
Charged Matter
2025
26 – 28 March 2025
ISTA
Institute of
Science and
Technology
Austria

Abstracts

Invited Session 1

Wednesday March 26, 9:10-10:55

Spontaneous charging of sliding water drops

9:10-9:45

Hans-Jürgen Butt[1]

[1]Max Planck Institute for Polymer Research, Mainz, Germany

Water drops moving on surfaces are not only an everyday phenomenon seen on windows but also form an essential part of many industrial processes. Like in triboelectricity, moving drops can separate electric charges. This phenomenon is called slide or contact electrification. Typically, water drops sliding down hydrophobic surfaces spontaneously acquire a positive charge while they deposit negative charges on the solid surface. Three questions will be addressed: How can one measure charge separation and describe it quantitatively? How does charging influence the motion of sliding water drops? What are other consequences of slide electrification?

Volcanic electrification: from ash plumes to geysers

9:45-10:20

Corrado Cimarelli[1]

[1]Ludwig-Maximilians-Universität München/Department of Earth and Environmental Sciences, Munich, Germany

Explosive volcanic eruptions generate strong electrical activity, as frequently shown by lightning activity observed in recent eruptions. However, it remains undetermined if electrification phenomena are ubiquitous over the whole spectrum of volcanic explosive activity and if such phenomena must be attributed to different mechanisms. We are contributing to this effort by pursuing a twofold approach using multi-parametric observation of the electrical activity at active volcanoes and by experimentally reproducing electrical discharges in particle-laden jets under controlled laboratory conditions. Our research efforts have focused on recent basaltic explosive eruptions, as they occupy the lower end of volcanic explosive volcanism as well as the record-breaking 2022 Hunga Tonga-Tonga Ha'apai explosive eruption. Furthermore, we have extended our investigations to water jets produced by geysers which, together with their associated geophysical signals, can be considered as analogues to low-viscosity magmatic systems. We will review recent field observations of electrification in a wide range of volcanic environments as well as analogue laboratory experiments.

Charged matter in exoplanet atmospheres

10:20-10:55

Christiane Helling[1,2]

[1]Space Research Institute, Austrian Academy of Sciences, Gray, Austria
[2]Graz University of Technology, Graz, Austria

Exoplanets orbit different host stars at different orbital distances such that they provide a rich ensemble of different radiation and ionization environments. Ultra-hot Jupiters are of particular interest since the harbor both, a hot, highly ionized dayside and a cold, cloud forming nightside affected by the interstellar and galactic radiation. This talk will present thinking on various ionization processes in exoplanet atmospheres, their different effects on the day-and the nightside for the local gas-phase chemistry and the mineral cloud particles.

Contributed Session 1

Wednesday March 26, 11:15-12:30

Triboelectrification of oxide insulators

11:15-11:30

Galien Grosjean[1] and Scott Waitukaitis[1]

[1]Institute of Science and Technology Austria, Klosterneuburg, Austria

Oxide insulators are among the most abundant solid materials in the universe. In granular form—such as in volcanic plumes, sandstorms, and protoplanetary disks—they undergo vast numbers of collisions. With each collision, charge separation can occur through the triboelectric effect, although the underlying mechanism remains largely unknown [1]. Initially insignificant, this effect can accumulate and generate substantial amounts of electrostatic potential energy, influencing cohesion and often leading to sparks or even lightning. Using acoustic traps, we isolate a single grain, induce controlled collisions with a substrate, and precisely measure the resulting electric charge [2]. Our results demonstrate that charging is controlled by a mixture of adsorbed species naturally recruited from the atmosphere [3]. Tiny variations in these adsorbates, linked to the sample's history, are responsible for symmetry breaking between otherwise identical grains. Furthermore, we observe this behavior consistently across oxide samples made of different materials, which may provide insight into their respective positions in the triboelectric series.

This work has received funding from the European Research Council Grant Agreement No. 949120 and from the Marie Skłodowska-Curie Grant Agreement No. 754411 under the European Union's Horizon 2020 research and innovation program.

[1] D. J. Lacks and T. Shinbrot, Nat. Rev. Chem. 3, **465** (2019).
[2] G. Grosjean and S. Waitukaitis, Phys. Rev. Lett. **130**, 098202 (2023).
[3] G. Grosjean et al., "Non-equilibrium surface adsorbates drive oxide contact electrification" (in preparation).

Electrifying polymers with ion implantation for electromechanical conversion

11:30-11:45

Andris Šutka[1], Holger Fiedler[2], Artis Linarts[1], Kaspars Mālnieks[1], Joseph Berry[3] and **Peter Sherrell[4]**

[1]Institute for Materials & Surface Engineering, Faculty of Natural Sciences and Technology, Riga Technical University, Riga, Latvia
[2]GNS Science, National Isotope Centre, Lower Hutt, New Zealand
[3]Department of Chemical Engineering, The University of Melbourne, Parkville, Australia
[4]School of Science, RMIT University, Melbourne, Australia

Understanding the electrification of dielectric polymers is a long-standing scientific challenge. Static charge accumulation from frictional contact electrification in these polymers has attracted significant interest, with researchers falling into an electron transfer [1], or a static ion transfer (molecular fragment) camp [2,3].

We have undertaken to probe the mechanisms of electrification across a broad suite of polymers in the context of chemical, mechanical, and topological properties, [4] enabling the engineering of triboelectric laminates with unprecedented internal static charge accumulation [5].

Here, I will discuss our work using ion implantation to further enhance polymer electrification. We demonstrate that implantation of Cu+ into polytetrafluoroethylene (PTFE) creates a space charge region. This space charge creates a 'piezoelectric-like' effect, demonstrated to induce charge flow on a parallel electrode in non-contact oscillation. In contact-separation testing the electromechanical conversion was improved by 30x (compared to non-implanted PTFE). This work changes the paradigm of ion implantation into polymers, and provides a new direction for designing electrified polymers.

[1] C. Xu *et al.,* Adv. Mat. **30**, 1706790 (2018).
[2] Y. Fang, C.K. Ao, Y. Jiang, Y. Sun, L. Chen and S. Soh, Nat. Comms. **15**, 1986 (2024).
[3] O. Verners *et al.,* Adv. Mat. Inter. **10**, 2300562 (2023).
[4] A. Šutka *et al.,* Adv. Mat. Inter. **10**, 2300323 (2023).
[5] A. Linarts *et al.,* Small **19**, 2205563 (2023).

Growing centimeter-sized clusters from charged sub-millimeter grains
11:45-12:00

Jakob Penner[1], Jens Teiser[1], Kolja Joeris[1], Florence Chioma Onyeagusi[1], Jonathan Kollmer[1], Dominique Daab[2] and Gerhard Wurm[1]
[1]University of Duisburg-Essen, Duisburg, Germany
[2]Swedish Space Corporation, Solna, Sweden

We conducted experiments with ensembles of colliding sub-millimeter basalt particles under prolonged microgravity conditions on a suborbital flight. In these experiments, the sample motion was excited at different levels. During these collisions, the particles charge, as was measured by applying an electric field. Further moderate shaking then leads to the formation of compact clusters of the charged beads, up to several centimeters in size.

How discharge dynamics control the liquid-solid contact electrification of a bouncing drop
12:00-12:15

Rachel Piednoir[1], Anne-Laure Biance[1] and Catherine Barentin[1]
[1]ILM, Université de Lyon, Université de Lyon 1 and CNRS, UMR5306, Villeurbanne, France

A drop impacting on a superhydrophobic surface acquires an electrical charge. The magnitude of this charge depends both on the hydrodynamics of the impact and on the physicochemical properties of the liquid. The motivation for our study is two-fold: fundamental for understanding the mechanisms at play in liquid-solid contact electrification, applicative to enhance or limit triboelectric charging for producing triboelectric nanogenerators or microelectronic devices. Here, we set up a robust experimental protocol to measure the charge acquired by an impacting drop and perform a parametric study by varying drop size, impact speed, salt concentration and viscosity. Our results for pure water droplets validate existing models [1], but drops with varying chemical composition stray away from these predicted trends. To explain these disparities, we propose a macroscopic electrical model based on charge and discharge dynamics at the liquid-solid interface. The amplitude of acquired charge depends directly on the ratio of the hydrodynamic impact time and the electrical discharge time.

[1] D. Díaz, D Garcia-Gonzalez, P. Bista, S. A. L. Weber, H.-J. Butt, A. Stetten and M. Kappl. Soft Matter **18**, 1628 (2022).

Dipolar polymer brushes: a study of the effect of an external field in brush force profiles

12:15-12:30

Joan J. Cerdà[1] and A. Fuster-Aparisi[1]

[1]Univ. de les Illes Balears, IAC3 and Dpt. Física, Palma, Spain

In this contribution we show via Langevin Dynamics numerical simulations how the properties of dipolar polymer brushes can be strongly modulated through external applied fields. External fields can be used to modify force profiles and favor the entrapping and retention of colloidal particles inside them for a later release [1]. Alternatively, by choosing right external field strengths it is also possible to develop force barriers that prevent colloidal particles from reaching the surface where polymers forming the brush are attached. This quite unexpected attraction between the brush and the penetrating particle can be reasoned in terms of an equilibrium between two opposite forces: the entropic repulsive force arising from the high density of monomers near the grafting surface, and an attractive force emerging from Kelvin forces due to the mismatch between the dipolar media created by the dipolar monomers of the brush, and the non-dipolar media existing inside the particle and the grafting surface.

The possibility to create and tune force profiles with stationary points can be used to favour applications of polymer brushes in which the entrapping and retention of colloidal particles for a later release is required. On the other hand, the possibility to create and control the strength of force barriers at a certain distance of the grafting surface can also be used, among other applications, to control the rate of adsorption and reactivity of catalytic surfaces.

Acknowledgment: research has been possible thanks to grants PID2020-118317GB-I00, and DPI2017-86610-P funded by MICIU/AEI/10.13039/501100011033.

[1] A. Fuster-Aparisi and Joan J. Cerdà (DOI:10.20944/preprints202412.1431.v1)

Invited Session 2

Wednesday March 26, 14:00-15:45

The driving force of charge transfer in polymer contact electrification

14:00-14:35

Linards Lapčinskis[1], Peter Sherrell, Artis Linarts[1], Līva Ģērmane[1] and **Andris Šutka[1]**

[1]Institute of Physics and Materials Science, Faculty of Natural Sciences and Technology, Riga Technical University, Riga, Latvia

[2]School of Science, RMIT University, Melbourne, Victoria, Australia

Polymer contact electrification (CE) has been among the most ambiguous processes under debate for more than 2500 years. The mechanism of polymer CE has attracted growing interest due to rising new application areas in energy harvesting, sensors in robotics and environmental monitoring, particle assembly, and catalysis.

The three most considered mechanisms in polymer CE are electron transfer, ion transfer among water adsorbate layers, and organoions from macromolecule bond cleavage. The organoions have been identified as the dominating charge species involved in polymer CE by a series of well-designed experiments. This has been highlighted by observing charging between identical polymers, which is increasing with a greater roughness differential result. Most interestingly, the rough surfaces always charge positively, while smooth surfaces charge negatively. This relationship has been observed for many different polymers.

In contact between different polymers, the driving force for charge transfer can be more favorable energy levels, surface acidity, or Zeta potential. However, the driving force for charge transfer between identical polymers in a controlled manner is unclear. Herein, we will discuss the polymer CE mechanisms and the flexoelectric field as a driving force for organoion transfer.

Modeling triboelectric charging using DEM with the moon in mind

14:35-15:10

Christine Hartzell[1], Yun Zhang[1], Melissa Buys[1] and Dylan Carter[1]

[1]University of Maryland, College Park, USA

Tribocharging can occur in a range of both mundane (e.g., walking across a carpet) and exciting (e.g., volcanic explosions, dust storms) applications on Earth. Despite its ubiquity, the phenomenon of triboelectric charging is difficult to accurately model in the terrestrial environment. As we consider establishing a long-term human presence on the surface of the Moon, there is a desire to understand the severity of risks associated with triboelectric charging of spacecraft and dust, or regolith, on the surface of the Moon. Tribocharging on the Moon may occur due to walking astronauts, rolling wheels or grain-grain collisions in plumes of dust kicked up by landing spacecraft. In order to make predictions for these exploration-relevant cases, we are in the process of implementing a model of triboelectric charging in a Discrete Element Method (DEM) model that includes both dielectric dust grains and a conducting object (inspired by a rover wheel). The grain-grain tribocharging model has been validated with experimental results. We will present our current progress implementing tribocharging of a conducting object in DEM.

