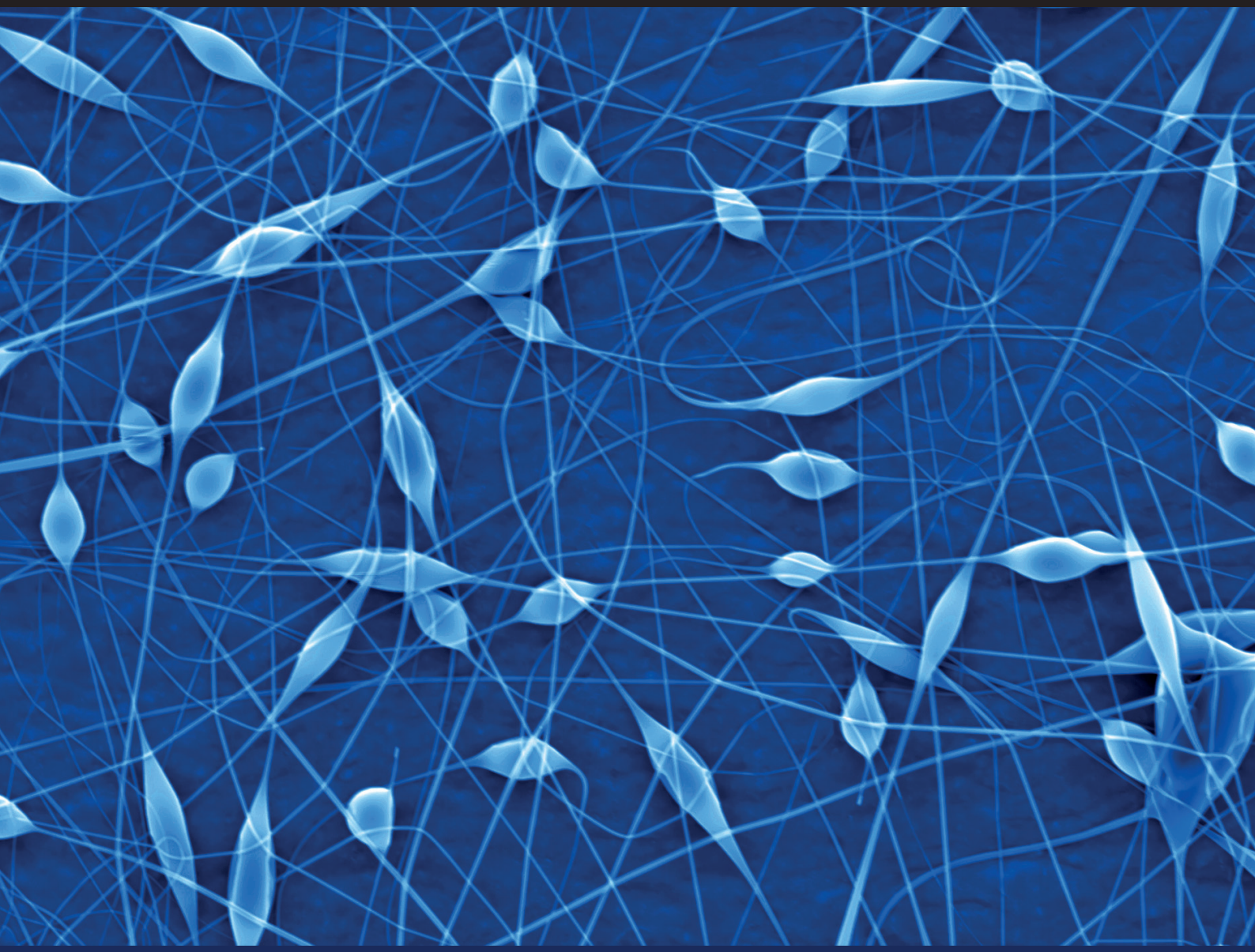
Abstract Booklet



Electrostatics 2019

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IOP Institute of Physics

Abstracts

Session 1: Electrostatics

(Invited talk) Bill Bright memorial lecture - Electrospinning: principles, practice and possibilities

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Polytechnic Institute of Leiria, Portugal

Electrospinning has had a long development from two centuries ago until now where it has received a new lease of life because of immense interest in manufacturing nanoscale materials and in the applications that follow directly (1).

