

## KFM 14: Materials for Energy Storage I (joint session KFM/ CPP)

Organizer: Martin Diestelhorst - Martin-Luther-Universität Halle-Wittenberg - Halle

Time: Wednesday 9:30–12:30

Location: EMH 025

**Invited Talk** KFM 14.1 Wed 9:30 EMH 025  
**Resource-efficient dielectric materials for short-time energy storage** — ●STEPHAN KROHNS — Experimental Physics V, University of Augsburg, 86159 Augsburg

Materials exhibiting so-called colossal effects have an enormous potential for future use in correlated electronics, including capacitors for energy storage. The search for functional dielectrics showing colossal dielectric constants (CDC) is still an active field of research [1].

Beside the pure materials properties, also the scarcity and possible future shortages of used key elements in this modern technology is in the focus of scientific interest. An imminent challenge of modern materials science is the development of materials with less critical elements that have comparable or better functionalities than those currently used.

In this talk, I address the pure materials science perspective focusing on the research of CDC materials like crystals showing barrier layer capacitances [2] as well as ionic liquids. The latter are promising candidates for electrolytes used in supercapacitors [3]. Furthermore, I present a practical guideline for basic research implementing resource strategy aspects [4] as well as a possible scenario for the system and market integration of those short-term energy storages [5].

- [1] S. Krohns et al., Nat. Mat. 10, 899 (2011).
- [2] E. Ruff et al., Phys. Rev. Lett. 118, 036803 (2017).
- [3] P. Sippel et al., Sci. Rep. 5, 13922 (2015).
- [4] Ch. Helbig et al., Sust. Mat. & Techn. 12, 1 (2017).
- [5] M. Hassler et al., OR Spectrum 38, 633 (2016).

KFM 14.2 Wed 10:00 EMH 025

**Dielectric properties of ionic liquid based electrolytes for future energy-storage systems** — ●PIT SIPPEL and STEPHAN KROHNS — Experimental Physics V, Center for Electronic Correlations and Magnetism, University of Augsburg, 86135 Augsburg, Germany

Electrolytes are essential for energy storage systems like electric double layer capacitor (EDLC). The so-called electrode polarization is the driving mechanism for energy storage in EDLCs. To enhance the properties of EDLCs, potential new electrolytes are investigated by various methods. Dielectric spectroscopy is a powerful tool analyzing the electric properties of liquids. This technique allows measuring the relaxation times of dynamic processes and ionic conductivity in a broad frequency and temperature range. Especially, the ionic conductivity is an essential figure of merit for any energy-storage application. This talk addresses the dielectric properties of ion conducting liquids with special emphasize put on ionic liquids (ILs). The revealed spectra are analyzed using equivalent circuits, which enable investigating the important electrode polarization effect. ILs offer outstanding properties (e.g., low volatility and high electrochemical stability) making them promising candidates for solvent-free electrolytes, which may improve energy-storage systems. However, the applicability of ILs is still hampered due to their rather low conductivity. We address the question if this conductivity can be optimized by mixing pure ILs taking into account the non-canonical super-Arrhenius temperature dependence [1]. [1] E. Thoms *et al.*, Sci. Rep. 7, 7463 (2017).

KFM 14.3 Wed 10:20 EMH 025

**Influence of the glass-ceramic synthesis route on the ionic conductivity of the sodium solid electrolyte  $\text{Na}_2\text{O}\text{-Y}_2\text{O}_3\text{-SiO}_2$**  — ●WOLFRAM MÜNCHGESANG<sup>1</sup>, DÖRTHE WAGNER<sup>2</sup>, MYKHAYLO MOTYLENKO<sup>3</sup>, JOCHEN SCHILM<sup>2</sup>, DAVID RAFAJA<sup>3</sup>, and DIRK C. MEYER<sup>1</sup> — <sup>1</sup>Institut für Experimentelle Physik, Technische Universität Bergakademie Freiberg, 09599 Freiberg, Germany — <sup>2</sup>Fraunhofer-Institut für Keramische Technologien und Systeme IKTS, 01277 Dresden, Germany — <sup>3</sup>Institut für Werkstoffwissenschaft, Technische Universität Bergakademie Freiberg, 09596 Freiberg, Germany

The development of room-temperature solid electrolytes (SEs) is one of the keys for the realization of solid-state batteries – a post lithium-ion technology, with probably better performance than this. For SEs, a glass-ceramic synthesis route (GCSR) is particularly suitable, because this is less expensive than other production methods and can be used on an industrial scale.

