KFM 9: Focus: Materials for Energy Storage

On the one hand efficient energy storage is a necessary prerequisite for a continuous electrical power supply on the basis of fluctuating energy sources like wind and solar energy. On the other hand the replacement of combustion engines in cars by electric motors requires energy storage systems with optimized properties like high power density, high energy density, low discharge and high reliability. The aim of the focus-session will be the discussion of different energy storage concepts with a main focus on capacitors, supercaps and other methods of direct electric energy storage, but not limited to these methods.

Chair: Martin Diestelhorst (Martin-Luther-University Halle-Wittenberg)

Time: Tuesday 9:30–12:50 Location: PHY 5.0.21

Invited Talk KFM 9.1 Tue 9:30 PHY 5.0.21

High Energy Density and Low Loss Dielectric Polymers for Electrical Applications — •Lei Zhu — Department of Macromolecular Science and Engineering, Case Western Reserve University, Cleveland, Ohio 44106-7202, United States

High dielectric constant polymers find numerous advanced electrical and power applications such as pulsed power, power conditioning, gate dielectrics for field-effect transistors, electrocaloric cooling, and electromechanical actuation. Unfortunately, it is generally observed that polymers do not have high dielectric constants (only 2-5) and high polarization tends to cause a significantly dielectric loss. Therefore, it is highly desirable that the fundamental science of all types of polarization and loss mechanisms be thoroughly understood for dielectric polymers. In this presentation, we intend to explore advantages and disadvantages for different types of polarization. Among a number of approaches, orientational polarization is promising for high dielectric constant and low loss polymer dielectrics, if the dipolar relaxation peak can be pushed to towards the gigahertz range. In particular, dipolar glass, paraelectric, and relaxor ferroelectric polymers will be discussed for the orientational polarization approach.

KFM 9.2 Tue 10:00 PHY 5.0.21

Self-discharge behaviour of poly(vinylidene fluoride-hexafluoropropylene) for dielectric energy storage — •Tino Band[1], Till Mälzer[2,3], Sandra Wickert[4], Hartmut S. Leipner[2], Stefan G. Ebbinghaus[4], Kathrin Dörr[1], and Martin Diestelhorst[1] — [1]Institute of Physics, Martin Luther University Halle-Wittenberg, Von-Danckelmann-Platz 3, 06099 Halle, Germany — [2]Interdisciplinary Center of Materials Science, Martin Luther University Halle-Wittenberg, Heinrich-Damerow-Straße 3, 06099 Halle, Germany — [3]enspring GmbH, Weinbergweg 23, 06120 Halle, Germany — [4]Institute of Chemistry, Martin Luther University Halle-Wittenberg, Kurt-Mothes-Straße 2, 06099 Halle, Germany

We present results about dielectric energy storage mechanisms in doctor blade coated P(VDF-HFP). One approach is using cyclic unipolar *D-E* characteristics to study conduction mechanisms. We define an effective conductivity for each cycle observing a Curie-von Schweidler law with steady-state conductivity. Therefore, an effective relaxation time can be obtained which is connected to self-discharge rate of the polymer. A second approach is made inversely. The self-discharge is directly investigated by means of charging-lift-discharging measurements, where the contact between measurement tip and electrode is interrupted for a specific time between charging and discharging process. Based on the self-discharge behaviour, we can conclude on conduction mechanisms. So we are able to separate the influence of polarization, depolarization and conduction mechanisms on the energy storage properties of dielectric materials in detail.

KFM 9.3 Tue 10:20 PHY 5.0.21

Influence of the morphology on the electrical conductivity of ceramic-polymer composite dielectrics — •Till Mälzer[1,3], Tino Band[2], Marius Falkenstein[2], Robert Schlegel[3], Martin Diestelhorst[2], Stefan Ebbinghaus[4], and Hartmut S. Leipner[1] — [1]Center of Materials Science, Martin-Luther-University Halle-Wittenberg (MLU), D06120 Halle (Saale) — [2]Department of Physics, MLU — [3]enspring GmbH, D06120 Halle (Saale) — [4]Department of Chemistry, MLU

Ceramic-polymer composites have been evaluated as a candidate for dielectric materials for a new type of capacitors, due to the possibility to tailor materials properties by proper design for specific applications. By rising the content of high-k ceramic filler, the energy density of composite materials can be increased. However, it causes also an increase in the electrical conductivity, a fact which has been disregarded in many studies.

We report on the influence of morphological aspects like particle size, particle distribution, agglomerate structure and percolating agglomerates on the electrical conductivity of the composite. The investigated material system consists of P(VDF-HFP) as polymer matrix and BaTiO3 or TiO2 as filler. Composite films with a variation of the particle size and the concentration of the filler, as well as different film thicknesses have been fabricated via a solution cast doctor blade method. We have applied charge-voltage measurements for electrical investigations and for morphological studies scanning electron microscopy and 3D X-ray microscopy.

KFM 9.4 Tue 10:40 PHY 5.0.21

The effect of filler distribution in the enhancement of the energy storage in nanocomposites — •Elshad Allahyarov — Theoretical Chemistry, Essen, UDE — Physics Department, CWRU, Cleveland OH, USA — Theoretical Department, RAS Moscow, Russia

Mixing dielectric polymers with high permittivity nano-sized inclusions affects their electrical properties. These nanocomposites are extensively used in actuation applications via employing electrostriction properties of the matrix, and in electrostatic energy storage applications employing high polarization fields of the fillers. In both cases existing theoretical studies mostly utilize mixing rule approaches that consider a homogeneous filler distribution in the matrix. Consequently, the effective permittivity of the composite never exceeds the the permittivity of the filler. We show that much higher effective permittivities can be achieved by manipulating the morphology of the inclusion distribution in the matrix. Simulation results for the field distribution reveal an enhancement of the field localization and dipole-dipole correlation effects in some proposed morphologies. By considering several possible clustering scenarios we found that a cylindrical clustering along the applied field has a potential to achieve an order of magnitude increase in the effective permittivity. The issue of chained filler configurations which lower the breakdown field threshold for the material is also addressed.