Electrospinning is a method to produce fibres which may vary from nanometre scale to the micrometre scale. The technique uses an electric force to draw charged threads of polymer solutions or molten polymers melts. It can be seen in the same family of techniques such as electro-spraying and conventional solution dry spinning of fibres. More recently alternatives for nanoscale fibres have been developed using different forces as in force spinning and gas assisted spinning. Electrospinning is a deceptively simple technique and many laboratories around the world has produced instrumentation to produce such fibre at relatively low cost. Now there are considerable commercial interests in the instrumentation. The simplicity and the intense interest has produced tens of thousands of scientific papers and it is reasonable to ask the question what have we learnt.

There are some obvious direct applications of such fibres for filtration whether of viruses or water or air and in the production of synthetic skin and other related applications. Part of the success of electrospinning comes from the ease of electrospinning almost any polymer of sufficient molecular weight. There are many parameters to optimise but there is much practice to direct users. Electrospinning still lacks a solid microscopic model which can be used to predict the fibres which will be produced and their properties.

An exciting relatively recent development has been that of melt electrospinning which offers the advantage that much of the chaotic trajectories of the melt electrospun fibre trajectories are suppressed and it has become more akin to 3d printing than electrospinning. As such, it can be seen as part of the direct digital manufacturing family but at the nanometre scale which has provide difficult with other technologies.

Most recently we have been able to conduct electrospinning on a synchrotron beam line and we report on the information which has been gained. In this lecture we will review the opportunities which exist for both research and for technology especially in the field direct digital manufacturing and identify the applications which are most likely to move forward.

Acknowledgements

This work is supported by the Fundação para a Ciência e a Tecnologia (FCT) and Centro2020 through the Project : UID/Multi/04044/2019; PAMI - ROTEIRO/0328/2013 (Nº 022158) and MATIS (CENTRO-01-0145-FEDER-000014 - 3362). The x-ray scattering measurements were performed at the ALBA Synchrotron Light Source in Collaboration with ALBA Staff.

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The importance of the electro-dynamic field in the pilot production of homogeneous nanofibrous layers for potential use in wound healing and cosmetics

M Pokorny, M Fogl, J Klemes, K Knotkova, and V Velebny

Contipro a.s., Czech Republic

In the few last years in our company, the production of nanofibrous layers containing the main component of hyaluronic acid was scaled-up from the research phase. Based on our experience with the development of technology of the laboratory apparatus with the commercial name 4SPIN LAB, a larger pilot plant was developed. A new device was designed to produce nanofibrous layers on an application-acceptable substrate material of at least 50 cm wide. The uniformity of the nanofibrous layer in a weight tolerance of maximum ±10 % in the production of layers with an areal weight up to 20 g/m^2 was also requested. During the development of the equipment, it has been shown that the continuous roll-to-roll production in electro-static deposition does not achieve the required quality of the layers, therefore the deposition method has been extensively modified.

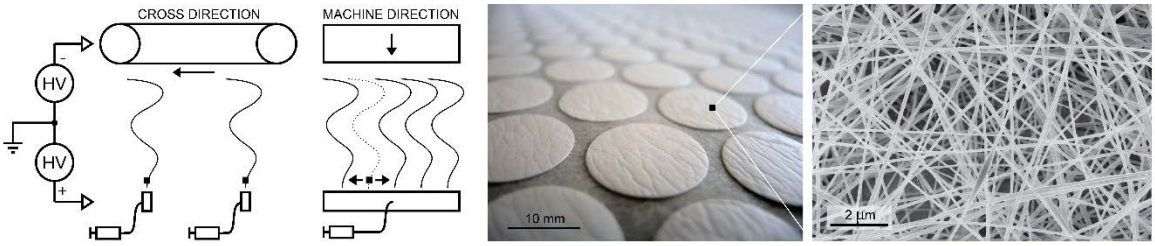

Fig. 1: Illustration of the spinning process in the electrically dynamic field. Processed layers and their morphology are shown.

