)
- Alicke Alexandra**, Soft Materials, D-MATL, ETH Zurich, [alexandra.alicke@mat.ethz.ch](mailto:alexandra.alicke@mat.ethz.ch)
- Alison Lauriane**, Complex Materials, D-MATL, ETH Zurich, [lauriane.alison@mat.ethz.ch](mailto:lauriane.alison@mat.ethz.ch)
- Ananthan Vidyasagar**, Mechanics & Materials, D-MAVT, ETH Zurich, [vidyasav@ethz.ch](mailto:vidyasav@ethz.ch)
- Aramesh Morteza, Dr.**, Biosensors & Bioelectronics, D-ITET, ETH Zurich, [aramesh@biomed.ee.ethz.ch](mailto:aramesh@biomed.ee.ethz.ch)
- Arcari Mario**, Food & Soft Materials, D-HEST, ETH Zurich, [mario.arcari@hest.ethz.ch](mailto:mario.arcari@hest.ethz.ch)
- Armbrecht Lucas**, Bioanalytics Group, D-BSSE, ETH Zurich, [Lucas.Armbrecht@bsse.ethz.ch](mailto:Lucas.Armbrecht@bsse.ethz.ch)
- Armutlulu Andac, Dr.**, Energy Science & Engineering, D-MAVT, ETH Zurich, [aandac@ethz.ch](mailto:aandac@ethz.ch)
- Baade Paul**, Nanoelectronics, D-ITET, ETH Zurich, [pbaade@iis.ee.ethz.ch](mailto:pbaade@iis.ee.ethz.ch)
- Bachmann Bjoern**, Thermodynamics in Emerging Technologies, D-MAVT, ETH Zurich, [bjoern@ethz.ch](mailto:bjoern@ethz.ch)
- Bagnani Massimo**, Food & Soft Materials, D-HEST, ETH Zurich, [massimo.bagnani@hest.ethz.ch](mailto:massimo.bagnani@hest.ethz.ch)
- Bao Yinyin, Dr.**, Drug Formulation & Delivery, D-CHAB, ETH Zurich, [yinyin.bao@pharma.ethz.ch](mailto:yinyin.bao@pharma.ethz.ch)
- Bargardi Fabio**, Complex Materials, D-MATL, ETH Zurich, [fabio.bargardi@mat.ethz.ch](mailto:fabio.bargardi@mat.ethz.ch)
- Beltramo Peter, Dr.**, Soft Materials, D-MATL, ETH Zurich, [peter.beltramo@mat.ethz.ch](mailto:peter.beltramo@mat.ethz.ch)
- Benedek Peter**, Nanoelectronics, D-ITET, ETH Zurich, [benedekp@iis.ee.ethz.ch](mailto:benedekp@iis.ee.ethz.ch)
- Binelli Marco Riccardo**, Complex Materials, D-MATL, ETH Zurich, [marco.binelli@mat.ethz.ch](mailto:marco.binelli@mat.ethz.ch)
- Bircher Kevin**, Experimental Continuum Mechanics, D-MAVT, ETH Zurich, [bircher@imes.mavt.ethz.ch](mailto:bircher@imes.mavt.ethz.ch)
- Blattmann Christoph**, Particle Technology Laboratory, D-MAVT, ETH Zurich, [blattmann@ptl.mavt.ethz.ch](mailto:blattmann@ptl.mavt.ethz.ch)
- Bolisetty Sreenath, Dr.**, BluAct (ETH Spin-Off), [sreenath.bolisetty@hest.ethz.ch](mailto:sreenath.bolisetty@hest.ethz.ch)
- Bologna Nicolas**, Electron Microscopy Center, Advanced Materials & Surfaces, Empa, [nicolas.bologna@empa.ch](mailto:nicolas.bologna@empa.ch)
- Boscaro Federica**, Physical Chemistry of Building Materials, D-BAUG, ETH Zurich, [fboscaro@ethz.ch](mailto:fboscaro@ethz.ch)
- Bouville Florian, Dr.**, Complex Materials, D-MATL, ETH Zurich, [florian.bouville@mat.ethz.ch](mailto:florian.bouville@mat.ethz.ch)
- Boyce Chris, Dr.**, Energy Science & Engineering, D-MAVT, ETH Zurich, [cboyce@ethz.ch](mailto:cboyce@ethz.ch)
- Brechbühler Raphael**, Optical Materials Engineering, D-MAVT, ETH Zurich, [raphabre@ethz.ch](mailto:raphabre@ethz.ch)
- Büchel Robert, Dr.**, Particle Technology Laboratory, D-MAVT, ETH Zurich, [buechel@ptl.mavt.ethz.ch](mailto:buechel@ptl.mavt.ethz.ch)
- Buttinoni Ivo, Dr.**, Interfaces, Soft Matter & Assembly, D-MATL, ETH Zurich, [ivo.buttinoni@mat.ethz.ch](mailto:ivo.buttinoni@mat.ethz.ch)
- Cantarella Giuseppe**, Wearable Computing, D-ITET, ETH Zurich, [giuseppe.cantarella@ife.ee.ethz.ch](mailto:giuseppe.cantarella@ife.ee.ethz.ch)
- Cao Yiping**, Food & Soft Materials, D-HEST, ETH Zurich, [yiping.cao@hest.ethz.ch](mailto:yiping.cao@hest.ethz.ch)
- Carpenter Julia**, Complex Materials, D-MATL, ETH Zurich, [julia.carpenter@mat.ethz.ch](mailto:julia.carpenter@mat.ethz.ch)
- Casdorff Kirstin**, Wood Materials Science, D-BAUG, ETH Zurich / Empa, [kcasdorff@ethz.ch](mailto:kcasdorff@ethz.ch)
- Cassard Hannah**, Nanoscience for Energy Technology & Sustainability, D-MAVT, ETH Zurich, [cassardh@student.ethz.ch](mailto:cassardh@student.ethz.ch)
- Castro Pedro**, Energy Science & Engineering, D-MAVT, ETH Zurich, [cpedro@ethz.ch](mailto:cpedro@ethz.ch)
- Cavalli Maria Chiara**, Experimental Continuum Mechanics, D-MAVT, ETH Zurich / Empa, [mariachiara.cavalli@empa.ch](mailto:mariachiara.cavalli@empa.ch)
- Chanana Munish, Dr.**, Wood Materials Science, D-BAUG, ETH Zurich / Empa, [chananam@ethz.ch](mailto:chananam@ethz.ch)
- Chen Ming**, Nanometallurgy, D-MATL, ETH Zurich, [ming.chen@mat.ethz.ch](mailto:ming.chen@mat.ethz.ch)
- Chen Xiangzhong, Dr.**, Multi-Scale Robotics, D-MAVT, ETH Zurich, [chenxian@ethz.ch](mailto:chenxian@ethz.ch)
- Chen Yong**, Energy Science & Engineering, D-MAVT, ETH Zurich, [yonchen@student.ethz.ch](mailto:yonchen@student.ethz.ch)
- Chong Josephine, Dr.**, Food & Soft Materials, D-HEST, ETH Zurich, [josephine.chong@hest.ethz.ch](mailto:josephine.chong@hest.ethz.ch)
- Cihova Martina**, Metal Physics & Technology, D-MATL, ETH Zurich, [martina.cihova@mat.ethz.ch](mailto:martina.cihova@mat.ethz.ch)
- Cocina Ario**, Optical Materials Engineering, D-MAVT, ETH Zurich, [ariococina@gmail.com](mailto:ariococina@gmail.com)
- Cohrs Nicholas**, Functional Materials Laboratory, D-CHAB, ETH Zurich, [nicholas.cohrs@chem.ethz.ch](mailto:nicholas.cohrs@chem.ethz.ch)
- Colombo Gabriele**, Soft Materials, D-MATL, ETH Zurich, [gabriele.colombo@mat.ethz.ch](mailto:gabriele.colombo@mat.ethz.ch)
- Conzelmann Nicholas**, Energy Science & Engineering, D-MAVT, ETH Zurich, [nconzelm@student.ethz.ch](mailto:nconzelm@student.ethz.ch)
- Cui Jian, Dr.**, Optical Materials Engineering, D-MAVT, ETH Zurich, [gunqwee@ethz.ch](mailto:gunqwee@ethz.ch)
- Danzi Mario**, Composite Materials & Adaptive Structures, D-MAVT, ETH Zurich, [mdanzi@ethz.ch](mailto:mdanzi@ethz.ch)
- Daus Alwin**, Wearable Computing, D-ITET, ETH Zurich, [dausa@ife.ee.ethz.ch](mailto:dausa@ife.ee.ethz.ch)
- De Leo Eva**, Optical Materials Engineering, D-MAVT, ETH Zurich, [deleo@ethz.ch](mailto:deleo@ethz.ch)
- De Marco Carmela, Dr.**, Multi-Scale Robotics, D-MAVT, ETH Zurich, [demarcoc@ethz.ch](mailto:demarcoc@ethz.ch)
- Del Carro Luca**, Complex Materials, D-MATL, ETH Zurich / IBM Research, [ldc@zurich.ibm.com](mailto:ldc@zurich.ibm.com)
- Del Don Céline**, Bioanalytics Group, D-BSSE, ETH Zurich, [deldonce@student.ethz.ch](mailto:deldonce@student.ethz.ch)