Triboelectrification through coffee
15:10-15:45

Joshua Méndez Harper[1]
[1]Portland State University, Portland, USA

Frictional and contact electrification—collectively called triboelectrification—are ubiquitous processes in the world around us. Virtually any set of surfaces can charge when rubbed together: amber against wool, a bike tire rolling over concrete, ground coffee tumbling out of a grinder. One surface is left with positive charge; the other becomes negatively charged. Some of the effects may be mundane and familiar; the electric shock you may feel when you touch the doorknob after dragging your feet against carpeted flooring is perhaps the best example. Others consequences, like volcanic lightning storms or the formation of planets from charged cosmic dust, are much more dramatic. Surprisingly, despite being such a well-known phenomenon, a complete understanding of why and how materials charge when rubbed together remains elusive. Here, we highlight the some of the physics of triboelectrification in granular materials through the preparation of coffee. The act of grinding coffee generates copious numbers of electrostatically-charged particles. When brewing, the electrostatically-bound particle aggregates affect liquid-solid surface accessibility, leading to variable extraction quality in espresso. Charging also causes spark discharges and material loss. The insights we have gained from our experiments extend well beyond the cup, impacting our knowledge of electrification processes associated with pharmaceutical powders, volcanic eruptions, and even the sand dunes of Saturn's moon Titan. Understanding charging during coffee grinding not only aids in the pursuit of the tastiest espresso, it also brings us closer to resolving long-standing questions in material science, engineering, and geophysics

Contributed Session 2

Wednesday March 26, 16:15-17:30

Flexoelectricity and surface ferroelectricity of water ice

16:15-16:30

Xin Wen[1,2], Qianqian Ma[2], Anthony Mannino[3], Marivi Fernandez-Serra[3], Shengping Shen[2] and Gustau Catalan[1]
[1]Institut Catala de Nanociencia i Nanotecnologia (ICN2), Barcelona, Sapin
[2]Xi'an Jiaotong University, Xi'an, China
[3]Stony Brook University, Stony Brook, USA

The phase diagram of ice is complex and contains many phases, but the most common (frozen water at ambient pressure, also known as Ih ice) is a non-polar material despite individual water molecules being polar [1]. Consequently, ice is not piezoelectric and cannot generate electricity under pressure [2]. On the other hand, the coupling between polarization and strain gradient (flexoelectricity) is universal [3], so ice may in theory generate electricity under bending. Here we report the experimental demonstration that ice is flexoelectric [4], finding a coefficient comparable to that of ceramics such as $SrTiO_3$ or TiO_3. Additionally, and unexpectedly, the sensitivity of flexoelectric measurements to surface boundary conditions has also revealed a ferroelectric phase transition around 163K confined in the near-surface region of the ice slabs. The electromechanical properties of ice may find applications for low-cost transducers made in-situ in cold and remote locations, but perhaps more important are the consequences for natural phenomena involving ice electrification. In particular, we have calculated the flexoelectric polarization generated in collisions between ice and graupel particles, which reproduces the experimentally reported results for contact electrification in such events, known to cause electrification in storm clouds.

[1] T. Bartels-Rausch *et al.*, Rev. Mod. Phys **84**, 885 (2012).
[2] V.F. Petrenko and R. W. Whitworth, Physics of Ice (OUP Oxford, 1999).
[3] P. Zubko, G. Catalan and A. K. Tagantsev, Annu. Rev. Mater. Sci. **43**, 387 (2013).
[4] X. Wen, Q. Ma, A. Mannino, M. Fernandez-Serra, S. Shen and G. Catalan, arXiv preprint arXiv:2212.00323 (2024)

Polarization effects in electrostatic interaction and charge exchange models between spherical particles

16:30-16:45

Maria Giordano[1], Francesca O. Alfano[1], Giovanni Iozzi[1], Francesco P. Di Maio[1] and Alberto Di Renzo[1]
[1]University of Calabria, Department of Computer Engineering, Modelling, Electronics and Systems Engineering, Rende, Italy

During particle-particle and particle-wall collisions, electrostatic charge exchange typically occurs, possibly leading to charge build-up, particularly with dielectric materials. In industrial applications, accumulation of static electricity affects the flowability of fine powders and causes irregular flow, segregation phenomena, particle adhesion to walls, among other issues. As a consequence, product quality is severely impacted by material loss, inhomogeneity and poor control. Particle-scale simulations can provide insight and understanding into the dynamics of charge transfers and accumulation as well as their effects on the particle motion. Yet, fundamental aspects regarding the charge transfer mechanisms during contacts (tribocharging) are still debated, as various hypotheses have been put forward. Correspondingly, different modelling approaches have been proposed, such as the charge transfer model, the surface state model, the condenser model, the

mosaic model. One of the aspects that has lacked consideration is the role of surface charge polarisation in interactions between particles of polarisable materials. In the present contribution, a charge plus effective dipole model of the electrostatic interactions between solid particles is demonstrated as a feasible solution for particle-scale simulations of large number of charged particles. Adapted from the approach of Chan [1] for polarisable ions to the case of solid particles, the model proves able to capture realistic attraction force values for like-charged particles or between a charged particle and a neutral particle, in comparison with rigorous, but much more complex, solutions of the force between two spherical particles with polarised surface charge distributions. Implementation of the effective dipole model in a Discrete Element Method code allowed systems containing hundreds of thousands of interacting charged particles to be readily simulated during shaking. Induced polarisation requires significant charge levels, so sufficient particle charging dynamics must have previously taken place. Interestingly, surface polarisation can also influence the elementary charge transferring process. In an attempt to contemplate such an effect in simulations, a possible extension of the condenser model to include polarisation effects is introduced and discussed. It is shown to allow the role of particle material properties, sizes and initial charges to be investigated on the charging dynamics and saturation levels.

This research has been supported by the project "ICSC National Center for High-Performance Scientific Computing", funded by the European Union – NextGenerationEU (grant number CN00000013, CUP: H23C22000360005).

[1] H.-K. Chan. J. Electrostatics **105**, 103435 (2020).

Triboelectric charging of rough particle surface: modelling study

16:45-17:00

Jarmila Pelcová[1], Jana Sklenářová[1] and Juraj Kosek[1]

[1]University of Chemistry and Technology Prague, Department of Chemical Engineering, Prague, Czechia

A variety of insulating materials is manufactured in granular or powdered form. Triboelectric charging of such materials due to particle collisions is often encountered phenomenon, which is generally unwelcome. In our work, we study the triboelectric charging on the level of particles with focus on the surface morphology. We show that the particle morphology has a significant effect on the amount of charge acquired by particle, on the charge distribution and overall charging dynamics. We use Discrete Element Method based model with modified Hertzian mechanics to evaluate the deformation of a rough particle during collision. Subsequently, we use probability-based charging model and calculate charge evolution in the system. The results show that the particle surface morphology can be responsible for many experimentally observed trends, such as the dependence of saturation charge on the impact velocity, size-dependent charging of particles, very slow charging rates, "infinite" charging without reaching constant charge and the uneven distribution of charge on particle surface.

Tribocharging during water intrusion-extrusion into-from nanopores: from regenerative shock-absorbers to self-powered pressure and temperature nanosensors

17:00-17:15

Luis Bartlomé[1], Simone Meloni[2] and **Yaroslav Grosu[1,3]**

[1]Centre for Cooperative Research on Alternative Energies Basque Research and Technology Alliance, Vitoria-Gasteiz, Spain
[2]University of Ferrara, Ferrara, Italy
[3]University of Silesia, Katowice, Poland

In this presentation, we demonstrate how water intrusion-extrusion into-from hydrophobic nanoporous materials can be used to convert environmental heat and mechanical energy of pressure or vibrations into useful electricity via triboelectrification [1-3]. The electro-intrusion approach is applicable to pressure and temperature nanosensors. It can be further developed for mechanical and/or thermal energy harvesting applications where excess energy is wasted [4], e.g. transport shock-absorbing, walking and body movement, vibrations of domestic appliances, etc. Electrification experiments of water intrusion-extrusion into/from superhydrophobic materials, such as grafted nanoporous silicon, silica and ZIF-8 Metal-Organic Framework (MOF), are presented to demonstrate this concept. In particular, these experimental findings are discussed within the framework of Horizon 2020 Electro-Intrusion project dedicated to these phenomena [5].

[1] Y. Grosu *et al.,* ACS Appl. Mater. Interfaces. **9**, 7044-7049 (2017).
[2] Lowe A. *et al.,* ACS Appl. Mater. Interfaces. **11**, 40842-40849 (2019).
[3] L. Bartolomé, J. D. Littlefair, E. Amayuelas, L. J. Johnson, A. Le Donne, A. Šutka, S. Meloni, and Y. Grosu, Adv. Mater. Technol. **9**, 2401744 (2024).
[4] Grosu, Y., Bartolomè, L., Meloni, S. Low-Bias Voltage Intrusion-Extrusion Electric Generator. Patent WO 2024/246189 A1
[5] https://www.electro-intrusion.eu

Spontaneous charge-driven surface oscillations on adhesive silicone gels

17:15-17:30

Katharine E. Jensen[1], Katrina Smith-Mannschott[1,2], June Jiwoo Han[1], Meredith Taghon[1], Yazen Oubari[1], Beatrice Pedroni[1] and Rosie Harris[1]

[1]Williams College, Williamstown, MA, USA
[2]ETH Zürich, Zürich, Switzerland

Soft, sticky silicone gel surfaces are commonly used in studies of adhesive contact because of their easily controllable material properties and range of both elastic and capillary behaviors. Here, we report measurements of spontaneous, charge-driven surface oscillations when a charged glass microsphere is brought close to flat polydimethylsiloxane (PDMS) substrates. This surprising phenomenon can last for hundreds of seconds, or more, depending on initial conditions, specific gel composition, and humidity. We develop brightfield imaging techniques to characterize the surface oscillations by measuring the deformation and recovery over time, in some cases with complementary force measurements.

This work has been supported by the National Science Foundation under Grants No. CMMI-2129463 and DMR-2340259.

Invited Session 3

Thursday March 27, 9:00-10:45

Triboelectrification of particulate solids

9:00-9:35

Mojtaba Ghadiri[1]
[1]University of Leeds/ School of Chemical and Process Engineering, Leeds, UK

Triboelectrification, caused by collisions and sliding contacts between materials, leads to the accumulation of electric charge. This phenomenon presents significant challenges in material handling and processing, often resulting in reduced manufacturing efficiency, out-of-specification products, wastage, and even explosion hazards.

Over the years, our research team has developed advanced tools and methodologies to characterise charge transfer at both the single-particle level and the bulk level, under conditions such as dense shear deformation and lean-phase pneumatic conveying. Our current research programme takes a comprehensive approach to the analysis of triboelectrification, addressing it from the molecular-level mechanisms of solid-state formation to large-scale industrial processes, including the manufacturing of active pharmaceutical ingredients and polymers. The programme consists of seven work packages, each focused-on topics of both scientific significance and industrial relevance.

These activities range from:

- Molecular-scale investigations, including solid-state work function calculations using Density Functional Theory (DFT);
- Characterisation of particle charge transfer, achieved through the development of specialised instruments for measuring charge distribution and Tribo Electric Nano Generators (TENG);
- Process-level analysis, involving unit operations such as fast fluidisation and risers, pneumatic conveying, and cyclone separation.

In this presentation, the overall scope of the research and the contributors involved will be introduced, and then a detailed overview of one key activity: the measurement of charge distribution in particulate systems will be provided.

Granular tendrils

9:35-10:10

Mary Pat Reiter[1], André Matias[2], Nuno Araujo[3] and **Troy Shinbrot[4]**
[1]University of Maryland, College Park, Maryland, USA
[2]Utrecht University, Utrecht, Netherlands
[3]University of Lisbon, Lisbon, Portugal
[4]Rutgers University, Piscataway, New Jersey, USA

Tendrils of grains, sometimes fused together, are seen in a surprising variety of systems. Polymer beads, toner particles, and spice grains—possibly even sand grains on a Mars rover—all spontaneously form tendrils, ranging in length from tens to hundreds of particles long. Other elongated structures form in non-granular media, for example Taylor cones in fluids, ice spikes on freezing water, and tin whiskers on metallic surfaces. In those systems, tendrils form from the bulk material outward, however granular tendrils appear to form by accretion: outside-in. In this talk, we examine the hypothesis that simple electrostatic forces may produce tendrils, beginning from a single charged seed particle. We derive the dimensionless group that sets a limit on the maximum length of such tendrils, and find on a theoretical basis that such tendrils can be remarkably long.

Liquid-liquid phase separation driven by charge heterogeneity
10:10-10:45

Daniele Notarmuzi[1] and **Emanuela Bianchi[1]**
[1]Institute für Theoretische Physik Technische Universität Wien, Vienna, Austria

The phase diagram of proteins is often characterized by a region where the system spontaneously separates into a dense and a dilute liquid phase, a process known as liquid-liquid phase separation (LLPS). Recent experiments show that the inherent charge heterogeneity of proteins, due to the surface clustering of amino acids in the same protonation state, can be exploited to control the LLPS [1-5]. This leads to the timely and fundamental question of how charge patchiness influences the LLPS and whether anisotropic electrostatics alone can drive this process. We tackle this challenge with extensive Monte Carlo simulations of a coarse-grained model built upon a robust mean-field description [6] that extends the DLVO theory to non-uniformly charged particles. Due to the relative simplicity of our model, we investigate the effect of charge patchiness and charge imbalance on varying these features independently and with the use of a few parameters only. We show that a limited bonding valence—usually associated only to site-specific interactions—is provided also by anisotropic electrostatic interactions and that electrostatics introduces morphological constraints that hinder the condensation of dense aggregates, thus disfavoring the LLPS [7,8].

[1] D. M. Mitrea *et al.,* Nat. Comm. **9**, 842 (2018).
[2] S. Kim *et al.,* Biomacromolecules **21**, 3026 (2020).
[3] H. Yamazaki *et al.,* Nat. Cell Bio. **24**, 625 (2022).
[4] H. Ausserwöger *et al.,* PNAS 120, e2210332120 (2023).
[5] J. Kim et al., J. Am. Chem. Soc. **146**, 3383 (2024).
[6] A. Gnidovec *et al.,* arXiv:2411.03045 (2024).
[7] D. Notarmuzi *et al.,* Soft Matter **20**, 7601 (2024).
[8] D. Notarmuzi *et al.*, Communications Physics **7**, 412 (2024).