The maximum achievable conductivity (C) of SEs is determined

by the used ionic-conductive phase (ICP), which is crystalline  $\text{Na}_5\text{YSi}_4\text{O}_{12}$  in our case. In practice C is strongly influenced by the microstructure of the SE, in particular by the formation of a suitable percolation path; which is determined by the ratio of the ICP and its crosslinking. We will present the influence of different GCSRs on the microstructure of the SE and the resulting conductivity change.

This work was financed by the Federal Ministry (FM) of Education and Research within the project SyNeSteSia (05K14OFA) and the FM for Economic Affairs and Energy within the project BaSta (0325563).

KFM 14.4 Wed 10:40 EMH 025

**Water Adsorption on a n-Si/NiO Photoanode - Cryo Photoelectron Spectroscopy in the Frozen Electrolyte Approach** — ●MATHIAS FINGERLE, SVEN TENGELER, WOLFRAM CALVET, THOMAS MAYER, and WOLFRAM JAEGERMANN — Surface Science Division, Department of Materials Science, Technical University Darmstadt, Otto-Berndt-Str. 3, D-64287 Darmstadt, Germany

In the course of the BMBF InnoEMat project Fundamentals of Electrochemical Interfaces: Semiconductor/Electrolyte, elemental charge transfer processes at solid/liquid interfaces are studied via cryo photoelectron spectroscopy and post-operando experiments. Here, the interaction of water with a magnetron-sputtered nickel oxide thin film on an n-type silicon photo-anode is investigated in perspective to oxygen evolution. The substrate was exposed in-situ stepwise to gas phase water up to 10 L at liquid N<sub>2</sub> temperature and analyzed via X-ray and UV photoelectron spectroscopy in the so called frozen electrolyte approach. Photoemission of the pristine NiOx layer shows the presence of stoichiometric NiO and Ni<sub>2</sub>O<sub>3</sub> as well as of non-stoichiometric phases. In the monolayer range, molecular and dissociative adsorption is detected assigned to the NiO respective Ni<sub>2</sub>O<sub>3</sub> phase. Initially, the emissions of the molecular adsorbed water species interacting with NiO are found at 0.8 eV lower binding energies as compared to water related emissions for higher coverages with binding energies commonly assigned to H<sub>2</sub>O-H<sub>2</sub>O interaction. In addition to the chemical analysis, the electronic structure of the n-Si/SiOx/NiOx/H<sub>2</sub>O photoanode is measured and discussed.

20 min. break

KFM 14.5 Wed 11:20 EMH 025

**Morphologischer Einfluss von BaTiO<sub>3</sub> Partikeln auf die Leitfähigkeit und Speicherzeit von Oxid\*Polymer-Filmkondensatoren** — ●SANDRA WICKERT<sup>1</sup>, TILL MÄLZER<sup>2</sup>, FRANK APSEL<sup>3</sup>, TINO BAND<sup>4</sup>, HARTMUT LEIPNER<sup>5</sup>, MARTIN DIESTELHORST<sup>6</sup> und STEFAN EBBINGHAUS<sup>7</sup> — <sup>1</sup>enfas GmbH, D-80809 — <sup>2</sup>enfas GmbH, D-80809 — <sup>3</sup>enfas GmbH, D-80809 — <sup>4</sup>Institut für Physik, MLU Halle-Wittenberg, D6120 — <sup>5</sup>IZM, MLU Halle-Wittenberg, D6120 — <sup>6</sup>Institut für Physik, MLU Halle-Wittenberg, D6120 — <sup>7</sup>Institut für Chemie, MLU Halle-Wittenberg, D6120