**Demiroers Ahmet, Dr.**, Complex Materials,  
D-MATL, ETH Zurich, [ahmet.demiroers@mat.ethz.ch](mailto:ahmet.demiroers@mat.ethz.ch)

**Demoulin Thibault, Dr.**, Physical Chemistry of Building Materials, D-BAUG, ETH Zurich, [tdemoulin@ethz.ch](mailto:tdemoulin@ethz.ch)

**Diamantopoulou Marianna**, Computational Modelling of Materials in Manufacturing, D-MAVT, ETH Zurich, [mdiamant@ethz.ch](mailto:mdiamant@ethz.ch)

**Diener Michael**, Food & Soft Materials,  
D-HEST, ETH Zurich, [michael.diener@hest.ethz.ch](mailto:michael.diener@hest.ethz.ch)

**Dirin Dmitry, Dr.**, Functional Inorganic Materials,  
D-CHAB, ETH Zurich, [dirin@inorg.chem.ethz.ch](mailto:dirin@inorg.chem.ethz.ch)

**Donat Felix, Dr.**, Energy Science & Engineering,  
D-MAVT, ETH Zurich, [donatf@ethz.ch](mailto:donatf@ethz.ch)

**Donnelly Claire**, Mesoscopic Systems,  
D-MATL, ETH Zurich / Paul Scherrer Institute (PSI),  
[claire.donnelly@psi.ch](mailto:claire.donnelly@psi.ch)

**Doswald Simon**, Functional Materials Laboratory,  
D-CHAB, ETH Zurich, [simon.doswald@chem.ethz.ch](mailto:simon.doswald@chem.ethz.ch)

**Dufresne Eric, Prof.**, Soft & Living Materials,  
D-MATL, ETH Zurich, [ericd@ethz.ch](mailto:ericd@ethz.ch)

**Dunand David D., Prof.**, Materials Science & Engineering, Northwestern University,  
[dunand@northwestern.edu](mailto:dunand@northwestern.edu)

**Esswein Tobias**, D-MATL, ETH Zurich,  
[tewein@student.ethz.ch](mailto:tewein@student.ethz.ch)

**Faber Jakob, Dr.**, Complex Materials,  
D-MATL, ETH Zurich, [jakob.faber@mat.ethz.ch](mailto:jakob.faber@mat.ethz.ch)

**Fanelli Nicoló**, Soft & Living Materials,  
D-MATL, ETH Zurich, [nfanelli@student.ethz.ch](mailto:nfanelli@student.ethz.ch)