Contributed Session 3

Thursday March 27, 11:15-12:30

Anisotropic DLVO-like interaction for charge patchiness in colloids and proteins

11:15-11:30

Andraz Gnidovec[1], Emanuele Locatelli[2], Simon Copar[1], **Anze Bozic[3]** and Emanuela Bianchi[4]
[1]Faculty of Mathematics and Physics, University of Ljubljana, Ljubljana, Slovenia
[2]Department of Physics and Astronomy, University of Padova, Padova, Italy
[3]Department of Theoretical Physics, Jozef Stefan Institute, Ljubljana, Slovenia
[4]Institut für Theoretische Physik, TU Wien, Vienna, Austria

The behaviour and stability of soft and biological matter depend significantly on electrostatic interactions, as particles such as proteins and colloids acquire a charge when dispersed in an electrolytic solution. A typical simplification used to understand bulk phenomena involving electrostatic interactions is the isotropy of the charge on the particles. However, whether arising naturally or by synthesis, charge distributions are often inhomogeneous, leading to an intricate particle-particle interaction landscape and complex assembly phenomena. The fundamental complexity of these interactions gives rise to models based on distinct assumptions and varying degrees of simplifications which can blur the line between genuine physical behaviour and artefacts arising from the choice of a particular electrostatic model. Building upon the widely-used linearized Poisson-Boltzmann theory, we propose a theoretical framework that—by bridging different models—provides a robust DLVO-like description of electrostatic interactions between inhomogeneously charged particles. By matching solely the single-particle properties of two different mean-field models, we find a quantitative agreement between the pair interaction energies over a wide range of system parameters. Our work identifies a strategy to merge different models of inhomogeneously charged particles and paves the way to a reliable, accurate, and computationally affordable description of their interactions.

Electrokinetic spectroscopy of ion dynamics near charged surfaces using modulated surface acoustic waves

11:30-11:45

Yifan Li[1], Sudeepthi Aremanda[1] and **Ofer Manor[1]**
[1]Chemical Engineering, Technion - Israel Institute of Technology, Haifa, Israel

We use MHz-level modulated surface acoustic waves (SAWs) to study the dynamics of ions near charged solid/solution interfaces in the electrical double layer (EDL). The SAW travels in the solid, and the EDL exists in the electrolyte solution; both phenomena are entangled through a field effect, a mechanical evanescent wave, which is invoked in the solution by the SAW [1] and vibrates ions in the EDL [2]. This is a new MHz-level spectroscopy for studying ion dynamics near surfaces.

Electrical double layers (EDLs) are nanometer-thick clouds of ions that appear at the charged interface between a substrate and an electrolyte solution. Ions diffuse and migrate through the EDLs as individuals or as groups (coupled diffusion) in micro- to nano-seconds: These are ion-specific times for charging and discharging the EDL, which are a product of the EDL structure and the ion size and charge and are known as the EDL relaxation-times.

Ion relaxation-times similar to the SAW periodic time result in an ion electro-mechanical resonance, which maximizes ion vibration and the leakage of electrical fields off the EDL. [3] The leakage identifies the relaxation-time spectrum of individual ions and coupled groups of ions and the intrinsic rate by which they charge and discharge EDLs.

[1] O. Manor, L. Y. Yeo, J. R. Friend, J. Fluid Mech. **707**, 482–495 (2012).
[2] O. Dubrovski and O. Manor. Langmuir **37**, 14679–14687 (2021).
[3] S. Aremanda and O. Manor. J. Phys. Chem. C **127**, 20911–20918 (2023).

Exploring triboelectric charging mechanisms with density functional theory
11:45-12:00

James Middleton[1], Andrew Scott[1] and Mojtaba Ghadiri[1]
[1]University of Leeds, Leeds, United Kingdom

The triboelectric effect, a phenomenon first documented by the ancient Greeks, remains a subject of scientific intrigue and debate. Despite extensive study, the fundamental mechanisms that drive this phenomenon—whether involving electrons, ions, or material nano-fragments—continue to be elusive, with no consensus among researchers. Recent technological developments in the field have facilitated the increased application of computational methodologies, particularly Density Functional Theory (DFT), which has opened new avenues for probing triboelectric charging mechanisms at the nanoscale. This study employs DFT to investigate the primary charge transfer mechanisms driving triboelectric interactions and to enhance the interpretation of experimental data. We apply DFT to gain insight into the fundamental molecular and atomic processes that underpin triboelectrification. Our approach includes evaluations of work functions across various crystal facets and polymers, which is considered an essential parameter for understanding how surface properties influence triboelectric charging. Additionally, we seek to explore the impact of environmental factors such as humidity and the presence of antistatic agents, both of which significantly affect triboelectric charging. Through this study, we probe the mechanisms of triboelectric charging and pave the way for innovative applications in energy harvesting and sensor technology.

Surface charge dynamics in dielectric materials and their Influence on AFM measurements
12:00-12:15

Mario Navarro-Rodriguez[1], Andres M Somoza[1] and Elisa Palacios-Lidon[1]
[1]University of Murcia, Centro de Investigación en Optica y Nanofísica, Murcia, Spain

The ability to retain localized charges at the surface or interface of dielectric materials is a universal property relevant to various fields, such as tribocharging, charge nanopatterning, and nanoxerography. The stability and discharge rate of these surface charges, determined by the material's conductivity and permittivity, are critical for determining potential applications. However, to accurately characterize this decay, it is essential to consider both surface and bulk properties, as they often differ significantly. Accordingly, we first derive equations to model the charge decay at a surface/interface and solve them incorporating both surface and bulk conduction. After establishing this theoretical framework, we validate it by means of atomic force microscopy (AFM) measurements. Furthermore, we show the existence of a dissipative Joule mechanism linked to the surface charge dynamics that may affect the measured thickness of 2D materials. This mechanism arises from a finite surface conductivity and it is particularly relevant when a 2D material is supported on an insulating substrate. Measurements on single-layer Graphene Oxide and reduced Graphene Oxide flakes co-deposited on a SiO_2 substrate demonstrate that the measured thickness is directly related to the surface conductivity and provide a pathway to understanding the effect of finite conductivity on AFM measurements.

Modeling of charged particles in dense granular matter

12:15-12:30

Matthias Sperl[1], Philipp Born[1], Jan Haeberle[1], and Ya Chun Wang[1]

[1]German Aerospace Center DLR, Cologne, Germany

Charged granular matter presents a challenge to space missions, and therefore an essential prerequisite to future space missions is the capability for efficient dust mitigation [1]. At the same time, charging and discharging of granular matter is a process of fundamental interest as well as practical importance. We shall report the statistical analysis of charging and discharging on single particles [2] as well as the consequences of charging on the crystalline structures in granular packings [3]. Beyond that, also the impact of charge on amorphous granular systems and their shear behavior shall be addressed, as done recently for granular hard spheres with dissipation but without charges [4].

[1] Y.C Wang, F. Cipriani, F. Johansson, M. Sperl and M. Adachi, Adv. Space Res. **74**, 6194-6204 (2024).

[2] J. Haeberle, A. Schella, M. Sperl, M. Schröter, and P. Born, Soft Matter **14**, 4987 (2018).

[3] J. Haeberle, J. Harju, M. Sperl and P. Born, Soft Matter **15**, 7179–7186 (2019).

[4] O. D'Angelo, M. Sperl, W.T. Kranz, “Rheological regimes in agitated granular media under shear,” *accepted for publication in Phys. Ref. Lett.*

Invited Session 4

Thursday March 27, 14:00-15:45

From charge distributions to gravity-free interactions: a two-front approach to understanding granular tribocharging

14:00-14:35

Macarena Lara[1], Berenice Muruaga[1], Nicolás Bravo[1], Carolina Espinoza[2], Sergio Rica[3], Scott Waitukaitis[4] and **Nicolás Mujica[1]**

[1]Departamento de Física, FCFM, Universidad de Chile
[2]Departamento de Sonido, Facultad de Artes, Universidad de Chile
[3]Instituto de Física, Pontificia Universidad Católica de Chile
[4]Institute of Science and Technology Austria, Klosterneuburg, Austria

Experiments have shown that particles of the same material exchange electrical charge during collisions, yet the underlying charge exchange mechanism is still not well understood. The fact that particles can become highly charged as a result of this effect has significant consequences for many settings, both in nature and industry, such as thunderstorms in volcanic eruptions, particle aggregation during planet formation, and the clogging of fluidized industrial granular beds. Toward understanding these systems, great efforts have been made on two fronts. On the first, the focus has been to develop precise in situ measurements for particle charge, e.g. to determine ensemble distributions or measure exchange in individual collisions. In the second, the aim has been to understand how charged grains interact, e.g. aggregation, orbits, and clustering. In this talk, I will review our recent experimental results that make significant advances on both of the fronts. In particular, we have developed experimental setups and protocols that allow us to: (1) obtain charge distributions with unparalleled accuracy for large ensembles of particles in the sub millimeter range; and (2) witness with exquisite detail the electrostatic interactions of charged particles in a gravity free environment. Our results make simultaneous progress in the primary two directions required for understanding how charged grains affect systems ranging from volcanic eruptions to fluidized beds.

Electrostatic charges and arthropod ecology

14:35-15:10

Beth H. Harris[1], Robert L. Harniman[2], Ryan A. Palmer[3] and Daniel Robert[1]

[1]University of Bristol, School of Biological Sciences, Bristol, United Kingdom
[2]University of Bristol, School of Chemistry, Bristol, United Kingdom
[3]University of Bristol, School of Engineering Mathematics and Technology, Bristol, United Kingdom

Aerial electroreception is the ability of an organism to perceive and learn external electric field stimuli. It is a recently discovered sense in terrestrial arthropods. Of the species studied, including bees, spiders, hoverflies, and caterpillars, electroreception has been shown to play a role in different ecological contexts including pollination, dispersal and predator detection. For many arthropods, electrostatics also contribute passively to their ecology, such as through enhanced pollen collection or parasitism. The main focus of research into the mechanism of aerial electroreception has been mechanosensory hairs, which are widespread amongst arthropods. Specifically, electrical cues are transduced by electromechanical actuation of the charged hair sensors. In electroreceptive species, these sensors are therefore considered multimodal, detecting, and in some cases discriminating between, air flow and electrostatic forces. Further understanding the mechanics of these sensors and the mechanisms by which charges are acquired and maintained represents an important direction for the field. Yet, multiple sensors may exist both within and between species. Here, we propose a new candidate aerial electroreceptor in bees, the placode sensilla, and present the first electrostatic force microscopy data on this class of antennal sensor. We show that the placodes always present a heterogeneous charge distribution and that the local charge of the antenna typically differs in polarity from the net charge of the bee. Whilst the specific electrostatic profile across the sensor differs, remarkably, surface charge heterogeneities are also measured in the antennae of long-dead bees. The mechanism by which these sensors generate charge and the putative role of electrostatic properties in sensing electric signals remain to be understood.

Lightning in a planet forming region: generation and implication

15:10-15:45

Taishi Nakamoto[1], Rho Nishiziawa[1], Fang Han[1], Tetsuo Taki[2], Mizuki Kamioka[1] and Hiroaki Kaneko[1]
[1]Institute of Science Tokyo, Tokyo, Japan
[2]University of Tokyo, Tokyo, Japan

Planets like our Earth form from small dust particles within a protoplanetary disk. Initially, these dust particles are approximately 0.1 micro-meter in size, but through a series of processes, they eventually aggregate to form planets of the order of 1,000 km to 100,000 km in diameter. A crucial intermediate stage in this process involves the formation of planetesimals, which are celestial bodies with diameters on the order of 10 km to 100 km. According to modern planet formation theories, regions within the protoplanetary disk where the density of small dust particles becomes sufficiently high can undergo self-gravitational instability. This instability leads to enhanced density and ultimately results in the formation of gravitationally bound planetesimals. However, the precise mechanisms underlying the formation of planetesimals remain poorly understood and are an active area of research.

During the process of planetesimal formation, small dust particles collide each other in the dense regions. Similar phenomena occur on Earth in systems such as cumulonimbus clouds and volcanic plumes [1], where dust particles acquire electric charges, generating electric fields that can lead to lightning. This analogy suggests the possibility that lightning might also be produced during the planetesimal formation process. In our study, we investigate the potential generation of lightning in association with planetesimal formation, exploring the mechanisms that might drive this phenomenon. Key differences from atmospheric lightning include the composition of the gas, which primarily consists of molecular hydrogen, the significantly lower gas pressure of around 10 Pa, and the gas flow dynamics.

We model the motion of small dust particles during the planetesimal formation process, their collisions, and the charging of particles. Specifically, our study employs a simple model that describes the charging induced by collisions between particles of different sizes. Because particles of different sizes experience different gas drag forces, they exhibit distinct motion, leading to large-scale charge separation and the generation of an electric field. By comparing the strength of the generated electric field with the breakdown field strength, we assess the probability of lightning production. Based on our simulations, we found that lightning is likely to occur during this process [2, 3].

We also investigate the potential byproducts of lightning during planetesimal formation. Lightning may heat small dust particles in the protoplanetary disk, and these heated particles could form chondrules—millimeter-sized spherical silicate objects found in chondritic meteorites. Studies of chondrules in meteorites indicate that they are created through rapid flash heating, melting, and subsequent re-solidification [4]. While the exact formation mechanism of chondrules remains unresolved, lightning associated with planetesimal formation could play a significant role in their creation [5]. If this hypothesis is correct, the enhancement of dust particle density within the disk could simultaneously explain both planetesimal formation and chondrule formation, offering a unified framework for understanding these processes.