Der Einfluss der Morphologie von BaTiO<sub>3</sub> Partikeln auf die Leitfähigkeit und die daraus resultierende Speicherzeit von BaTiO<sub>3</sub>/P(VDF-HFP)-Folienkondensatoren wurde untersucht. Dazu wurden über die Mischoxidsyntheseroute BaTiO<sub>3</sub>\*Partikel unterschiedlicher Form und Größe hergestellt und in Lösungen des ferroelektrischen Polymers P(VDF-HFP) suspendiert. Über eine Rakelanlage wurden diese Lösungen in Folien gegossen und nach verschiedenen Verfahren getrocknet. Nach Kontaktierung erfolgte die dielektrische Auswertung der so erhaltenen Kondensatoren mittels unipolarer zyklischer Polarisationsmessungen. Es konnte gezeigt werden, dass sowohl die Größe als auch die Form der BaTiO<sub>3</sub>-Partikel eine entscheidende Rolle für die Gesamtleitfähigkeit des Systems spielen. Außerdem konnte das bisherige core-shell-Modell für die Bildung von BaTiO<sub>3</sub> erweitert werden, so dass nicht nur die Entstehung der Einzelpartikel beschrieben wird, sondern auch die Bildung von Agglomeratstrukturen erklärt werden kann.

KFM 14.6 Wed 11:40 EMH 025

**Investigation of electrical conductivity and dielectric properties in ceramic-polymer composite films** — ●TILL MÄLZER<sup>1,4</sup>, TINO BAND<sup>2</sup>, SANDRA WICKERT<sup>3,5</sup>, FRANK APSEL<sup>1,5</sup>, HARTMUT S. LEIPNER<sup>1</sup>, MARTIN DIESTELHORST<sup>2</sup>, and STEFAN EBBINGHAUS<sup>3</sup>

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Dielectric materials with high energy storage density are of great importance for power electronics. Ceramic-polymer composites have been evaluated as a candidate for dielectric materials for new-type capacitors, due to the possibility to tailor materials properties by proper design for specific applications. Besides dielectric properties in majority of studies, the electrical conduction of the ceramic-polymer composite films has been disregarded. We report on results of composite films consisting of the two ferroelectric materials P(VDF-HFP) as polymer matrix and BaTiO<sub>3</sub> as filler, each known for its high permittivity in its particular material class. Composite films with different size and concentration of BaTiO<sub>3</sub> particles were fabricated via a solution cast doctor blade method. We studied the influence of particle size, agglomeration, particle distribution and filler concentration on electrical conductivity and the dielectric properties energy density, permittivity and breakdown strength of the composite films. We used charge-voltage measurements for dielectric investigations and for morphological studies X-ray diffraction and scanning electron microscopy.

Invited Talk

KFM 14.7 Wed 12:00 EMH 025

### Dielectric Polymer Nanocomposites for Electrical Energy Storage — ●QING WANG — The Pennsylvania State University

The demand for high-performance dielectric materials arises from numerous emerging energy storage and conditioning applications such as electric vehicles, wind generators, solar converters, and aerospace power systems. This talk will describe our most recent efforts to develop the dielectric polymer nanocomposites for capacitive energy storage applications. Specifically, the introduction of boron nitride nanosheets (BNNSs) into the polymers yields significantly reduced high-field loss and improved thermal conductivity, giving rise to great improvements in the charge-discharged efficiency and discharged energy density at high temperatures. The sandwich-structured composites with BNNSs spreading throughout the outer polymeric layers and high-dielectric-constant nanoparticles in the interior layer has been designed and experimentally demonstrated. More recently, chemical-vapor-deposited hexagonal boron nitride (h-BN) has been coated onto the surface of the polymer films. The h-BN-coated polymer films are capable of operating with >90% efficiencies and delivering high energy densities even at a temperature close to the glass transition temperature of polymer. Challenges along with future research opportunities will also be discussed.