**Flatt Robert J., Prof.**, Physical Chemistry of Building Materials, D-BAUG, ETH Zurich, [flattr@ethz.ch](mailto:flattr@ethz.ch)

**Fleckenstein Peter**, Polymer Chemistry,  
D-CHAB, ETH Zurich, [peter.fleckenstein@chem.ethz.ch](mailto:peter.fleckenstein@chem.ethz.ch)

**Flohr Felicitas**, Bone Biomechanics,  
D-HEST, ETH Zurich, [flohrf@ethz.ch](mailto:flohrf@ethz.ch)

**Forro Csaba**, Biosensors & Bioelectronics,  
D-ITET, ETH Zurich, [forro@biomed.ee.ethz.ch](mailto:forro@biomed.ee.ethz.ch)

**Frey Marion**, Wood Materials Science,  
D-BAUG, ETH Zurich / Empa, [marionfrey@ethz.ch](mailto:marionfrey@ethz.ch)

**François-Martin Claire, Dr.**, Soft & Living Materials,  
D-MATL, ETH Zurich, [claire.francois@mat.ethz.ch](mailto:claire.francois@mat.ethz.ch)

**Fujisaki Tomoyuki**, Polymer Chemistry,  
D-MATL, ETH Zurich, [tfujisak@student.ethz.ch](mailto:tfujisak@student.ethz.ch)

**Fujiwara Kakeru, Dr.**, Particle Technology Laboratory,  
D-MAVT, ETH Zurich, [fujiwara@ptl.mavt.ethz.ch](mailto:fujiwara@ptl.mavt.ethz.ch)

**Gantenbein Silvan**, Complex Materials,  
D-MATL, ETH Zurich, [gasilvan@ethz.ch](mailto:gasilvan@ethz.ch)

**Ghanbari Reza**, Food & Soft Materials,  
D-HEST, ETH Zurich, [reza.ghanbari@hest.ethz.ch](mailto:reza.ghanbari@hest.ethz.ch)

**Grange Rachel, Prof.**, Optical Nanomaterial Group,  
D-PHYS, ETH Zurich, [orange@phys.ethz.ch](mailto:orange@phys.ethz.ch)

**Grossman Madeleine**, Complex Materials,  
D-MATL, ETH Zurich, [madeleine.grossman@mat.ethz.ch](mailto:madeleine.grossman@mat.ethz.ch)

**Gu Hongri**, Multi-Scale Robotics,  
D-MAVT, ETH Zurich, [hgu@student.ethz.ch](mailto:hgu@student.ethz.ch)

**Guntlin Christoph**, Functional Inorganic Materials,  
D-CHAB, ETH Zurich / Empa, [cguntlin@student.ethz.ch](mailto:cguntlin@student.ethz.ch)

**Güntner Andreas, Dr.**, Particle Technology Laboratory,  
D-MAVT, ETH Zurich,  
[Andreas.Guentner@ptl.mavt.ethz.ch](mailto:Andreas.Guentner@ptl.mavt.ethz.ch)

**Haag Fabian**, Metal Physics & Technology,  
D-MATL, ETH Zurich, [fabian.haaq@mat.ethz.ch](mailto:fabian.haaq@mat.ethz.ch)

**Haug Matthias**, Complex Materials,  
D-MATL, ETH Zurich, [matthias.haug@mat.ethz.ch](mailto:matthias.haug@mat.ethz.ch)

**Hausmann Michael**, Complex Materials,  
D-MATL, ETH Zurich / Empa,  
[michael.hausmann@empa.ch](mailto:michael.hausmann@empa.ch)

**Hejazi Zahra Alsadat**, Biochemical Engineering,  
D-CHAB, ETH Zurich, [hejaziz@student.ethz.ch](mailto:hejaziz@student.ethz.ch)

**Hernandez Alexander**, Optical Materials Engineering,  
D-MAVT, ETH Zurich, [hernanda@student.ethz.ch](mailto:hernanda@student.ethz.ch)

**Heyderman Laura, Prof.**, Mesoscopic Systems,  
D-MATL, ETH Zurich / Paul Scherrer Institute (PSI),  
[laura.heyderman@psi.ch](mailto:laura.heyderman@psi.ch)

**Hirt Luca, Dr.**, Biosensors & Bioelectronics,  
D-ITET, ETH Zurich, [hirt@biomed.ee.ethz.ch](mailto:hirt@biomed.ee.ethz.ch)

**Hoes Marie**, Renewable Energy Carriers,  
D-MAVT, ETH Zurich, [mhoes@ethz.ch](mailto:mhoes@ethz.ch)

**Hoop Marcus**, Multi-Scale Robotics,  
D-MAVT, ETH Zurich, [mhoop@ethz.ch](mailto:mhoop@ethz.ch)

**Hosseini Davood**, Energy Science & Engineering,  
D-MAVT, ETH Zurich, [davoodh@student.ethz.ch](mailto:davoodh@student.ethz.ch)

**Huang Hen-Wei**, Multi-Scale Robotics,  
D-MAVT, ETH Zurich, [hhuang@ethz.ch](mailto:hhuang@ethz.ch)

**Ibáñez María, Dr.**, Functional Inorganic Materials,  
D-CHAB, ETH Zurich, [ibanez@inorg.chem.ethz.ch](mailto:ibanez@inorg.chem.ethz.ch)

**Ijavi Mahdiye**, Soft & Living Materials,  
D-MATL, ETH Zurich, [Mahdiye.ijavi@mat.ethz.ch](mailto>Mahdiye.ijavi@mat.ethz.ch)

**Imtiaz Qasim, Dr.**, Energy Science & Engineering,  
D-MAVT, ETH Zurich, [qimtiaz@student.ethz.ch](mailto:qimtiaz@student.ethz.ch)