The device uses two parallel needleless electrodes and a rotating collector in the form of an endless belt with a voltage difference of up to 120 kV (see Figure 1). To achieve the desired thickness homogeneity, two parameters were shown to be highly critical. The first of these parameters is the surface velocity of the substrate material, which was increased from the original 2 cm/min up to a hundred-fold. For this reason, the roll-to-roll system was replaced by an endless belt. Secondly, the movable mechanism near the nozzles destabilizing the position of the Taylor cones led to the overall elimination of the resulting patterns and stripes in the thickness of the layer. Thus, the modified deposition process can be characterized as highly electrodynamic, and not clearly electrostatic as is known from the standard electrospinning method arrangement.

The produced nanofibrous hyaluronic acid-based layers are prepared within 130 minutes with a surface area of (110 x 55) cm^2. The thickness of the nanofibrous layer weighing 18 g/m^2 is uniform in the above-mentioned tolerance to more than 95 % of the usable area. The validation of the manufacturing process was verified by two independent measuring methods, i.e. by weighing and analyzing the images produced by passing light. The layers prepared after further processing, e.g. cutting, then separation from the substrate material, packing, meet high-quality requirements and then can be distributed and used in applications in dermatology and cosmetics.

Session 2: Nature and Biology

Bumblebee hair motion in electric fields

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Bees have been observed to detect and learn the presence of weak electric fields in various behavioural experiments in the lab. The electro-sensitivity of bumblebees has also been suggested to be important for pollination. However, the structure and function of electro-sensory organs are yet to be described. Bees, like other arthropods, are known to have evolved various mechanoreceptors. Antennae and hairs have mechanosensory functions and have been shown to respond to weak electric fields. Current proposals posit that hairs and antennae can act as electromechanical sensors. To investigate this hypothesis, the mechanical response of bumblebee hairs stimulated by an electric field was measured using microscanning laser Doppler vibrometry. Hair vibration velocity is shown to be proportional to charge triboelectrically deposited on the bee and the effect of polarisation charge is seen to be negligible. Hair motion due to acoustic stimuli is also measured and compared to hair electromechanical response. Preliminary results show that the electro-sensitivity of charged bee hairs is comparable to hair sensitivity to acoustic stimuli.

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Measurements of electric charges on foraging bumblebees (bombus terrestris)

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Bumblebees carry electric charge. Almost always positive, this charge facilitates pollen transfer between bumblebee and flower during pollination and is likely to play a role in the detection of electric fields. Models of the Coulomb forces acting on pollen grains during pollination are predominantly based upon laboratory measurements of bumblebee charge. Using a novel method, the charges on bumblebees are measured outdoors for the first time. Outdoor bumblebees are found to carry similar positive charges to those previously measured in the laboratory. Bee charge is affected by local weather conditions, with the most positive charges being found on bees flying in warm, dry conditions. Results show that bee charges used in previous models of pollen transfer are representative of wild foraging bumblebees, and that pollen transfer between bee and flower is likely to be affected by local weather conditions.

Acknowledgements

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Session 3: Triboelectrification

Experimental study of the triboelectric charging of a glass bead impacting against a polymer plate

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Triboelectric charging of a glass bead impacting against different polymer targets is investigated under a carefully controlled environment. The charging properties of a particle during a single impact have been studied before in different articles. Despite these contributions, there remains incomprehension about the very mechanisms at the origin of charge transfer, and predictions regarding the tribocharging of a dielectric particle against another material are still rather unreliable. Glass, found with various different chemical compositions, is a good example of a material that defies the expectations of triboelectric series. The many local parameters, sometimes interdependent, that can influence the impact charge explain the variability usually observed in tribocharging results. Their complex interaction makes triboelectric charging a particularly delicate phenomenon to investigate experimentally.

We report in this article the development of a setup generating a single impact between a glass bead and a dielectric target with compressed air. The charge carried by the bead is measured both before and after impact in order to determine entirely the impact charge. Additionally, a measurement is performed on the target for verification purposes. Relevant parameters are thoroughly monitored and fixed, in order to untangle their respective contributions to triboelectric charging. The experiment takes place in a humidity controlled

environment. The velocity of the bead and the impact angle can be adjusted. A fast camera records the movement of the bead during the impact in order to study the mechanical interaction at the interface. The geometrical and chemical properties of the surfaces of the bead and the target are also carefully prepared and examined in order to characterize the contact conditions as precisely as possible. The first results obtained on the setup during parametric studies are presented and discussed in details.