[1] C. Cimarelli, M. A. Alatorre-Ibarguengoitia, K. Aizawa, A. Yokoo, A. Diaz-Marina, M. Iguchi, and D. B. Dingwell, Geophysical Research Lett. **43**, 4221-4228 (2016)
[2] R. Nishizawa and T. Nakamoto, *submitted*
[3] F. Han, T. Taki, and T. Nakamoto, *in preparation*
[4] S. Desch, M. A. Morris, H. C. Connolly, Jr., and A. P. Boss, Meteoritics and Planetary Sci. **47**, 1139-1156 (2012)
[5] H. Kaneko, K. Sato, C. Ikeda, and T. Nakamoto, Astrophysical J. **947**,15 (22pp) (2023)

Contributed Session 4

Thursday March 27, 16:15-17:30

Spontaneous ordering of identical materials into a triboelectric series

16:15-16:30

Juan Carlos Sobarzo[1], Felix Pertl[1], Daniel M. Balazs[1], Tommaso Costanzo[1], Markus Sauer[2], Annette Foelske[2], Markus Ostermann[3], Christian M. Pichler[3], Yongkang Wang[4], Yuki Nagata[4], Mischa Bonn[4] and Scott Waitukaitis[1]

[1]Institute of Science and Technology Austria, Klosterneuburg, Austria
[2]Analytical Instrumentation Center, TU Wien, Vienna, Austria
[3]Centre of Electrochemical and Surface Technology, Wiener Neustadt, Austria
[4]Molecular Spectroscopy Department, Max Planck Institute for Polymer Research, Mainz, Germany

Experiments have long suggested Contact Electrification (CE)—the exchange of electric charge through contact—is transitive, with different materials ordering into 'triboelectric series' based on the sign of charge acquired. At the same time, the effect is plagued by unpredictability, preventing consensus on the mechanism and casting doubt on the order series imply. Here we expose an unanticipated connection between the unpredictability and order in CE: nominally identical materials initially exchange charge randomly and intransitively, but over repeated experiments self-organize into triboelectric series [1]. We find that this evolution is driven by the act of contact itself—samples with more contacts in their history charge negatively to ones with less. Capturing this 'contact bias' in a minimal model, we recreate both the initial randomness and ultimate order in numerical simulations, and leverage it experimentally to force the appearance of a triboelectric series of our choosing. With a battery of surface sensitive techniques to search for the underlying alterations contact creates, we only find evidence of nanoscale morphological changes, pointing to a mechanism strongly coupled with mechanics. Our results urge us to more carefully consider the essential role of contact history in CE and suggest that focusing on the unpredictability may hold the key to understand it.

*This project has received funding from the European Research Council Grant Agreement No. 949120 under the European Union's Horizon 2020 research and innovation program. The AIC of the TU Wien acknowledges support by the FFG project 'ELSA' under grant n°: 884672. C.M.P and M.O. acknowledge the state of Lower Austria and the European Regional Development Fund under grant number WST3-F-542638/004-2021. This research was supported by the Scientific Service Units of The Institute of Science and Technology Austria through resources provided by the Miba Machine Shop, Nanofabrication Facility, Scientific Computing Facility, Electron Microscope Facility, and Lab Support Facility.

[1] J.C. Sobarzo, *et al.*, Nature **638**, 664–669 (2025).

Triboelectrification of functionalised glass beads during pneumatic conveying

16:30-16:45

Wei Pin Goh[1], James Middleton[1], Otome Obukohwo[2], Mohsen Isaac Nimvari[2], Poupak Mehrani[2] and Mojtaba Ghadiri[1]

[1]School of Chemical and Process Engineering, University of Leeds, Leeds, UK
[2]Department of Chemical and Biological Engineering, University of Ottawa, Ottawa, Canada

Triboelectrification, the process of charge generation through friction, plays a crucial role in various industrial applications, including pneumatic conveying. This phenomenon can lead to significant processing issues such as particle agglomeration, equipment fouling, and even explosions.

Understanding the charging behaviour of materials is essential for mitigating these risks and ensuring safe and efficient operations. In this study, we investigate the triboelectrification of functionalised glass beads during pneumatic conveying. We address the effect of surface treatment on triboelectrification by modifying the surface properties of glass beads. This is achieved by making the beads hydrophilic through acid washing and hydrophobic through silanisation. The charging behaviour of these beads is characterised using an in-house aerodynamic dispersion method and compared with the actual charge acquired during pneumatic drying. Additionally, we study the effects of mass loading and conveying air velocity on the charging behaviour to understand how different quantities of material and air speeds influence the triboelectric charge. Experiments were conducted under both nitrogen and air atmospheres to assess the impact of different conveying environments. Our findings reveal a small but notable difference in the charging behaviour between the two environments, providing insights into the impact of functionalisation, mass loading, air velocity, and conveying conditions on triboelectrification.

Charging of regolith particles under UV and ion irradiation and its effects on electrostatic mitigation technique for lunar explorations

16:45-17:00

Masato Adachi[1], Keisuke Kohara[1], Shunsuke Mitsunaga[1] and Takato Morishita[2]

[1]Kyoto University/Department of Mechanical Engineering and Science, Kyoto, Japan

[2]Japan Aerospace Exploration Agency/Institute of Space and Astronautical Science, Kanagawa, Japan

Lunar regolith, the fine particulate material covering the Moon's surface, provides valuable insights into planetary science. However, it poses significant challenges for both manned and unmanned missions due to its tendency to adhere to exploration equipment and spacesuits, leading to deterioration and malfunction. Therefore, effective cleaning technologies suitable for use in the lunar environment are crucial for the success of future lunar explorations. The Electrodynamic Dust Shield (EDS) system is an advanced cleaning technique that uses an electrostatic traveling wave to remove charged particles from target surfaces without the need for mechanically moving parts or pneumatic materials. Although the cleaning performance of the EDS system depends on the charge state of the particles, this aspect has not been thoroughly studied. Moreover, developing additional charging methods for deposited particles is critical for practical applications of EDS when the particles are not sufficiently charged. In our study, we experimentally investigated the impact of various charging methods, such as the use of UV and ions under different irradiation conditions, on the charging behaviors of particles and the cleaning performance of the EDS system. Since lunar surfaces are naturally exposed to such charging sources, our findings provide practical means of dust mitigation as well as fundamental insights into the charging behaviors of lunar regolith particles in space environments.

Electric and magnetic field-induced morphology transitions in desiccation cracks

17:00-17:15

Megha Emerse[1], Hisay Lama[1], Sanket Kumar[1], Madivala G. Basavaraj[2,3], Rajesh Singh[1,3] and **Dillip K. Satapathy[1,3]**
[1]Department of Physics, IIT Madras, Chennai, India
[2]PECS Laboratory, Department of Chemical Engineering, IIT Madras, Chennai, India
[3]Center for Soft and Biological Matter, IIT Madras, Chennai, India

Desiccation cracks, or drying-induced cracks, form in particulate deposits as liquid evaporates during drying. Such cracks are commonly observed in nature, as in dried mud or paint on walls. Previous studies have demonstrated that the spatial arrangement of these cracks can be manipulated using external fields. This work explores various intriguing crack morphologies, such as well-separated lines, concentric circular rings, and interconnected networks, induced solely by application of external fields like electric fields [1] and magnetic fields [2]. In this talk, I will present an experimental and theoretical investigation into desiccation crack patterns formed in hematite ellipsoid deposits under an alternating current (ac) electric field. By varying the frequency and strength of the applied field, a series of crack morphology transitions are observed. These transitions are explained through a linear stability analysis of the equations governing the effective dynamics of ellipsoids subjected to an externally applied ac electric field.

[1] M. Emerse, H. Lama, M.G. Basavaraj, R. Singh and D.K. Satapathy. Phys. Rev. E **109**, 024604 (2024).
[2] H. Lama, M.G. Basavaraj and D.K. Satapathy, Phys. Rev. Mat. **2**, 085602 (2018).

Tribocharging of granular matter: from bulk flow to flying grains

17:15-17:30

T. Gemine[1], N. Preud'homme[1], E. Opsomer[1], S. Dehareng[2], T. Andrianne[2] and **G. Lumay[1]**
[1]GRASP Laboratory, CESAM Research Unit, University of Liège, Liège, Belgium
[2]Wind Tunnel Lab, University of Liège, Liège, Belgium

When two objects are rubbed against each other, they charge because of the triboelectric effect. This effect is predominant in granular materials which show significant charging due to the large rate of collisions between its constituents.

The charge buildup in bulk granular flows has been studied in our group trough both experiments and DEM simulations [1,2]. In simulations, we consider the existence of acceptor and donor sites (also called patches) of charges at the surface of the particles. These patches could be donors or acceptors of charges. We have shown in different flowing geometries than the simulations reproduce quite well the experimental results.

In this presentation, we will also present recent results related to electrostatic charge build-up in granular materials carried by airflow. Using a small-scaled custom 3D-printed wind tunnel, we are investigating the coupling between the tribo-electrostatic charging mechanisms, the airflow characteristics, and the adhesion to surfaces. We are investigating systematically the influence of material type, particle size, mass and airflow velocity on triboelectric charging. These findings extend previous work by providing quantitative insights into charging behavior under controlled dynamic conditions, offering a new framework for understanding particle electrification in motion.

[1] N. Preud'homme, G. Lumay, N. Vandewalle and E. Opsomer, Soft Matter **19**, 8911 (2023).
[2] N. Preud'homme, J. Schockmel, E. Opsomer and G. Lumay, Soft Matter **20**, 9060 (2024).

Invited Session 5
Friday March 28, 9:00-10:45

In situ and operando characterization of photo- and electrocatalytically active faceted nanoparticles
9:00-9:35

Frieder Mugele[1]
[1]Physics of Complex Fluids, University of Twente, Enschede, Netherlands

Photo- and electrocatalytically active materials are expected to play an essential role in the transition towards sustainable processes for energy storage and chemical conversion. Performance and stability of the materials still need to be improved. Yet, the microscopic origin of their current limitations is poorly understood. One key limitation is the lack of suitable techniques that allow for a detailed characterization of the structural and electrical properties of the interfaces on the nanometer scale. In this lecture, I describe our recent progress in establishing in situ and operando AFM spectroscopy for characterizing the surface charge and its response to illumination on photocatalytically active faceted nanoparticles of SrTiO3 and BiVO4 in ambient electrolytes of variable composition. Our measurements demonstrate the existence and pH-dependence of differences in the surface potential between adjacent crystal facets, which are believed to drive the separation of photo-generated electron-hole pairs in photocatalysis. For visible light-driven BiVO4, we monitor the variations of the local surface charge upon illumination, from which we extract the local surface photovoltage and thus the accumulation of charge carriers at the interfaces. The measurements suggest a strong influence of surface defects such as steps and disordered regions between adjacent facets for the accumulation of photo-excited charge carriers.

I will conclude the lecture with an outlook on upcoming challenges in AFM-based characterization of electrocatalytic materials for the energy transition and their transformations under operando conditions.

Atmospheric electricity on Earth and Venus
9:35-10:10

Blair McGinness[1], Giles Harrison[1], Karen Aplin[2] and Martin Airey[1]
[1]University of Reading, Reading, UK
[1]Univeristy of Bristol, Bristol, UK

On Earth, “atmospheric electricity” is not just concerned with lightning, and describes a range of electrical processes across many scales, having in common the presence and movement of electrical charges. These processes can have important impacts across other disciplines—such as atmospheric chemistry and cloud physics. A central concept in describing the Earth’s atmospheric electric environment is the “global atmospheric electric circuit”. This is a system which distributes charge globally, through the conductive upper atmosphere and surface of Earth. In disturbed weather regions—principally where there are thunderstorms, but also shower clouds—charge separation leads to a potential difference between the surface and the upper atmosphere. Electrical charges are then distributed globally across these conductive layers. In distant fair-weather regions, a vertical flow of current allows the charge exchange of the disturbed regions to be globally balanced. Many studies of atmospheric electricity focus on the dramatic processes in disturbed regions—such as lightning—however it is just as important to consider these fair-weather regions to obtain a complete picture of the electrical system.

Ionisation is present in the atmosphere of all planets in our solar system, providing a universal source of electric charges. “Planetary atmospheric electricity” describes the investigation of atmospheric electricity in these extra-terrestrial atmospheres. Atmospheric electricity-related processes have been observed in other planets, with lightning observed on all four Jovian planets in our solar system. It is unclear, however if any of these atmospheres could harbour a global electric circuit, as exists on Earth.

The possibility of a global electric circuit in Venus' atmosphere is discussed here, using in-situ data recorded by the Venera 13 & 14 spacecraft to drive an electrical model of the atmosphere. This electrical model considered the interaction between atmospheric ions and haze particles to determine the electrical signals which would be detected by the Venera spacecraft. This modelling approach revealed that a global atmospheric electric circuit would provide the simplest explanation of the data recorded in-situ in Venus' atmosphere.

Unconventional additives for static charge dissipation on common polymers

10:10-10:45

Bilge Baytekin[1]

[1]Bilkent University, Chemistry Department and UNAM, Ankara, Turkey

Static charging is a significant problem, especially critical for the polymer and plastics industry. In technologies involving the manufacturing or utilization of insulator polymers, electrostatic sticking or discharges cause severe problems. The conventional method to mitigate charges operates on increasing the surface conductivity, which may not be appropriate in some cases, such as in polymer electronic coatings. In this presentation, I will display our chemical approaches to mitigate triboelectric charges on common polymers. In these approaches—whether the lignins, the organic dyes, or the quantum dots are used as the additive—the mechanochemically generated surface species and their interactions with each other and these additives play the central role. However, depending on the nature of the additive, new physical-chemical pathways open for charge dissipation (and retention!). Since common polymers are produced by ca. 350 million tons every year and play a pivotal role in many industries, static charge mitigation by (unconventional) additives can contribute to the scientific understanding of the discharge phenomenon and resolve some current industrial problems.