**Isa Lucio, Prof.**, Interfaces, Soft Matter & Assembly,  
D-MATL, ETH Zurich, [lucio.isa@mat.ethz.ch](mailto:lucio.isa@mat.ethz.ch)

**Ivannikov Sergey**, Energy Science & Engineering,  
D-MAVT, ETH Zurich, [isergey@ethz.ch](mailto:isergey@ethz.ch)

**Jain Vijay**, Photonics Laboratory,  
D-ITET, ETH Zurich, [jainv@ethz.ch](mailto:jainv@ethz.ch)

**Jain Abhishek**, Durability of Engineering Materials,  
D-BAUG, ETH Zurich, [abjain@ethz.ch](mailto:abjain@ethz.ch)

**Jensen Katharine, Dr.**, Soft & Living Materials,  
D-MATL, ETH Zurich, [katharine.jensen@mat.ethz.ch](mailto:katharine.jensen@mat.ethz.ch)

**Jeoffroy Etienne**, Complex Materials,  
D-MATL, ETH Zurich / Empa,  
[etienne.jeoffroy@mat.ethz.ch](mailto:etienne.jeoffroy@mat.ethz.ch)

**Kashima Keita, Dr.**, Polymer Chemistry,  
D-MATL, ETH Zurich, [keita.kashima@mat.ethz.ch](mailto:keita.kashima@mat.ethz.ch)

**Keitel Robert**, Optical Materials Engineering,  
D-MAVT, ETH Zurich, [keitelr@ethz.ch](mailto:keitelr@ethz.ch)

**Kholghy Reza, Dr.**, Particle Technology Laboratory,  
D-MAVT, ETH Zurich, [mkholghy@ethz.ch](mailto:mkholghy@ethz.ch)

**Kierzkowska Agnieszka, Dr.**, Energy Science & Engineering, D-MAVT, ETH Zurich, [akierzko@ethz.ch](mailto:akierzko@ethz.ch)

**Kim Sung Min**, Energy Science & Engineering,  
D-MAVT, ETH Zurich, [kimsu@student.ethz.ch](mailto:kimsu@student.ethz.ch)

**Knobelispies Stefan**, Wearable Computing,  
D-ITET, ETH Zurich, [stefan.knobelispies@ife.ee.ethz.ch](mailto:stefan.knobelispies@ife.ee.ethz.ch)

**Kompalla Julia**, Particle Technology Laboratory,  
D-MAVT, ETH Zurich, [juliako@ethz.ch](mailto:juliako@ethz.ch)

**Köpfli Stefan**, Optical Materials Engineering,  
D-MAVT, ETH Zurich, [koepfli@student.ethz.ch](mailto:koepfli@student.ethz.ch)

**Kostic Sanja**, Wood Materials Science,  
D-BAUG, ETH Zurich / Empa, [kostics@ethz.ch](mailto:kostics@ethz.ch)

**Kumar Sudhir, Dr.**, Interface & Surface Engineering of Nanomaterials, D-CHAB, ETH Zurich,  
[sudhir.kumar@chem.ethz.ch](mailto:sudhir.kumar@chem.ethz.ch)

**Kumar Priyank Vijaya, Dr.**, Optical Materials Engineering, D-MAVT, ETH Zurich, [pkumar@ethz.ch](mailto:pkumar@ethz.ch)

**Kurlov Alexey**, Energy Science & Engineering, D-MAVT, ETH Zurich, [kurlova@ethz.ch](mailto:kurlova@ethz.ch)

**Ladosz Agnieszka**, Transport Processes & Reactions, D-MAVT, ETH Zurich, [aladosz@ipe.mavt.ethz.ch](mailto:aladosz@ipe.mavt.ethz.ch)

**Lange Ralph**, Polymer Chemistry, D-MATL, ETH Zurich, [r lange@ethz.ch](mailto:r lange@ethz.ch)

**Larrazabal Gaston**, Advanced Catalysis Engineering, D-CHAB, ETH Zurich, [gaston.larrazabal@chem.ethz.ch](mailto:gaston.larrazabal@chem.ethz.ch)

**Leroux Jean-Christophe, Prof.**, Drug Formulation & Delivery, D-CHAB, ETH Zurich, [jleroux@ethz.ch](mailto:jleroux@ethz.ch)

**Liang Kun, Dr.**, Drug Formulation & Delivery, D-CHAB, ETH Zurich, [kun.liang@pharma.ethz.ch](mailto:kun.liang@pharma.ethz.ch)

**Liao Wei-Chih**, Surface & Interfacial Chemistry, D-CHAB, ETH Zurich, [liao@inorg.chem.ethz.ch](mailto:liao@inorg.chem.ethz.ch)

**Libanori Rafael, Dr.**, Complex Materials, D-MATL, ETH Zurich, [libanori@mat.ethz.ch](mailto:libanori@mat.ethz.ch)

**Lin Tsung-Han**, Interface & Surface Engineering of Nanomaterials, D-CHAB, ETH Zurich, [lin@inorg.chem.ethz.ch](mailto:lin@inorg.chem.ethz.ch)

**Lin Weyde**, Nanoelectronics, D-ITET, ETH Zurich, [weydelin@iis.ee.ethz.ch](mailto:weydelin@iis.ee.ethz.ch)

**Löbbert Laura**, Multifunctional Materials, D-MATL, ETH Zurich, [lauralo@student.ethz.ch](mailto:lauralo@student.ethz.ch)

**Loepfe Michael, Dr.**, Novamem Ltd (ETH Spin-Off), [michael.loepfe@chem.ethz.ch](mailto:michael.loepfe@chem.ethz.ch)

**Lucchini Mattia Alberto, Dr.**, Multifunctional Materials, D-MATL, ETH Zurich, [mattia.lucchini@mat.ethz.ch](mailto:mattia.lucchini@mat.ethz.ch)