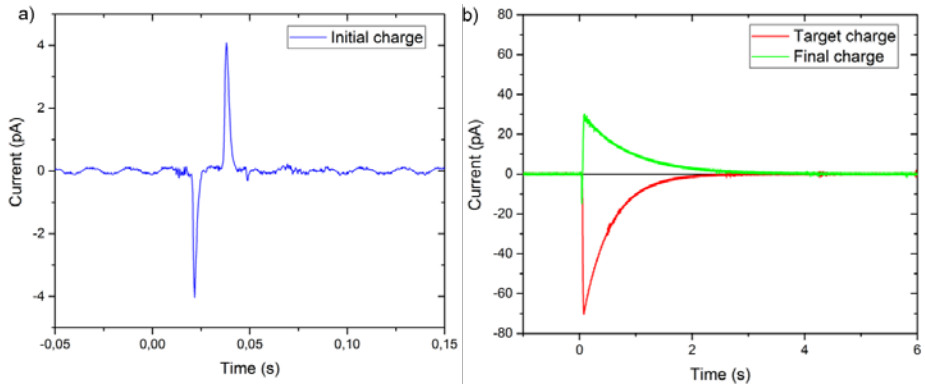

Fig. 1: Typical current measurements obtained during an experiment. a) Initial charge measured with a capacitive method directly on the bead. b) Final charge on the bead and charge on the target measured with a conduction method.

Contact electrification of adhesion films on flat panel displays

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Contact electrification of a protective adhesion film on a flat panel display may result in high charge accumulation on an electrically insulating surface affecting production yield and field failures. Tendency for triboelectric charging on planar surfaces was evaluated with the different film structures and different plane materials. Manual separation and constant speed separation techniques were adopted in the experiments. Triboelectrification had random effects that may be difficult to control without electrical conductivity. Electrostatic dissipative properties on the adhesion surface may increase charging of the insulating display. An inherently dissipative layer of the adhesion film significantly mitigated charge accumulation of the film itself.

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Triboelectric charging of polyethylene powders: experimental and modelling study of bipolar charging

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The manufacturing and handling of polyethylene (PE) powders is associated with undesired charging, resulting in agglomeration of charged particles and wall sheeting that can eventually lead to the plugging of reactors/conveyors. In the processing and transport of insulator powders (for example, polymers, drugs, pigments or flour) collisions occur both among powder particles and between particles and a device wall. During such collisions, charge carriers are redistributed asymmetrically among the particles, which results in charging. Many theories have been proposed aiming to describe the triboelectric charging. However, these are mostly specialized on one type of charging and are rarely useful for the quantitative prediction of charging. Because the mechanics of electrostatic charging is still not fully understood, our predictions of which and how parameters affect the charging are limited, which underlines the importance of experimental research in this area.

Thus, we measured the particle-particle and particle-wall charging of PE particles and a metal wall simultaneously to provide results relevant to industrial processes. The crucial part of our equipment is a free fall electrostatic separator, which separates the pre-charged sample particles according to the charge density and afterwards we directly measure the charge of separated particles in the Faraday pail connected to an electrometer. In our work, we focused mostly on the effect of following parameters on charging Volume fraction and particle size distribution significantly affects the charging behaviour. Similar results were predicted also by our Discrete Element Method model that incorporates the balance of transferable charged species participating in the charging mechanism. Moreover, the effect of temperature and impact velocity on charging was studied. The results indicate that the effect of these parameters on the saturation charge of PE particles is associated with the properties of the particles; namely Young modulus significantly affects the saturation charge at elevated temperatures. The saturation charge of PE particles decreases with increasing air humidity. Moreover, experiments with controlled rapid change of humidity showed a rapid change in the saturation charge, but only in the case when charged PE particles collided with other particles or metal wall. The repeated experiment showed no hysteresis, excluding the role of adsorption dynamics in the charging. Such observations suggest that the common interpretation of humidity-dependent charging, namely the effect of adsorbed water leading to the reduced surface resistivity, or the charge decay in humid air, are not sufficient to explain the humidity-dependent charging of PE particles.