Break 20 min

Invited Talk KFM 9.5 Tue 11:20 PHY 5.0.21

Storing electrical energy using glasses and glass ceramics — •Martin Letz — SCHOTT AG, Hattenbergstr. 10, 55122 Mainz, Germany

Power electronics is a strongly growing field since highly fluctuating demand and supply of electrical energy needs efficient electronics for switching or for transformation between different voltage levels. In this situation the classes of materials, glasses (i) and glass ceramics (ii), which are nearly ever used as dielectrics for capacitors can enable innovations. Recent technical development makes it possible to produce ultrathin glasses (i) with extremly large dielectric breakdown strength up to 600 kV/mm which enable high storage densities at elevated temperatures. Glass ceramics (ii) allow to reach higher polarizabilities and are produced in a two step process. In a first step a transparent glass with a solely amorphous structure is molten. In a second and independent step crystallites are grown in such glasses by applying a well defined time–temperature profile. By growing nanosized crystallites with ferro- or para-electric phases, pore free dielectric materials with very high homogeneity and high dielectric strength can be obtained. We present two types of such material. Besides capacitors there are further fields of applications for glasses and glass ceramics in improving

saftey and storage density of batteries.

KFM 9.6 Tue 11:50 PHY 5.0.21

Properties of composite films for Li-ion batteries — •Lena Kuske[1], Frank Apsel[2], Robert Schlegel[2], Till Mälzer[1,2], Richard Schalinski[3], Stefan Ebbinghaus[4], Ralf Wehrspohn[3], and Hartmut Leipner[1] — [1]Center of Materials Science, Martin-Luther-University Halle-Wittenberg (MLU), 06120 Halle (Saale) — [2]enspring GmbH, 06120 Halle (Saale) — [3]Department of Physics, MLU — [4]Department of Chemistry, MLU

The development of new, safer and good performing materials for long life batteries to provide storage possibilities that fulfil the distinct requests of different portable devices is highly demanded.

A promising material class for lithium ion batteries are polymer composite materials. We combine the distinct properties of P(VdF-HFP) as a flexible and mechanical stable polymer matrix with the electric properties of nanosized ceramic $Li_7La_3Zr_2O_{12}$ as a highly Li-ion conducting material and different Lithium salts to develop electrolyte materials with the desired properties of high ionic and low electron conductivity, good mechanical stability and homogeneity.

Thin layers of the composite materials were fabricated via a solution cast doctor blade process. Their ion and electron conductivity was analysed in view of their use as electrolyte material in lithium ion batteries. Besides electrochemical investigations, the morphology of the composite layers were studied with X-ray diffraction and electron microscopy.

KFM 9.7 Tue 12:10 PHY 5.0.21

Tungsten sulfide: An intercalation-type anode material for potassium-ion battery — •Yuhan Wu, Yang Xu, Chenglin Zhang, and Yong Lei — Institut für Physik & IMN MacroNano (ZIK), Technische Universität Ilmenau, 98693, Ilmenau, Germany

The intercalation-type materials have rarely been discovered as anodes for potassium-ion batteries (PIBs) except graphite and conventional transition metal oxides. Here we reported the first two-dimensional transition metal dichalcogenide (2D TMD), WS2, as an intercalation-type anode material for PIBs. It is found for the first time that the WS2 undergoes an unexpected intercalation dominated K storage at deep-discharge condition (0.01 V vs. K+/K), attributing to the facilitation of K+ transport derived from the intercalation reaction that is confirmed by a kinetic study. Electrochemical characterizations reveal that WS2 exhibited a reversible capacity of 103 mAh/g at 0.1 A/g after 100 cycles. It also delivered a high rate capability (62 mAh/g at 0.8 A/g) and long-term stability at high rate (90% retention at 0.5 A/g after 400 cycles). Furthermore, a full-cell with intercalation-type WS2 as anode and Prussian blue as cathode exhibited a charge plateau around 3.3 V and a discharge slope between 1.5 and 3.2 V, delivering a reversible capacity of 60 mAh/g at 0.1 A/g after 50 cycles. This work highlights the unusual electrochemical properties when replacing Li+ and Na+ with K+ for the battery application, and may induce more future work in this regard.

KFM 9.8 Tue 12:30 PHY 5.0.21

Water splitting by pyroelectric single crystals — •Wolfram Münchgesang, Thomas Köhler, Erik Mehner, Hartmut Stöcker, and Dirk C. Meyer — Institut für Experimentelle Physik, Technische Universität Bergakademie Freiberg, Leipziger Str. 23, 09599 Freiberg, Germany

The generation of hydrogen through water electrolysis has been understood for a long time and will be used for large-scale conversion of electrical energy into chemical energy in the future. The direct conversion of residual heat into hydrogen is completely new to our knowledge, but feasible when making use of pyroelectric materials. In pyroelectrolysis, a cyclic temperature excitation generates an electric field between the crystal surfaces due to an imbalance between polarization and compensation charges. This field can be used for water splitting, theoretical.

For the verification of the water splitting with pyroelectric single crystals an electrochemical measuring cell with optical heating was developed. With this setup, the proof of water splitting has been achieved. Furthermore, the reaction rates could be determined from the amount of transferred charges and compared with the theory.