**Lüchtefeld Ines**, Biosensors & Bioelectronics, D-ITET, ETH Zurich, [luechtefeld@biomed.ee.ethz.ch](mailto:luechtefeld@biomed.ee.ethz.ch)

**Luo Alan**, Polymer Physics, D-MATL, ETH Zurich, [aluo@mat.ethz.ch](mailto:aluo@mat.ethz.ch)

**Lustenberger Urs**, Functional Materials Laboratory, D-CHAB, ETH Zurich, [urs.lustenberger@chem.ethz.ch](mailto:urs.lustenberger@chem.ethz.ch)

**Martinez Vincent, Dr.**, nanoleq (ETH Spin-Off), [martinez@biomed.ee.ethz.ch](mailto:martinez@biomed.ee.ethz.ch)

**Masania Kunal, Dr.**, Complex Materials, D-MATL, ETH Zurich, [kunal.masania@mat.ethz.ch](mailto:kunal.masania@mat.ethz.ch)

**McLaren Christopher**, Energy Science & Engineering, D-MAVT, ETH Zurich, [mclarenc@ethz.ch](mailto:mclarenc@ethz.ch)

**Mehmann Andreas**, Wearable Computing, D-ITET, ETH Zurich, [andreas.mehmann@ife.ee.ethz.ch](mailto:andreas.mehmann@ife.ee.ethz.ch)

**Meng Liu**, Energy Science & Engineering, D-MAVT, ETH Zurich, [liume@student.ethz.ch](mailto:liume@student.ethz.ch)

**Mezzenga Raffaele, Prof.**, Food & Soft Materials, D-HEST, ETH Zurich, [raffaele.mezzenga@hest.ethz.ch](mailto:raffaele.mezzenga@hest.ethz.ch)

**Michel Ann-Katrin, Dr.**, Optical Materials Engineering, D-MAVT, ETH Zurich, [micheann@ethz.ch](mailto:micheann@ethz.ch)

**Mikutis Gediminas**, Haelixa (ETH Spin-Off), [g.mikutis@chem.ethz.ch](mailto:g.mikutis@chem.ethz.ch)

**Mishra Ratan, Dr.**, Physical Chemistry of Building Materials, D-BAUG, ETH Zurich, [rkmishra@ifb.baug.ethz.ch](mailto:rkmishra@ifb.baug.ethz.ch)

**Moghimikheirabadi Ahmad**, Polymer Physics, D-MATL, ETH Zurich, [ahmad.moghimikheirabadi@mat.ethz.ch](mailto:ahmad.moghimikheirabadi@mat.ethz.ch)

**Mule Aniket Sandip**, Optical Materials Engineering, D-MAVT, ETH Zurich, [amule@ethz.ch](mailto:amule@ethz.ch)

**Müller Christoph, Prof.**, Energy Science & Engineering, D-MAVT, ETH Zurich, [muelchri@ethz.ch](mailto:muelchri@ethz.ch)

**Murer Christoph**, Magnetism & Interface Physics, D-MATL, ETH Zurich, [christoph.murer@mat.ethz.ch](mailto:christoph.murer@mat.ethz.ch)

**Nadjafi Manouchehr**, Energy Science & Engineering, D-MAVT, ETH Zurich, [mnadjafi@student.ethz.ch](mailto:mnadjafi@student.ethz.ch)

**Naeem Muhammad Awais**, Energy Science & Engineering, D-MAVT, ETH Zurich, [naeemm@student.ethz.ch](mailto:naeemm@student.ethz.ch)

**Nazarenko Olga**, Functional Inorganic Materials, D-CHAB, ETH Zurich / Empa, [naolqa@student.ethz.ch](mailto:naolqa@student.ethz.ch)

**Nedelcu Georgian**, Functional Inorganic Materials, D-CHAB, ETH Zurich, [nedelcug@student.ethz.ch](mailto:nedelcug@student.ethz.ch)

**Nelson Bradley, Prof.**, Multi-Scale Robotics, D-MAVT, ETH Zurich, [bnelson@ethz.ch](mailto:bnelson@ethz.ch)

**Ni Songbo**, Interfaces, Soft Matter & Assembly, D-MATL, ETH Zurich, [songbo.ni@mat.ethz.ch](mailto:songbo.ni@mat.ethz.ch)

**Nowak Maximilian**, Machine Tools & Manufacturing, D-MAVT, ETH Zurich, [manowak@ethz.ch](mailto:manowak@ethz.ch)

**Ochsenbein Stefan, Dr.**, Functional Inorganic Materials, D-CHAB, ETH Zurich, [stefano@ethz.ch](mailto:stefano@ethz.ch)

**Ofner Alessandro**, Complex Materials, D-MATL, ETH Zurich, [alessandro.ofner@mat.ethz.ch](mailto:alessandro.ofner@mat.ethz.ch)

**Okle Philipp**, Nanometallurgy, D-MAVT, ETH Zurich, [oklep@ethz.ch](mailto:oklep@ethz.ch)

**Olaniran Samuel**, Wood Materials Science, D-BAUG, ETH Zurich / Empa, [olsamuel@ethz.ch](mailto:olsamuel@ethz.ch)

**Pané i Vidal Salvador, Dr.**, Multi-Scale Robotics, D-MAVT, ETH Zurich, [vidalp@ethz.ch](mailto:vidalp@ethz.ch)

**Penn Alexander**, Energy Science & Engineering, D-MAVT, ETH Zurich, [penn@biomed.ee.ethz.ch](mailto:penn@biomed.ee.ethz.ch)

**Pierobon Leonardo**, Metal Physics & Technology, D-MATL, ETH Zurich, [lpierob@mat.ethz.ch](mailto:lpierob@mat.ethz.ch)

**Pineau Nicolay**, Particle Technology Laboratory, D-MAVT, ETH Zurich, [pineaun@student.ethz.ch](mailto:pineaun@student.ethz.ch)

**Piveteau Laura**, Functional Inorganic Materials, D-CHAB, ETH Zurich / Empa, [laurapi@student.ethz.ch](mailto:laurapi@student.ethz.ch)