Contributed Session 5

Friday March 28, 11:15-12:30

The role of thin dielectric layers in contact electrification of metals

11:15-11:30

Andre Mölleken[1], Hermann Nienhaus[1] and **Rolf Möller[1]**

[1]University of Duisburg-Essen/Faculty of Physics, Duisburg, Germany

The induced charge of a sphere bouncing on a plate of a parallel plate capacitor is used to measure the charge transfer in contact with the surface [1]. The contact electrification of a metallic sphere upon contact with a copper surface without and with oxide or hydroxide layers of various thicknesses reveals that although a metallic contact is achieved by the impact of the sphere, the charge can be increased by a factor of about 10 compared to the pure metallic case. Details of the way how the contact is formed between the sphere and the plate can be derived by high temporal resolution analysis of the transient signal. It reveals a fine structure characteristic for the different contact scenarios. Different mechanisms to explain the enhanced charging will be discussed. The results provide a route to generate charges in metallic contacts including a thin dielectric layer which are significantly higher than what is normally observed for metallic contacts.

[1] M. Kaponig, A. Mölleken, H. Nienhaus and R. Möller, Science Advances **7**, eabg7595 (2021).

Charged granular gases

11:30-11:45

Thomas Schwager[1], Nikolai Brilliantov[2], Arno Formella[3], Satoshi Takada[4] and **Thorsten Pöschel[1]**

[1]Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany
[2]Skolkovo Institute of Science and Technology, Moscow, Russia
[3]University of Vigo, Vigo, Spain
[4]Tokyo University of Agriculture and Technology, Tokyo, Japan

Charged granular gases, systems composed of electrically charged inelastic particles, exhibit complex dynamics influenced by both dissipative collisions and long-range Coulomb forces. These systems deviate significantly from neutral granular gases due to unique phenomena such as modified transport coefficients, altered energy dissipation rates, and distinct instabilities. We present results from kinetic theory and molecular dynamics simulations. The characteristic deviations of the velocity distribution from Maxwellian distributions lead to non-trivial decay of temperature, transport coefficients, and stability modes. Analytical and numerical studies reveal that the energy dissipation rate transitions from a Haff-like decay to logarithmic slowing, depending on the system's temperature and particle interaction regimes.

Ultrasoft charged micelles with long-range electrostatic interactions
11:45-12:00

R. A. Mohamed Yunus[1], U. Gurel[1], A. Guzik[1], P. Dieudonne-George[2], I. Gjerapic[1], W. Arends[1], M. Stuart[1], C. Likos[3], P. Raffa[1], D. Truzzolillo[2], **A. Giuntoli[1]** and D. Parisi[1]
[1]University of Groningen, Groningen, Netherlands
[2]Laboratoire Charles Coulomb (L2C), UMR 5221 CNRS-Universitè de Montpellier, Montpellier, France
[3]University of Vienna, Vienna, Austria

We report a combined study of the synthesis, rheology, electron microscopy, and molecular dynamics of polymeric micelles with a ~10nm polystyrene (PS) core and a ~100 nm highly charged polymethacrylic acid (PMAA) outer block completely stretched in the absence of salt. Rheology shows a liquid-to-solid transition at a mass concentration as low as 0.25 wt.% and a non-vanishing elastic modulus even at lower concentrations, while simulations show a threefold decrease of the effective radius of the micelles in the 0.1-1% concentration range and long-range peaks in the radial distribution function. These ultrasoft colloids have size and caging behavior which is extremely sensitive to changes in pH or the presence of additives, so that these systems can be the basis for a class of tunable soft colloidal glasses. Additional molecular dynamics simulations show their conformational tunability and jamming vs self-assembly behavior in the presence of oppositely-charged linear chains of varying concentration and length.

Removal of model polystyrene microplastics by induced aggregation
12:00-12:15

Brijitta Joseph Boniface[1], Aurel Radulescu[1], Armin Kriele[2] and Christian Lang[3]
[1]Jülich Centre for Neutron Science, Forschungszentrum Jülich GmbH, Garching, Germany
[2]German Engineering Materials Science Centre, Helmholtz-Zentrum Hereon, Garching, Germany
[3]VTA Institute for Health & Environment, Rottenbach bei Haag, Austria

Plastic particles smaller than 5 mm are a growing concern and are termed microplastics (MPs). Their small size facilitates ingestion by many organisms, leading to bioaccumulation and health effects. As polystyrene is one of the commonly detected MPs, we developed a model microplastic system comprised of 140±6 nm polystyrene (PS) spheres and investigated its removal from water using Nanofloc®. Here, the polystyrene particles are analogs to the microbeads in commercial face washes/scrubs and have a Zeta potential, ζ=58 mV for a volume fraction, ϕ=1e-5. Nanofloc is positively charged; a 0.17 vol% solution showed ζ=56 mV. The PS-nanofloc aggregation kinetics was investigated by light scattering and the aggregation attachment efficiency, α, was determined to understand the aggregation kinetics as a function of PS and nanofloc concentration. It is observed that even for very low concentrations of nanofloc, the PS MPs aggregated rapidly. The aggregation follows power-law kinetics. Our studies highlight the effectiveness of Nanofloc® in facilitating the rapid aggregation of PS MPs from water, offering a promising solution for mitigating microplastic contamination.

This work has received funding from the European Union's Horizon 2020 research and innovation program under the Marie Skłodowska-Curie grant agreement No 101034266.

Contact electrification of single particle

12:15-12:30

Simon Jantač[1] and Holger Grosshans[1,2]
[1]Physikalisch-Technische Bundesanstalt (PTB), Braunschweig, Germany
[2]Otto von Guericke University of Magdeburg, Institute of Apparatus- and Environmental Technology, Magdeburg, Germany

Accurate particle charge measurement is crucial for understanding triboelectrification, particularly in explaining bipolar charging and charge reversal. Stochastic models require variations in particle properties to capture these phenomena, but pre-measurement contact and uncontrolled conditions introduce uncertainties, complicating parameter estimation. We address these challenges using a levitation-based method that preserves the particle's initial state by preventing unintended pre-contact effects. Our approach enables precise control over environmental factors like humidity and temperature, as well as particle charge. Impact angle and velocity are also tightly regulated, ensuring consistent experimental conditions. Our method directly measures charge transfer during a particle's first collision, unaffected by pre-existing electric fields. Analysis of a large dataset under identical conditions revealed that charge variation arises from intrinsic differences in particle triboelectric properties rather than measurement uncertainties. These findings offer critical insights into bipolar charging and charge reversal in insulating powders, processes driven by the availability of transferable species and particle-specific properties which varies among particles.

Invited Session 6

Friday March 28, 14:00-15:45

Static charge is an ionic molecular fragment

14:00-14:35

Siow Ling Soh[1]
[1]National University of Singapore, Singapore

What is static? Despite being studied for more than 2000 years, the chemical identity of static charge is not known. Besides commonly referred to as a conceptual point charge, there is a lot of debate in the scientific community about what is the actual chemical species of a single static charge and the mechanism of contact electrification for generating the static charge. This presentation discusses these two most important questions of the chemistry of electrostatics: what is the mechanism by which static charge is generated and what is the chemical identity of static charge. Investigations have been challenging due to the complexity of surfaces. Our study involves the molecular-scale analysis of contact electrification using highly well-defined surfaces functionalized with a self-assembled monolayer of alkylsilanes. Analyses show the elementary molecular steps of contact electrification: the exact location of heterolytic cleavage of covalent bonds (i.e., the Si-C bond), exact charged species generated (i.e., alkyl carbocation), and transfer of molecular fragments. Static charge is thus an alkyl carbocation in this study. In general, static charge is an ionic molecular fragment. Based on this understanding at the solid-solid interface, the dynamic behaviors of static charge at the solid-liquid and solid-gas interfaces are discussed.

A new stochastic particle charging model

14:35-15:10

Holger Grosshans[1,2], Simon Jantač[1] and Gizem Ozler[1,2]
[1]Physikalisch-Technische Bundesanstalt (PTB), Braunschweig, Germany
[2]University of Magdeburg, Magdeburg, Germany

We present a stochastic model for the contact charging of particles that applies to the flow of insulative particles bounded by conductive and grounded walls. The model extracts statistical properties of controlled impact experiments of PMMA and PC particles on a plane aluminum surface. Then, these statistics are scaled to other impact conditions. Finally, a CFD simulation predicts the charge transfer of each impact using Monte Carlo simulations that apply the scaled statistical properties. The model is computationally fast and successfully predicts size-dependent charging, bipolar charging, charge reversal, and stochastic scatter.

Electrostatically charged aerosols for lung scintigraphy

15:10-15:45

Philip Chi Lip Kwok[1], Darson Dezheng Li[1], Patricia Tang[1], Luke Fincher[2], Effie Browne[2], Warren H. Finlay[3], and Hak-Kim Chan[1]

[1]Advanced Drug Delivery Group, Sydney Pharmacy School, Faculty of Medicine and Health, The University of Sydney, Camperdown, New South Wales, Australia

[2]Department of Nuclear Medicine, St George Hospital, Kogarah, New South Wales, Australia

[3]Department of Mechanical Engineering, University of Alberta, Edmonton, Alberta, Canada

Particles and droplets generated from pharmaceutical inhalation devices are naturally charged. The levels of these electrostatic charges may potentially affect lung deposition. However, this has not been confirmed in vivo. Human lung scintigraphic studies using radiolabelled, charged particles would provide important data on mapping the deposition locations. This presentation focuses on an aerosol charging rig developed for this purpose. Droplets from an Aerogen® Solo vibrating mesh nebuliser radiolabelled with technetium-99m were charged by induction and then dried to produce positively charged particles. Particles carrying near-neutral and 10-4,000 elementary charges per particle were obtained at induction voltages of -0.4 and -4.5 kV, respectively. Particle charges generally decreased with radioactivity, especially for solutions at 400 and 800 MBq/mL. We speculate that this is due to the indirect ionising effect of gamma radiation, which produced bipolar ions in the air that neutralised the initially charged particles. Radioactivity at 100 MBq/mL generated the highest particle charges that may be high enough to alter in vivo deposition. The aerosol charging rig is suitable for use in human scintigraphy studies that we will soon conduct.

Contributed Session 6

Friday March 28, 16:15-17:30

Measuring electric charging and discharging of individual aerosol particles in an optical trap

16:15-16:30

Andrea Stoellner[1], Isaac Lenton[1,2], Caroline Muller[1] and Scott Waitukaitis[1]
[1]Institute of Science and Technology Austria, Klosterneuburg, Austria
[2]University of Manchester, Manchester, United Kingdom

Charge accumulation on aerosol particles, e.g. dust, volcanic ash or cloud ice, plays a critical role in a variety of natural and industrial processes. It gives rise to lightning in thunder- and sandstorms and can lead to dangerous dust explosions during industrial processing [1]. In our experiment, we utilize optical tweezers to levitate individual aerosol particles and observe their charging and discharging dynamics over days-to-weeks time periods and with elementary-charge resolution. Our approach allows us to study these processes without losing information to ensemble averages or external interference from other particles or substrates [2], and is applicable to solid and liquid particles in the micrometer size range. Using multi-photon absorption from the trapping laser [3] we can charge the trapped particle at different rates and to different values, observing every charging and discharging event along the way. Additionally, the experiment allows us to control the relative humidity around the particle and to fully discharge the particle using air ions. By studying the charge-saturation behavior of the particle and the spontaneous discharges it is undergoing, we hope to contribute to a better understanding of the microphysical processes involved in lightning initiation and adjacent electrical phenomena in the atmosphere.

This project has received funding from the European Research Council (ERC) under the European Union's Starting Grant (A. Stoellner, I.C.D. Lenton & S.R. Waitukaitis received funding from ERC No. 949120, C. Muller received funding from ERC No. 805041).

[1] L. Zhang, Z. Gu, C. Yu, Y. Zhang and Y. Cheng, Indoor and Built Environ. 25, 437 (2016).
[2] F. Ricci, M. T. Cuairan, G. P. Conangla, A. W. Schell and R. Quidant, Nano Lett. 19, 6711 (2019).
[3] A. Ashkin and J. M. Dziedzic, Phys. Rev. Lett. 36, 267 (1976).

Triboelectric charge contributions in Faraday cup measurements

16:30-16:45

Tom F. O'Hara[1], David P. Reid[1], Gregory L. Marsden[1] and Karen L. Aplin[1]
[1]University of Bristol, Bristol, United Kingdom

The triboelectric charging of granular material is a long-standing and poorly understood phenomenon, with numerous scientific and industrial applications ranging from volcanic lightning to pharmaceutical production. The Faraday cup is the most widely utilised apparatus for the study of such charging; however, existing analyses of its measurements are often simplistic and fail to distinguish charging due to particle-particle interactions from charging occurring through other mechanisms. Here, we outline a modular approach for interpreting these measurements, enabling triboelectric phenomena to be explored in greater detail. Our approach fits approximated charge distribution shapes to experimental Faraday cup traces. The fitting process combines measured size distributions with simplified models of charge distribution and particle dynamics to predict the relative contributions of different charging mechanisms. This modular approach provides scope for adaptation of each component, allowing fine-tuning for specific applications and making the technique broadly generalisable to any insulating granular material. As a case study, volcanic ash samples from the Grímsvötn and Atitlán volcanoes were examined. Grímsvötn ash was found to charge with a greater proportion of particle-particle interactions than Atitlán ash. Experimental validation using sieved volcanic ash fractions showed that broader size distributions exhibited greater particle-particle charging. Non-particle-particle charging scaled with particle size as $\propto d_p^{-0.85\pm0.03}$, approximately correlating with the particles' effective surface area.