**Poloni Erik**, Complex Materials, D-MATL, ETH Zurich, [erik.poloni@mat.ethz.ch](mailto:erik.poloni@mat.ethz.ch)

**Poulikakos Lisa**, Optical Materials Engineering, D-MAVT, ETH Zurich, [plisa@ethz.ch](mailto:plisa@ethz.ch)

**Protesescu Loredana, Dr.**, Functional Inorganic Materials, D-CHAB, ETH Zurich, [protesel@student.ethz.ch](mailto:protesel@student.ethz.ch)

**R. Velasquez Sara Tatiana**, Complex Materials, D-MATL, ETH Zurich, [rosara@student.ethz.ch](mailto:rosara@student.ethz.ch)

**Rabouw Freddy, Dr.**, Optical Materials Engineering, D-MAVT, ETH Zurich / Utrecht University, [rabouwf@ethz.ch](mailto:rabouwf@ethz.ch)

**Raino Gabriele, Dr.**, Functional Inorganic Materials, D-CHAB, ETH Zurich, [raino@inorg.chem.ethz.ch](mailto:raino@inorg.chem.ethz.ch)

**Rechberger Felix, Dr.**, Multifunctional Materials, D-MATL, ETH Zurich, [Felix.Rechberger@mat.ethz.ch](mailto:Felix.Rechberger@mat.ethz.ch)

**Reichmuth Andreas**, Biosensors & Bioelectronics, D-ITET, ETH Zurich, [reichmuth@biomed.ee.ethz.ch](mailto:reichmuth@biomed.ee.ethz.ch)

**Reiser Alain**, Nanometallurgy, D-MATL, ETH Zurich, [alain.reiser@mat.ethz.ch](mailto:alain.reiser@mat.ethz.ch)

**Reiter Lex**, Physical Chemistry of Building Materials, D-BAUG, ETH Zurich, [reiter@ethz.ch](mailto:reiter@ethz.ch)

**Rekhtina Margarita**, Energy Science & Engineering, D-MAVT, ETH Zurich, [mrekhtin@ethz.ch](mailto:mrekhtin@ethz.ch)

**Renz Aline**, Biosensors & Bioelectronics, D-ITET, ETH Zurich, [renz@biomed.ee.ethz.ch](mailto:renz@biomed.ee.ethz.ch)

**Rosenboom Jan-Georg**, Chemical Reaction & Separation Engineering, D-CHAB, ETH Zurich, [janr@ethz.ch](mailto:janr@ethz.ch)  
**Rossinelli Aurelio**, Optical Materials Engineering, D-MAVT, ETH Zurich, [aurelior@ethz.ch](mailto:aurelior@ethz.ch)  
**Rühs Patrick, Dr.**, Complex Materials, D-MATL, ETH Zurich, [patrick.ruehs@mat.ethz.ch](mailto:patrick.ruehs@mat.ethz.ch)  
**Sachs David**, Nonlinear Dynamics, D-MAVT, ETH Zurich, [dsachs@ethz.ch](mailto:dsachs@ethz.ch)  
**Sai Tianqi**, Soft & Living Materials, D-MATL, ETH Zurich, [sait@student.ethz.ch](mailto:sait@student.ethz.ch)  
**Salvati Manni Livia**, Dr., Food & Soft Materials, D-HEST, ETH Zurich, [livia.salvati@gmail.com](mailto:livia.salvati@gmail.com)  
**Sanz Pont Daniel**, Dr., Physical Chemistry of Building Materials, D-BAUG, ETH Zurich, [daniel.sanz@ethz.ch](mailto:daniel.sanz@ethz.ch)  
**Schärdli Gian Nutal**, Particle Technology Laboratory, D-MAVT, ETH Zurich, [scqian@ethz.ch](mailto:scqian@ethz.ch)  
**Scheidegger Laura**, Soft Materials, D-MATL, ETH Zurich, [laura.scheidegger@mat.ethz.ch](mailto:laura.scheidegger@mat.ethz.ch)  
**Schildknecht Dominik**, Mesoscopic Systems, D-MATL, ETH Zurich / Paul Scherrer Institute (PSI), [dominik.schildknecht@psi.ch](mailto:dominik.schildknecht@psi.ch)  
**Schmid Yannick R. F.**, Bioanalytics Group, D-BSSE, ETH Zurich, [yannick.schmid@bsse.ethz.ch](mailto:yannick.schmid@bsse.ethz.ch)  
**Schneider Elia**, Dr., Functional Materials Laboratory, D-CHAB, ETH Zurich, [elia.schneider@chem.ethz.ch](mailto:elia.schneider@chem.ethz.ch)  
**Schon Stéphanie**, Particle Technology Laboratory, D-MAVT, ETH Zurich, [sschon@ethz.ch](mailto:sschon@ethz.ch)  
**Schreck Murielle**, Multifunctional Materials, D-MATL, ETH Zurich, [murielle.schreck@mat.ethz.ch](mailto:murielle.schreck@mat.ethz.ch)  
**Schulz Jessica**, Dr., Drug Formulation & Delivery, D-CHAB, ETH Zurich, [jessica.schulz@alumni.ethz.ch](mailto:jessica.schulz@alumni.ethz.ch)  
**Shih Chih-Jen**, Prof., Interface & Surface Engineering of Nanomaterials, D-CHAB, ETH Zurich, [chih-jen.shih@chem.ethz.ch](mailto:chih-jen.shih@chem.ethz.ch)  
**Silvan Staufert**, Micro & Nanosystems, D-MAVT, ETH Zurich, [silvan.staufert@micro.mavt.ethz.ch](mailto:silvan.staufert@micro.mavt.ethz.ch)  
**Smatsi Natalia**, Particle Technology Laboratory, D-MAVT, ETH Zurich, [nsmatsi@student.ethz.ch](mailto:nsmatsi@student.ethz.ch)  
**Smith Kathleen**, Food & Soft Materials, D-HEST, ETH Zurich, [kathleen.smith@hest.ethz.ch](mailto:kathleen.smith@hest.ethz.ch)  
**Smith-Mannschott Katrina**, Soft & Living Materials, D-MATL, ETH Zurich, [katrina.smith-mannschott@mat.ethz.ch](mailto:katrina.smith-mannschott@mat.ethz.ch)  
**Spanke Hendrik**, Soft & Living Materials, D-MATL, ETH Zurich, [hendrik.spanke@mat.ethz.ch](mailto:hendrik.spanke@mat.ethz.ch)  
**Spencer Nicholas**, Prof., Surface Science & Technology, D-MATL, ETH Zurich, [nspencer@ethz.ch](mailto:nspencer@ethz.ch)  
**Speziale Chiara**, Food & Soft Materials, D-HEST, ETH Zurich, [chiara.speziale@hest.ethz.ch](mailto:chiara.speziale@hest.ethz.ch)  
**Spolenak Ralph**, Prof., Nanometallurgy, D-MATL, ETH Zurich, [spolenak@mat.ethz.ch](mailto:spolenak@mat.ethz.ch)  
**Stucki Mario**, Functional Materials Laboratory, D-CHAB, ETH Zurich, [mario.stucki@chem.ethz.ch](mailto:mario.stucki@chem.ethz.ch)  
**Studart André R.**, Prof., Complex Materials, D-MATL, ETH Zurich, [andre.studart@mat.ethz.ch](mailto:andre.studart@mat.ethz.ch)  
**Testa Paolo**, Mesoscopic Systems, D-MATL, ETH Zurich / Paul Scherrer Institute (PSI), [ptesta@student.ethz.ch](mailto:ptesta@student.ethz.ch)  
**Tian Tian**, Interface & Surface Engineering of Nanomaterials, D-CHAB, ETH Zurich, [tian.tian@chem.ethz.ch](mailto:tian.tian@chem.ethz.ch)

**Tomasikova Zuzana**, Complex Materials, D-MATL, ETH Zurich / Empa, [zuzana.tomasikova@empa.ch](mailto:zuzana.tomasikova@empa.ch)  
**Torlakcik Harun**, Multi-Scale Robotics, D-MAVT, ETH Zurich, [tharun@student.ethz.ch](mailto:tharun@student.ethz.ch)  
**Tou Maria**, Renewable Energy Carriers, D-MAVT, ETH Zurich, [toum@ethz.ch](mailto:toum@ethz.ch)  
**Tsoukalou Athanasia**, Energy Science & Engineering, D-MAVT, ETH Zurich, [atsoukal@student.ethz.ch](mailto:atsoukal@student.ethz.ch)  
**Türk Daniel-Alexander**, Product Development Group, D-MAVT, ETH Zurich, [dtuerk@ethz.ch](mailto:dtuerk@ethz.ch)  
**Tutcuoglu Abbas**, Mechanics & Materials, D-MAVT, ETH Zurich, [tabbas@ethz.ch](mailto:tabbas@ethz.ch)  
**Ugrinic Martina**, Biochemical Engineering, D-CHAB, ETH Zurich, [martina.ugrinic@chem.ethz.ch](mailto:martina.ugrinic@chem.ethz.ch)  
**Usov Ivan**, Dr., Scientific Computing, Paul Scherrer Institute (PSI), [ivan.usov@psi.ch](mailto:ivan.usov@psi.ch)  
**Usuelli Mattia**, Food & Soft Materials, D-HEST, ETH Zurich, [mattia.usuelli@hest.ethz.ch](mailto:mattia.usuelli@hest.ethz.ch)  
**Vailati Chiara**, Wood Materials Science, D-BAUG, ETH Zurich / Empa, [cavailati@ethz.ch](mailto:cavailati@ethz.ch)  
**Vallooran Jijo**, Dr., Food & Soft Materials, D-HEST, ETH Zurich, [vijjo@ethz.ch](mailto:vijjo@ethz.ch)  
**van den Broek Jan**, Particle Technology Laboratory, D-MAVT, ETH Zurich, [vanjan@ethz.ch](mailto:vanjan@ethz.ch)  
**van Swaay Dirk**, Dr., Wunderlichips (ETH Spin-Off), [dirkvs@gmail.com](mailto:dirkvs@gmail.com)  
**van't Hag Leonie**, Dr., Food & Soft Materials, D-HEST, ETH Zurich, [leonie.vant@hest.ethz.ch](mailto:leonie.vant@hest.ethz.ch)  
**Varga Matija**, Wearable Computing, D-ITET, ETH Zurich, [matija.varga@ife.ee.ethz.ch](mailto:matija.varga@ife.ee.ethz.ch)  
**Vasudevan Siddarth**, Interfaces, Soft Matter & Assembly, D-MATL, ETH Zurich, [siddarth.vasudevan@mat.ethz.ch](mailto:siddarth.vasudevan@mat.ethz.ch)  
**Vogler-Neuling Viola Valentina**, Optical Nanomaterial Group, D-PHYS, ETH Zurich, [voglerv@phys.ethz.ch](mailto:voglerv@phys.ethz.ch)  
**Volpi Marco**, Nanometallurgy, D-MATL, ETH Zurich, [marco.volpi@mat.ethz.ch](mailto:marco.volpi@mat.ethz.ch)  
**Vorobyeva Evgeniya**, Advanced Catalysis Engineering, D-CHAB, ETH Zurich, [evorobye@chem.ethz.ch](mailto:evorobye@chem.ethz.ch)  
**Wagner Marius**, Nanometallurgy, D-MATL, ETH Zurich, [Wagnerma@ethz.ch](mailto:Wagnerma@ethz.ch)  
**Walde Peter**, Prof., Polymer Chemistry, D-MATL, ETH Zurich, [peter.walde@mat.ethz.ch](mailto:peter.walde@mat.ethz.ch)  
**Willeke Martin**, Dr., D-MATL, ETH Zurich, [martin.willeke@mat.ethz.ch](mailto:martin.willeke@mat.ethz.ch)  
**Winkler Jan**, Optical Materials Engineering, D-MAVT, ETH Zurich, [janwinkler@ethz.ch](mailto:janwinkler@ethz.ch)  
**Xiao Yuan**, Nanometallurgy, D-MATL, ETH Zurich, [yuan.xiao@mat.ethz.ch](mailto:yuan.xiao@mat.ethz.ch)  
**Xu Qin**, Dr., Soft & Living Materials, D-MATL, ETH Zurich, [qin.xu@mat.ethz.ch](mailto:qin.xu@mat.ethz.ch)  
**Yakunin Sergii**, Dr., Functional Inorganic Materials, D-CHAB, ETH Zurich, [yakunin@inorg.chem.ethz.ch](mailto:yakunin@inorg.chem.ethz.ch)  
**Yoon Ji-Wook**, Dr., Particle Technology Laboratory, D-MAVT, ETH Zurich, [jyoon@ethz.ch](mailto:jyoon@ethz.ch)  
**Yoshimoto Makoto**, Dr., Polymer Chemistry, D-MATL, ETH Zurich, [makoto.yoshimoto@mat.ethz.ch](mailto:makoto.yoshimoto@mat.ethz.ch)  
**Yuzbasi Nur Sena**, Energy Science & Engineering, D-MAVT, ETH Zurich, [nury@student.ethz.ch](mailto:nury@student.ethz.ch)