The authors acknowledge funding from the Engineering and Physical Sciences Research Council through the Centre for Doctoral Training in Aerosol Science (no. EP/S023593/1) and UK Space Agency Aurora program (no. ST/W002485/1).

How surface and substrate chemistry affect slide electrification

16:45-17:00

B. Leibauer[1], O. Pop-Georgievski[2], **M. Sosa[1]**, Y. Don[1], W. Tremel[1,3], H.-J. Butt[1] and W. Steffen[1]
[1]Max Planck Institute for Polymer Research, Mainz, Germany
[2]Institute of Macromolecular Chemistry, Prague, Czech Republic
[3]Johannes-Gutenberg University, Mainz, Germany

When water droplets move over a hydrophobic surface, they and the surface become oppositely charged by what is known as slide electrification. This effect can be used to generate electricity, but the physical and especially the chemical processes that cause droplet charging are still poorly understood. The most likely process is that at the base of the droplet, an electric double layer forms, and the interfacial charge remains on the surface behind the three-phase contact line. Here, we investigate the influence of the chemistry of surface (coating) and bulk (substrate) on the slide electrification. We measured the charge of a series of droplets sliding over hydrophobically coated (1–5 nm thickness) glass substrates. Within a series, the charge of the droplet decreases with the increasing droplet number and reaches a constant value after about 50 droplets (saturated state). We show that the charge of the first droplet depends on both coating and substrate chemistry. For a fully fluorinated or fully hydrogenated monolayer on glass, the influence of the substrate on the charge of the first droplet is negligible. In the saturated state, the chemistry of the substrate dominates. Charge separation can be considered as an acid base reaction between the ions of water and the surface. By exploiting the acidity (Pearson hardness) of elements such as aluminum, magnesium, or sodium, a positive saturated charge can be obtained by the counter charge remaining on the surface. With this knowledge, the droplet charge can be manipulated by the chemistry of the substrate.

Granular flows in reduced gravity: to flow or not to flow

17:00-17:15

Olfa D'Angelo[1,2], Oliver Gries[3] and Jonathan Kollmer[3]
[1]Institut Supérieur de l'Aéronautique et de l'Espace, Université de Toulouse, Toulouse, France
[2]Institute for Multiscale Simulation, Universität Erlangen-Nürnberg, Erlangen, Germany
[3]Universität Duisburg-Essen, Physics Department, Duisburg, Germany

Granular flow models tend to fail in low gravity. Beyond a critical acceleration, cohesion forces dominate—including electrostatic forces—leading to a shift in flow properties. Yet, these models are still used for preparing space exploration missions, for lack of better ones. We investigate the influence of partial gravity on the flow behavior of granular materials through an orifice. We use an hourglass with different aperture sizes and compare multiple regolith simulants, all measured under vacuum, enhancing tribocharging. We find that lunar gravity consistently increases the clogging

probability and slows down the flow rate, which deviates from the scaling predicted by the Beverloo equation. Both are associated with the appearance of clusters, linked to tribocharging. We propose a clogging state diagram and a correction to the Beverloo equation, both based on the granular Bond number, ultimately aiming to predict how granular flow properties will change in low gravity.

Charged granules in granular flows

17:15-17:30

Yanlin Zhao[1], Haoyu Liu[1] and **Jun Yao[1]**

[1]China University of Petroleum, Beijing, China

In past decades, the electrostatics of granules and granular flows has obtained more and more attention due to many industrial problems and the associated development of new technologies. Granule-wall collision causes electrification, where charge transfer can be characterized by work function, electron transfer, ion transfer, and material transfer. Electrification is affected by many factors and increases with granule processing, and the charge amount can reach a saturated state where electrification no longer increases, which has been confirmed by single granule and granule conveying systems. In addition, the presence of electrostatic charges has profound influences in relevant areas, including chemistry, chemical engineering, energy, pharmaceuticals, and so on. The measurement technology of electrostatics used in granule conveying systems has been improved with the continuous progress of industry. Furthermore, electrostatics of granules and granular flows will be developed into a more accurate area together with other subjects as an interdisciplinary problem to be concerned. In addition, in the pneumatic conveying system, granule-wall and granule-granule collision or friction can cause material transfer due to material breakage. The working mechanism of the material transfer due to collision or friction has never been fully understood. Such problems will be solved gradually in the future.

Posters

Wednesday March 26, 17:30-19:30

Plasma-liquid interface dynamics and its application in hydrogen production from methanol (#1)

Wei Zhang[1,3], Junfeng Wang[1,2] and Mingdong Dong[3,4]
[1]School of Energy and Power Engineering, Jiangsu University, Zhenjiang, China
[2]School of Energy and Power Engineering, Chongqing University, Chongqing, China
[3]Interdisciplinary Nanoscience Center, Aarhus University, Aarhus, Denmark
[4]Institute for Biomedical Engineering, Department of Information Technology and Electrical Engineering, ETH Zurich, Zurich, Switzerland

Coupling charged particles and fluid interfaces under electric fields has been widely studied for applications in materials science, biology, and industry, including electrospinning and electrospray. While fluid interface deformation and fragmentation are traditionally explained by the Rayleigh limit theory, we present experimental evidence of a cross-scale transition from microscopic to macroscopic bubbles in a charged liquid-gas system under strong electric fields. This phenomenon, diverging from Rayleigh's predictions, arises from the interplay of ionized matter and natural particles. The formation of plasma bubbles and unique interfacial phenomena at the gas-liquid interface involving weakly ionized gases have profound implications for hydrodynamics, interfacial stability, and mass transfer. Notably, the enhanced mass transfer properties of plasma bubbles show promise for hydrogen production from liquid fuels such as methanol, offering a new perspective on energy conversion technologies and advancing the understanding of interface physics in plasma-liquid systems.

Hidden in plain sight: bulk conductivity's sneaky role in masking surface charge from KPFM (#2)

Felix Pertl[1], Isaac Lenton[1], Lubuna Shafeek[1], Tobias Cramer[2] and Scott Waitukaitis[1]
[1]Institute of Science and Technology Austria, Klosterneuburg, Austria
[2]University of Bologna, Bologna, Italy

Kelvin Probe Force Microscopy (KPFM) is a powerful tool for studying contact electrification (CE), using electrical signals from a nanoscale AFM tip to spatially map a voltage above a surface that is caused by the presence of charge [1]. Among the most influential results obtained with KPFM are observations of surface charge heterogeneity, i.e. mosaic-like patterns of +/- polarity after CE [2]. Such experiments are often done with PDMS, due to its ability to create conformal contacts. In trying to reproduce such results, we instead observe signatures of spatially uniform surface potential that displays prominent temporal decay over a few minutes. We propose that this is due to the material's bulk conductivity, which lowers the KPFM potential via the movement of non-CE charge carriers in the electric field gradient between the surface and back electrode. With a simple capacitor model, where the only adjustable parameter is the bulk conductivity, we obtain a value that is consistent with electrical resistivity measurements of PDMS. As further support, we observe the same temporal decay on several polymers, mica and SiO_2 surfaces, but with time constants that scale in agreement with their significantly lower conductivities. Going further, we consider more sophisticated models beyond the simple capacitor to account for non-linearities in the conductive response, such as using dielectric response functions [3]. Our results call into question the presence/stability of surface charge patterns on certain materials, and highlight the role of bulk conductivity during and after CE.

[1] M. Nonnenmacher, M.P. O'Boyle and H.K. Wickramasinghe, Appl. Phys. Lett. **58**, 2921-2923 (1991).
[2] H.T. Baytekin, A.Z. Patashinski, M. Branicki, B. Baytekin, S. Soh and B.A. Grzybowski, Science **333**, 308-312 (2011).
[3] P. Molinié, J. Electrostat. **129**, 103930 (2024).

Preparation, properties, and molecular dynamics investigation of a novel melting point-modified composite phase change material for heat pump energy storage (#3)

Biao Li[1] and Yueshe Wang[1]
[1]Xi'an Jiaotong University, State Key Laboratory of Multiphase Flow in Power Engineering, Xi'an, Shaanxi, China

The thermal properties of the heat storage medium in the air source heat pump (ASHP) systems must be aligned with the system's heat generation temperature while satisfying the heat demand. In this study, a novel composite phase change material (CPCM) for efficient heat storage in ASHP systems was developed. Our investigation revealed that the incorporation of 8wt% KNO3, 1.5wt% thickener, and 1.0wt% Al2O3 nanoparticles into sodium acetate trihydrate resulted in the manifestation of desirable properties suitable for ASHP systems. The compound exhibited a suitable melting point of 48.66 °C, high latent heat of 235.97 kJ/kg, low supercooling degree of 2.25 °C, and good thermal conductivity of 0.905 W/(m·K). Furthermore, the novel CPCM demonstrated exceptional thermal stability, with only an 8.64% loss of latent heat after undergoing 200 cycles, while maintaining a supercooling degree within a range of 6 °C for each cycle. Moreover, molecular dynamics simulation results further indicated that the presence of KNO3 weakened the interaction between CH3COONa molecules and water molecules, leading to a reduction of the melting point. These findings have significant implications for the selection and composition design of thermal storage materials in ASHP systems.

Triboelectric sorting of plastic waste: the role of counter-materials used in the tribocharging unit (#4)

Marek Drápela[1], Mikuláš Vaszi[1], Jana Sklenářová[1], **Jiří Perner[1]** and Juraj Kosek[1]
[1]University of Chemistry and Technology Prague, Praha, Czechia

Triboelectric sorting of plastic waste has many advantages, such as low cost and no use of chemicals. It uses charging by contact with other objects: different materials obtain a different charge by frictional contact with a suitable counter-material. Charged particles are then separated in an electrostatic separator. Our work focuses on improving triboelectric separation by experimentally finding suitable counter-materials to effectively separate multi-component plastic mixtures by separating one material per cycle and then recharging the remaining mixture with different counter-materials during the next cycle. We studied the charging of waste/counter-material pairs with a wide range of materials, and we showed that the choice of the counter-material and charging method can control the magnitude and polarity. These results can be used to guide the selection of suitable counter-materials for the efficient separation of different plastic mixtures, as we have demonstrated with various case studies. Finally, we are investigating the effect of additives – many additives are used in the polymer industry to improve products, but these substances can cause problems during recycling. Thus, sorting plastic waste not only by bulk material but also by additive content can be valuable.

Adhesion-driven research of triboelectric charge: exploring magnitude and polarity in PDMS-based nanogenerators (#5)

Līva Ģērmane[1], Andris Šutka[1] and Linards Lapčinskis[1]
[1]Riga Technical University, Riga, Latvia

The triboelectric effect, a fundamental principle behind triboelectric nanogenerators (TENGs), offers a sustainable approach to energy harvesting. In this study, we explore the interplay between adhesion and triboelectric charge properties—magnitude and polarity—using polydimethylsiloxane (PDMS). By systematically altering adhesion conditions and evaluating their influence on charge transfer dynamics, we uncover critical insights into how interfacial interactions govern energy output in TENGs. Our findings demonstrate that adhesive forces significantly influence the magnitude of triboelectric charge. These effects are attributed to variations in molecular interactions and surface dynamics at the interface. By tailoring adhesion properties, we present a strategy to enhance triboelectric performance, paving the way for application-specific advancements in energy harvesting, wearable devices, and self-powered systems.

Collisions of charged clusters in microgravity (#6)

Kai Stuers[1], Florence Chioma Onyeagusi[1], Gerhard Wurm[1] and Jens Teiser[1]
[1]University Duisburg-Essen, Duisburg, Germany

Many processes in planet formation are not yet understood. Whereas μm-sized dust particles grow to mm-sized aggregates by collisions, further growth beyond mm-size is halted by too small bounding energies [1]. Previous experiments underline the importance of charge to overcome this barrier [2]. Still, there are open questions regarding the stability and limits of this growth. In recent microgravity experiments at the ZARM drop tower, we brought tribocharged clusters into collision. The principle of our experimental setup and first insights are presented.

[1] G. Wurm and J. Teiser, Nat. Rev. Phys. **3**, 405-421 (2021).
[2] T. Steinpilz et al., Nat. Phys. **16**, 225-229 (2020).

Hydrodynamic dimensions of charged proteins at different ionic strengths (#7)

Radost Waszkiewicz[1], Barbara P. Klepka[1], Agnieszka Michaś[1], Michał Wojciechowski[1], and Anna Niedzwiecka[1]
[1]Institute of Physics, Polish Academy of Sciences, Warsaw, Poland

Intrinsically disordered proteins (IDPs) are elastic biopolymers characterized by a high level of conformational dynamics. The conformational ensembles of two classes of such biopolymers that carry significant charge density, namely polyelectrolytes and polyampholytes, are sensitive to environmental conditions. Variations in the ionic composition of the buffer solution can profoundly influence their conformational properties, posing challenges for accurate theoretical modeling, even under typical buffer conditions.

First, we present a coarse-grained computational framework for predicting the putative conformations of IDPs that incorporates interactions between charged amino acid residues within the protein chain and with both monovalent and divalent counterions responsible for the electrostatic screening of these interactions. This framework employs a direct conformational sampling method, eliminating the need for extensive all-atom or coarse-grained molecular

dynamics simulations. This method allows the study of the hydrodynamic properties of IDP molecules, which are several thousand residues long, which was impossible previously.