**Zahn Raphael, Dr.**, Nanoelectronics,  
D-ITET, ETH Zurich, [raphael.zahn@is.ee.ethz.ch](mailto:raphael.zahn@is.ee.ethz.ch)  
**Zaidi Ali, Dr.**, Energy Science & Engineering,  
D-MAVT, ETH Zurich, [zaidi@ethz.ch](mailto:zaidi@ethz.ch)  
**Zambelli Tomaso, Dr.**, Biosensors & Bioelectronics,  
D-ITET, ETH Zurich, [zambelli@biomed.ee.ethz.ch](mailto:zambelli@biomed.ee.ethz.ch)  
**Zanini Michele**, Interfaces, Soft Matter & Assembly,  
D-MATL, ETH Zurich, [michele.zanini@mat.ethz.ch](mailto:michele.zanini@mat.ethz.ch)  
**Zhang Ning**, Biosensors & Bioelectronics,  
D-ITET, ETH Zurich, [zhang@biomed.ee.ethz.ch](mailto:zhang@biomed.ee.ethz.ch)  
**Zhou Tao**, Food & Soft Materials,  
D-HEST, ETH Zurich, [tao.zhou@hest.ethz.ch](mailto:tao.zhou@hest.ethz.ch)  
**Zuercher Joel**, Particle Technology Laboratory,  
D-MAVT, ETH Zurich, [zjoel@ethz.ch](mailto:zjoel@ethz.ch)

## THE ORGANIZING COMMITTEE

**Albani Davide**, Advanced Catalysis Engineering,  
D-CHAB, ETH Zurich, [davide.albani@chem.ethz.ch](mailto:davide.albani@chem.ethz.ch)  
**Blickenstorfer Yves**, Biosensors & Bioelectronics,  
D-ITET, ETH Zurich, [blickenstorfer@biomed.ee.ethz.ch](mailto:blickenstorfer@biomed.ee.ethz.ch)  
**Danzi Stefano**, Nanometallurgy,  
D-MATL, ETH Zurich, [stefano.danzi@mat.ethz.ch](mailto:stefano.danzi@mat.ethz.ch)

**Hsu Chiao-Peng**, Interfaces, Soft Matter & Assembly,  
D-MATL, ETH Zurich, [chiao-peng.hsu@mat.ethz.ch](mailto:chiao-peng.hsu@mat.ethz.ch)  
**Knüsel Philippe**, Optical Materials Engineering,  
D-MAVT, ETH Zurich, [pknuesel@ethz.ch](mailto:pknuesel@ethz.ch)  
**Kuravi Ramachandra**, Experimental Continuum Mechanics, D-MAVT, ETH Zurich / Empa,  
[kuravi@imes.mavt.ethz.ch](mailto:kuravi@imes.mavt.ethz.ch)  
**Lobsiger Nadine**, Functional Materials Laboratory,  
D-CHAB, ETH Zurich, [nadine.lobsiger@chem.ethz.ch](mailto:nadine.lobsiger@chem.ethz.ch)  
**Magrini Tommaso**, Complex Materials,  
D-MATL, ETH Zurich, [tommaso.magrini@mat.ethz.ch](mailto:tommaso.magrini@mat.ethz.ch)  
**Morgenthaler Kobas Sara, Dr.**, D-MATL, ETH Zurich,  
[sara.morgenthaler@mat.ethz.ch](mailto:sara.morgenthaler@mat.ethz.ch)  
**Mushtaq Fajer**, Multi-Scale Robotics,  
D-MAVT, ETH Zurich, [fmushtaq@ethz.ch](mailto:fmushtaq@ethz.ch)  
**van Nisselroy Cathelijn**, Biosensors & Bioelectronics,  
D-ITET, ETH Zurich, [vannisselroy@biomed.ee.ethz.ch](mailto:vannisselroy@biomed.ee.ethz.ch)  
**Vidiella del Blanco Marta**, Wood Materials Science,  
D-BAUG, ETH Zurich / Empa, [mvidiella@ethz.ch](mailto:mvidiella@ethz.ch)  
**Schefer Larissa, Dr.**, Competence Center for Materials and Processes (MaP), ETH Zurich,  
[larissa.schefer@mat.ethz.ch](mailto:larissa.schefer@mat.ethz.ch)

## **NOTES**