Second, we introduce a post-processing technique for the generated conformations to calculate diffusion coefficients without requiring any molecular dynamics simulations in a matter of minutes [1]. This approach facilitates comparison with experimental measurements of the hydrodynamic sizes of a wide range of IDPs.

Finally, we compare our predictions with new experimental data obtained by fluorescence correlation spectroscopy (FCS) and size exclusion chromatography (SEC), explicitly examining the dependence of the hydrodynamic radius of a highly charged IDP, AGARP, on the ionic strength of the buffer and the type of counterion.

[1] R. Waszkiewicz, A. Michas, M. K. Białobrzewski, B. P. Klepka, M. K. Cieplak-Rotowska, Z. Staszałek, B. Cichocki, M. Lisicki, P. Szymczak, and A. Niedzwiecka. J. Phys. Chem. Lett. **15**, 5024-5033 (2024).

Controlling interfacial ionic dynamics through mode coupling with the solid wall (#8)

Baptiste Coquinot[1], Damien Toquer[2], Nikita Kavokine[3] and Lydéric Bocquet[2]
[1]Institute of Science and Technology, Klosterneuburg, Austria
[2]École Normale Supérieure, PSL University, Paris, France
[3]École Polytechnique Fédérale de Lausanne, Lausanne, Switzerland

At the solid-liquid interface, interactions between fluctuating excitation modes in the solid and in the liquid are expected to be a consequent—when not dominant—part of friction. This contribution, referred to as Van der Waals friction, can be understood in terms of couplings between the modes of the solid (electrons, phonons, ...) and of the liquid. In this contribution, we extend this effect to surface charges and show that ions also present microscopic modes which couple effectively with the solid at the interface. For this purpose, we use both analytical perturbation theory and force-field molecular dynamics simulations. We investigate the structure factors, informing us about the modes originating from the ions. Then, we both deduce and measure the resulting friction coefficient. Numerically, it is computed with semi-classical non-equilibrium simulations where Drude oscillators mimic the excitation modes of the solid. Most strikingly, the frequency at which the friction is maximum depends on the ionic properties: diffusion coefficient, radius, *etc.* This leads to ion-specific friction and paves the way to spectral separation.

Effect of surfactants on the motion of an elongated bubble in an electric field (#9)

Changwoo Bae[1], Menghua Zhao[1], Christophe Ybert[1] and Anne-Laure Biance[1]
[1]Universite Claude Bernard Lyon 1, CNRS, Institut Lumière Matière, Villeurbanne, France

Interactions between charged matter and liquids are typically considered surface phenomena. Here, we focus on the specific case of a “charged bubble” in an ionic surfactant solution. The motion of elongated bubbles in narrow tubes, commonly referred to as Taylor bubbles, is traditionally driven by pressure gradients originated from buoyancy or external forces. In this study, we explore an alternative mechanism: electrically driven bubble motion. An electric field induces bubble migration, or bubble electrophoresis, through ionic surfactant adsorption on the bubble surface. Our experiments reveal unexpected behaviors: changes in surfactant concentration influence not only the speed of bubble motion but also its direction. These observations are explained using a model that accounts for electrostatic interactions at both the liquid/bubble and liquid/tube interfaces. These findings advance the understanding of bubble dynamics and suggest promising applications in designing soft, reconfigurable nanofluidic channels.

This project was funded by the ANR project Soft Nanoflu (ANR-20-CE09-0025-03).

Influence of the initial conditions on liquid/solid contact electrification (#10)

Hadrien Monluc[1], Delong He[1] and **Jinbo Bai[1]**
[1]Université Paris-Saclay, CentraleSupélec, ENS Paris-Saclay, CNRS, LMPS-Laboratoire de Mécanique Paris-Saclay, Gif-sur-Yvette, France

From energy harvesting to contact-electrocatalysis, liquid/solid contact electrification has garnered growing interest from research communities. Despite its widespread applications, few comprehensive explanations of the phenomenon have been proposed. Most studies focus on microscopic mechanisms, leaving macroscopic analysis and quantitative tools for predicting its effects largely unexplored.

The aim of this work is to enhance the macroscopic understanding of liquid/solid contact electrification. To achieve this, we investigated the influence of initial conditions on the electrical performance of droplet-based double-electrode triboelectric nanogenerators. Key trends were identified, including the effects of the initial film charge, the droplet's initial energy, and the droplet's initial charge. Additionally, the experiment revealed water's dual role: depending on the material, it can either generate or neutralize charges on the generator surface. These findings inspired the development of an experiment-based macroscopic model to predict contact electrification.

This work offers a pathway to optimize water-droplet-based triboelectric nanogenerators, enabling effective energy harvesting from water streams or rainfall. Furthermore, it paves the way for the development of inexpensive charge neutralization methods.

Discharge of tribocharged grains (#11)

Tim Becker[1], **Gretha Völke[1]**, Tobias Steinpilz[1], Florence Chioma Onyeagusi[1], Jens Teiser[1] and Gerhard Wurm[1]
[1]Universität Duisburg-Essen, Fakultät für Physik, Duisburg, Germany

The persistence of tribocharging depends on discharge timescales. The discharge is influenced by external ions or internal conductivity, with water on the surfaces playing a central role. Experiments show that the resistance of dust particles increases with decreasing pressure, which allows charge to persist for weeks to years under the conditions in a protoplanetary disk.

A model for size dependent tribocharging (#12)

Gerhard Wurm[1], Chioma Onyeagusi[1] and Jens Teiser[1]
[1]Universität Duisburg-Essen, Fakultät für Physik, Duisburg, Germany

Size dependent polarity in granular systems is widespread. In collisions between particles of similar material but with different size, the small particles usually charge with one polarity, the large ones with the other. We present a generic mechanism that might explain this generic findings.

Size dependent polarity of dust aggregates (#13)

Christopher Grünebeck[1], Florence Chioma Onyeagusi[1], Jens Teiser[1] and Gerhard Wurm[1]
[1]University of Duisburg-Essen/Faculty of Physics, Duisburg, Germany

We study tribocharging of (sub-)mm dust aggregates under microgravity. The constituent dust grains add complexity to the process in various ways. This includes the additional dust size scale, shifting grains during collisions, and material-dependent tribocharging with a non-homogeneous dust composition. Despite the complexity, the small aggregates charge predominantly negatively and the large population predominantly positively.

This project is supported by DLR Space Administration with funds provided by the Federal Ministry for Economic Affairs and Climate Action (BMWK) under grant number 50 WM 2142, 50 WM 2442, and 50 WK 2270C.

A ferroelectric phase transition underlying the liquid-liquid phase transition in supercooled water (#14)

Maria Grazia Izzo[1], John Russo[1] and Giorgio Pastore[1]
[1]Ca' Foscari University of Venice, Department of Molecular Sciences and Nanosystems, Venice, Italy

A liquid-liquid phase transition (LLPT) between high-density and low-density liquids in supercooled water has emerged as a compelling hypothesis to explain its equilibrium anomalies. Although the possibility of a ferroelectric phase transition in supercooled water was proposed by Stillinger in 1977, no link has been conceived between liquid-liquid and ferroelectric phase transitions in the numerous studies of LLPT in water, and the role of the dipolar degrees of freedom has been overlooked. By analyzing extensive state-of-the-art molecular dynamics simulations and developing a mean-field classical density functional theory for polar liquids, we demonstrate not only a link between ferroelectricity and LLPT but also the role of ferroelectricity in promoting the LLPT [1]. The two foundational elements of the theory are: the liquid's molecules positional disorder and the functional form of dipolar potential interaction. While both factors support the emergence of ferroelectricity, the latter introduces a density-polarization coupling term in the free energy, enabling the description of ferroelectricity and LLPT as interconnected facets of the same phenomenon. Similarities with ferroelasticity or flexoelectricity can be considered. Extensions to other states of water, related phenomena, or analogous systems can be envisioned.

[1] M. G. Izzo, J. Russo and G. Pastore, Proc. Nat. Acad. Sci. **121**, e2412456121 (2024)

Stacking the deck towards ion transfer in tribocharging (#15)

John Hoffman[1], Juan Carlos Sobarzo[1], Stefan Freunberger[1] and Scott Waitukaitis[1]
[1]Institute of Science and Technology Austria, Klosterneuburg, Austria

The driving force for charge transfer during contact electrification has been debated as a product of either electron transfer, ion transfer, or material transfer. While it has been demonstrated that electron transfer occurs between conducting metals through differences in work functions, the driving force for similar charge transfer in polymeric materials remains uncertain. In order to better elucidate the roles each type of transfer may play in contact electrification, this work specifically evaluates the role of ion transfer through controlled functionalization of ionomer brushes onto the surface of silicon wafers, which then exchange charge during contact with polydimethylsiloxane (PDMS) samples. Through the introduction of covalently attached bound charges, a series of

mobile ions were introduced to the sample to evaluate how the impact on charge transfer. Initial work has focused on the introduced a carboxylic acid moiety, which is a weak acid and can associate with multiple mobile ions, such as Na+, K+, and Li+. The charge transfer of these groups exhibits the trend of charging positively through the transfer of mobile cations, with differences in the value of transfer charge being attributed to how the ions interact with the bound functional group and the subsequent mobility of the ion.

Chasing the lower limit of volcanic lightning (#16)

Carina Poetsch[1], Corrado Cimarelli[1], Markus Schmid[1] and Jeffrey Johnson[2]
[1]Ludwig-Maximilians-Universität München/Department of Earth and Environmental Sciences, Munich, Germany
[2]Boise State University/Department of Geosciences, Boise, Idaho, United States

Explosive volcanic eruptions disperse large amounts of ash, posing a significant risk to humans and infrastructure, yet frequently exhibit visible lightning produced due to electrification of the emitted ash. The resulting detectable variations in the atmospheric field reveal apparent correlations with eruption magnitude and style [1]. While a precise relationship or lower limit for volcanic plume electrification remains unresolved, establishing such would significantly advance volcano monitoring by enabling immediate detection and assessment of the dimensions of ash emission from active volcanoes.

This work has been funded by the ERC Consolidator Grant “VOLTA” under contract Nº 864052.

[1] C. Cimarelli, S. Behnke, K. Genareau, J. Méndez-Harper and A.R. Van Eaton, Bull. Volcanol. **84**, 78 (2022).

High stability charged clusters in planet formation (#17)

Jonas Schwaak[1], Florian Führer[1], Dietrich Wolf[1], Lindsey Posorski[1], Lothar Brendel[1], Jens Teiser[1] and Gerhard Wurm[1]
[1]University Duisburg-Essen, Duisburg, Germany

During the planet formation process in protoplanetary disks, the bouncing barrier impedes the initial particle growth at the submillimeter-scale. Bouncing leads to tribocharging, causing an electrostatic attraction. This additional attraction allows larger clusters to be formed, which are more susceptible to further concentration mechanisms, such as the streaming instability.

We aimed to measure the strength of these electrostatic bonds.

Using an acoustic trap to levitate clusters of submillimeter-sized glass particles, we find that grains are regularly strongly bound to their neighbors and that the forces at ejection can exceed the trap's attractive force, surpassing the expectation by several orders of magnitude.

Considering that electrostatic forces are long-range forces compared to van der Waals forces, we conclude that charged aggregates are more stable, enabling growth into centimeter-sized clusters and advancing planetesimal formation across a broad region of the protoplanetary disk.

Electrical charge in slow impacts on asteroid surfaces (#18)

Matthias Keulen[1], Gerhard Wurm[1] and Jonathan Kollmer[1]
[1]University Duisburg-Essen, Duisburg, Germany

We investigated the transfer of electric charge between an accelerated particle and a granular surface. For this, steel spheres of a diameter of 4,5 mm hit a mass of 0,5-1mm basalt particles with varying velocities. The released basalt particles, or the ejecta, was collected and in parts fell into a Faraday cup. In the Faraday cup, the charge of the ejecta was measured. Following that, the ejecta from the cup and the whole of it was weighed. Charges of ejecta produced by faster impacts (369±46 cm/s) were more frequently negative than for slower impacts (215±33 cm/s) for this stochastic process of tribocharging. Due to the impactor being part of some, not all, charge measurements, it was possible to determine a typical impactor charge of $(73\pm5)\times10^{-12}$ Coulomb. While the typical ejecta charge was determined at $(-58\pm4)\times10^{-12}$ Coulomb. Both of those charges were transferred by a single impact. The separation of big, positive impactors and small, negative ejecta particles matches with pre-existing research regarding charging in granular matter.

Charged clouds of ionized gas emerge from tribocharging grains (#19)

Patrick Hock[1], Jens Teiser[1] and Gerhard Wurm[1]
[1]University of Duisburg-Essen, Duisburg, Germany

At the bouncing barrier in protoplanetary disks, particles carry charges after a collision. However, this charge transfer is not restricted to the grains. Also the gas phase becomes ionized. This ionization mechanism might influence the physics and chemistry in protoplanetary disks. We carried out laboratory experiments to quantify this ionization, which we find to be significant. It might be the dominant ionization source in the midplane.

Micro-particle behavior in micro-meter sized high-voltage gaps (#20)

Niels Smith[1], Sander Nijdam[1], Stein van Eden[1] and Jeroen Raaymakers[1]
[1]Eindhoven University of Technology, Eindhoven, The Netherlands

In high-voltage applications, small particles and dust can cause materials to suddenly lose their insulating properties, in extreme cases leading to a particle-induced breakdown. To date, research has primarily concentrated on larger particles (1 mm and above), with minimal to no focus on particles sized 10 µm and smaller. Additionally, the behavior of these micro-meter sized particles in high-voltage environments has never been observed in real-time.

Goal of this research: recording the dynamics and behavior of 10 µm particles exposed to high voltages within a micrometer-sized electrode gap.

This project is funded by Holland High Tech I TKI HTSM via the PPP Innovation Scheme (PPP-I) for public-private partnerships.

Impact of particle morphology on triboelectric charging of polyolefin powders (#21)

Jana Sklenářová[1], Jarmila Pelcová[1], Marek Drápela[1] and Juraj Kosek[1]
[1]University of Chemistry and Technology Prague, Prague, Czechia

The production of polyolefins in gas-phase fluidized bed reactors often results in significant electrostatic charging due to frequent particle collisions, leading to operational challenges and economic losses. Understanding and mitigating the factors contributing to this charging is complex, particularly due to the interplay between catalyst type and reactor operating conditions, which influence the morphology of the product. In this study, we propose a method to standardize the interpretation of experimental measurements of triboelectric charging in rough polyolefin powders, aiming to isolate the effects of morphology. Traditional experimental methods use a Faraday cup to estimate the charge-to-mass ratio of powder samples. To validate models that account for real contact areas and surface roughness, it is essential to convert these measurements to charge-to-surface area ratios. Polyolefin particles typically exhibit non-spherical shapes, roughness, and porosity, complicating the recalculation of experimental data. We present experimental data on the morphology of various polyolefin samples and introduce a set of corrections to improve the accuracy of charging experiments, moving beyond the sphere approximation. Contact charging strongly depends on the contact area; thus, we believe that the proposed method and recalculated results can be directly used in models accounting for the effect of morphology.

Impact of collision velocity on electrostatic charging of rough polyolefin particles (#22)

Marek Drápela[1], Jana Sklenářová[1], Jarmila Pelcová[1] and Juraj Kosek[1]
[1]University of Chemistry and Technology Prague, Prague, Czechia

When two objects, such as a particle and a plate, come into contact, friction between their surfaces generates a surface charge—a phenomenon known as triboelectric charging. This effect can be problematic in industrial processes, particularly in the manufacturing of granular materials like polymers or pharmaceuticals, causing issues such as temperature control problems or product inhomogeneity due to agglomeration. This study investigates the impact of surface morphology on the charging behavior of polyolefin samples. The samples were placed in stainless steel cells and subjected to collisions through vibration. The evolution of charge over time was measured to determine the saturation charge and charging rate constant. Results indicate that charge transfer correlates with the actual contact area, which is influenced by surface roughness and collision velocity. Higher collision velocities increase the contact area, leading to higher saturation charges. However, larger particles with lower surface roughness show a different trend at higher velocities compared to smaller particles. The study demonstrates that rougher surfaces result in smaller contact areas and lower saturation charges. These findings confirm the significant role of surface morphology in the charging process and offer valuable data for models addressing rough particle charging.

Synergistic heat transfer enhancement due to macro-structured surface and electric field during spray cooling (#23)

Bin Chen[1], Jiameng Tian[2] and Junfeng Wang[2]
[1]Xi'an Jiaotong University, Xi'an, China
[2]Jiangsu University, Zhenjiang, China

The synergistic enhancement of film heat transfer upon the spray impingement via electric fields and macro-structural surfaces presents a promising approach to address the high-heat-flux thermal dissipation challenges of electronic devices [1-3]. In this presentation, four macro-structured surfaces machined with cubic pin fins, conical pin fins, wavy fins, and straight fins are compared to one flat surface under an electric field to shed lights on the combined heat transfer enhancement mechanism during ethanol spray cooling. A CHF of 7.93 W/cm^2 is achieved by the cubic-pin-fin surface with an applied voltage of 4.5 kV at T_s = 145^o C, corresponding to a 63% enhancement over the flat surface. When applying an electric field, the bubble departure frequency increases by up to 80%, while the bubble departure diameter decreases by 28%. Analysis of the CHF enhancement ratio indicates that liquid film thickness has the greatest impact on CHF improvement (0.37), followed by rib spacing (0.24) and electric field voltage (0.20).

This work has been funded by the National Natural Science Foundation of China, grant number 52036007.

[1] J.D. Benther, J.D. Pelaez-Restrepo, C. Stanley and G. Rosengarten, Int. J. Heat Mass Transfer **178**, 121587 (2021).
[2] J. Tian, C. He, Y. Chen, Z. Wang, Z. Zuo, J. Wang, B. Chen and J. Xiong, Int. J. Heat Mass Transfer **220**, 125015 (2024).
[3] A. Inbaoli, C.S. Sujith Kumar and S. Jayaraj, Appl. Therm. Eng. **214**, 118805 (2022).

Charge-induced gel surface dynamics prior to adhesive contact initiation (#24)

Meredith M. Taghon[1], Jiwoo Han[1] and Katharine E. Jensen[1]
[1]Williams College, Williamstown, USA

Adhesive contact initiation with compliant interfaces is an important process in many applications, especially those that involve object gripping and manipulation. The mechanics of contact initiation in very soft materials, such as gels, rely on a complex physical interplay between viscous, elastic, and capillary forces as well as the structure of the gel elastic network. The introduction of additional electrostatic forces presents an interesting pathway for controlling the gel surface before the interface formation process. In this work, we measure the dynamic interactions between a charged rigid glass microsphere and a compliant silicone gel prior to establishing adhesive contact. Our instrumental design draws inspiration from traditional JKR theory as well as interferometry techniques to visualize and quantify the pre-contact deformation profile of the gel surface. The high sensitivity of these measurements at both short length and time scales poises our work to elucidate the relationship between applied electrostatic force and gel surface motion. These findings hold implications for managing adhesive contact initiation and subsequent interfacial growth, both of which processes play a fundamental role in various modern technologies.

This work has been funded by the National Science Foundation under grant CMMI-2129463.

A versatile experimental setup to study the contact electrification of in situ prepared surfaces (#25)

Andre Mölleken[1], Hermann Nienhaus[1] and Rolf Möller[1]
[1]University of Duisburg-Essen/Faculty of Physics, 47057 Duisburg, Germany

Recent experiment reveal that the physical and chemical properties of the involved materials may have a crucial influence on the charge transferred in contact electrification. We have developed a new apparatus to study the charging of spheres of different materials and sizes dropped on the lower plate of a horizontal parallel plate capacitor. The charge transfer may be measured with high sensitivity and ultrahigh temporal resolution by monitoring the induced charges in both plates. The experiments are performed either in vacuum or well-defined gaseous atmospheres. The contact plate as well as the spheres can be treated in situ to prepare well defined surfaces. Moreover, the spheres can be discharged right before the free fall. Preliminary results for the combination of insulating spheres and metallic surfaces will be presented.

Granular matter assembly driven by electrostatics and acoustics (#26)

Sue Shi[1], Maximilian Huebl[1], Galien Grosjean[1], Carl Goodrich[1] and Scott Waitukaitis[1]
[1]Institute of Science and Technology Austria, Klosterneuburg, Austria

Electrostatic interactions provide a powerful mechanism for manipulating and assembling granular matter, offering opportunities to explore new configurations and dynamics. By integrating controlled electrostatic charging with acoustic levitation, we achieve dynamic self—assembly of complex, many—bodied granular structures free from the constraints of gravity or container walls. In the presence of an acoustic field alone, particles aggregate into densely packed or "collapsed" formations due to attractive forces arising from acoustic scattering. However, introducing long—range electrostatic repulsion enables some particles to overcome these attractions, resulting in "expanded" and "mixed" structures. For small particle numbers, electrostatic forces can dominate entirely, leading to fully expanded structures that closely match simulated electrostatic ground states. For larger ensembles, the interplay of acoustic and electrostatic forces typically yields mixed structures with a dense core surrounded by "satellite" particles—a configuration unattainable with either interaction alone. We observe and investigate the synchronized oscillations and coupled motions between the dense core and the satellite particles. Additionally, we can neutralize the electrostatic charges of the expanded and mixed structures with soft X-rays, which trigger their collapse and induce rotation. Our approach opens the door to precise control over the configurations and dynamics of complex granular assemblies.

Rolling at right angles: the dynamics of superparamagnetic active rollers (#27)

Eavan Fitzgerald[1], Cécile Clavaud[2], Debasish Das[3] and Scott Waitukaitis[1]
[1]Institute of Science and Technology Austria, Klosterneuburg, Austria
[2]Institute of Physics of Rennes, Rennes, France
[3]University of Strathclyde, Glasgow, Scotland

Quincke rotation is the spontaneous rotation of a dielectric particle in a conducting fluid subject to an external E-field once $E > E_c$, coupling with surface friction to drive rolling at constant speeds. Typical Quincke systems showcase individual random walks, with collective motion arising at sufficient densities. We introduce an additional degree of freedom using superparamagnetic colloids, and observe markedly different dynamics. With no B-field, roller trajectories consist of tight

circular orbits, increasingly interspersed with short "walks" at higher E-fields. Introducing a homogeneous in-plane B alongside E linearises their motion: the rollers' induced magnetic moment aligns with B, fixing the rotation axis to stabilise rolling perpendicular to the B-field lines, consistent with other work. However by increasing the applied B-field (>200 G), we see the emergence of an anomalous secondary mode, with rollers travelling parallel to the B-field axis. We have used a model of anisotropic magnetic susceptibility to successfully reproduce these quasi-stable trajectories in numerical simulations, showing the magnetic dipole moment tumbling in the plane orthogonal to motion. We have complemented these simulations with an analytical energetic model to better elucidate and strengthen our proposed stabilising mechanism.

Beyond rings and chains: exploring porous crystals and flexible networks with two patch magnetic particles (#28)

Carina Karner[1], Eric McPherson[2], Ilona Kretschmar[2] and Emanuela Bianchi[1]
[1]Technical University of Vienna, Institute for Theoretical Physics, Vienna, Austria
[2]City College of New York, Mechanical Engineering, New York, USA

We report on the self-assembly of magnetic colloids engineered with two distinct magnetic patches positioned at their poles, an advancement from traditional Janus particles with a single magnetic dipole. While Janus particles are known to form a variety of superstructures—including chains, rings, and close-packed arrangements [1,2]—the two-patch design significantly expands the range of achievable structures. Our simulation study reveals the formation of porous networks with adjustable flexibility, variable pore sizes, and controllable crystalline order. Notably, we observe the formation of a porous Kagome lattice, reminiscent of the experimental Kagome lattice observed colloids with two hydrophobic patches, the well-known "Janus-triblock" system [3]. This enhanced self-assembly behavior in two-patch magnetic particles opens up further possibilities for creating fully tunable, field-responsive ferrofluids. Such systems could useful for applications requiring externally modulated viscosity, such as adaptive damping systems in automotive and aerospace engineering.

[1] E. Yammine, E. Souaid, S. Youssef, M. Abboud, S. Mornet, M. Nakhl and E. Duguet, Part. & Part. Syst. Charact. **37**, 2000111 (2020).
[2] G.I. Vega-Bellido, R.A. DeLaCruz-Araujo, I. Kretzschmar and U.M. Córdova-Figueroa, Soft Matter **15**, 4078-4086 (2019).
[3] Q. Chen, S.C. Bae and S. Granick, Nature **469**, 381-384 (2011).

Self-assembly of nanoparticles charged with organic molecules (#29)

Sumit Roy[1] and Rafal Klajn[1]
[1]Institute of Science and Technology Austria, Klosterneuburg, Austria

The realization of static electricity, the creation of intricate DNA structures, and the simple crystallization of salts all depend on charged species, which inspired us to study a variety of natural phenomena in the context of chemistry and nanoscience [1]. In this regard, we have selected charged gold nanoparticles as our building blocks and studied their co-assembly with oppositely charged nanoparticles and oligoanions [2,3] In the first example, we have studied the effect of surface in the crystallization of oppositely charged gold nanoparticles. A controlled modulation of surface polarity through functionalization of surface with a series of polar and nonpolar molecules led to the formation in different crystal morphologies. Further, time dependent study revealed the nonclassical crystallization pathway which transformed a nearly amorphous aggregate into Winterbottom constructions and further transformed it into classic rhombic-dodecahedral crystals with the CsCl (bcc) structure [4]. This study will help us to better understand the complex interfacial crystallization. In the second instance, we studied the electrostatic co-assembly of positively charged gold nanoparticles with oligoanions bearing increasing number of negative charges. One significant finding from these investigations is the proof that the aggregation threshold changes from -2/-3 to -3/-4 when the bulkiness of the nanoparticle ligand increases, hence lowering its positive charge density [4]. This finding enables highly selective self-assembly of nanoparticles into transient aggregates in two-component nanoparticle systems which will be useful to develop temporal functions in the future.

[1] K. J. M. Bishop, C. E. Wilmer, S. Soh, and Bartosz A. Grzybowski Small **5**, 1600– 1630 (2009).
[2] T. Bian, A. Gardin, J. Gemen, L. Houben, C. Perego, B. Lee, N. Elad, Z. Chu, G. M. Pavan, and R. Klajn Nat. Chem. **13**, 940–949 (2021).
[3] T. Bian, I. Lobato, J. Wang, T. A. Nitka, T. S. Peled, B. Lee, S. V. Aert, S. Bals, L. Vuković, T. Altantzis, P. Král, and R. Klajn ChemRxiv. 2022; doi:10.26434/chemrxiv-2022-klncg
[4] In preparation