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Dielectric barrier discharge surface treatment of granular materials for improved triboelectric charging

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[1]Pprime Institute, France, [2]APELEC laboratory, Algeria

Dielectric barrier discharge (DBD) is a promising technology for surface modification of materials. The aim of the present study is to evaluate the effect of three major operating parameters of the DBD reactor on the triboelectric charging of plasma-exposed granular insulating materials. The factors considered in this study were: the distance between the two electrodes of the plasma reactor, the thickness of the dielectric and its position. The plasma treated Polyethylene (PE) particles were then tribocharged in a vibrating device; the acquired charge was measured using a Faraday pail connected to an electrometer. Results show that both the distance between the electrodes and the thickness of the dielectric barrier have a considerable effect on the tribocharge acquired after DBD treatment. Conversely, for fixed gap spacing, the dielectric barrier configuration does not have a significant effect on charge enhancement.

Session 4: Dielectrophoreses, particle control and transport

(Invited) Finding the secrets of life by looking down a well

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Dielectrophoresis was first demonstrated to be effective for cell separation and characterisation over half a century ago, but has only recently become sufficiently adapted to commercial exploitation. The DEP-Well approach pioneered at the University of Surrey has led to the development of two new tools, the 3DEP cell analyser and the Deparator cell separation platform. We have developed 3D, well-based DEP structures that can be manufactured at low cost, but which allow significantly higher throughput – for example, allowing the capture of a 20-point, 20,000-cell DEP spectrum in 10 seconds. Furthermore, we have found that unlike other systems where internal inter-electrode losses limit the maximum conductivity that can be used, we have shown good results in media of 0.8S/m and some preliminary results indicating that measurements can be taken in 1.5S/m (physiological strength) media. We are able to take measurements to 50MHz, enabling us to see the whole of the DEP spectrum including the high-frequency plateau. The speed of measurement allows 100-point spectra to be collected in five minutes, and high-resolution studies of time-variant phenomena to be made. Expanding our range of study has allowed us to explore a wide range of cells in relatively unusual conditions, which has yielded intriguing results that raise fundamental questions about what we interpret from interpret from DEP data.

Electrostatic formation of liquid marbles – progress and prospects

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[1]University of Australia, [2] Department of Applied Chemistry, Faculty of Engineering, Japan, [3]Nanomaterials Microdevices Research Center, Japan

A statistical treatment is developed for the electrostatic transfer of particles from a powder bed to a pendent droplet during liquid marble and aggregate formation. The model uses Weibull statistics to calculate the probability of particle transfer events of a given size occurring, for the given electric field strength and geometry. This is used in Monte Carlo simulations of the transfer process. In this preliminary study, some of

the most distinctive features of the experiments – transfer event size and spacing, scaling with driving potential – are well-captured using physically plausible parameter values. Other features, such as denuding of the particle bed, are less well reproduced, and require refinement.

Acknowledgements

This research was supported by the Australian Research Council (DP170100578). CAT and BTL each thank the Australian Government for a Research Training Program (RTP) Scholarship.

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Analysis of the behavior of charged particles in electrical relay devices

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This paper presents the results of analytical and experimental studies on the motion of a charged foreign object in an electrical relay. In the numerical approach, the motion of the lower and upper electrodes was solved by the finite element method. The colliding force between the foreign object and the electrodes was calculated by Hertzian contact theory. The electric field strength in the electrical relay was solved by the finite difference method. In the experimental approach, a spherical particle with a radius of 0.097mm made of polystyrene divinylbenzene was used as the foreign object. The validity of the analytical method was examined by comparing its results with the experimental results. It was shown that the motion of the particle is considerably affected by the electrostatic force.

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Nanoparticle deposition during electrospraying: discrete element model

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Nanostructured materials became an integral part of the customer market and so did the products based on nanoparticle layers (e.g. electrodes in supercapacitors, superhydrophobic coating). For the production of nanostructured layers, electrospraying is a suitable method offering several advantages compared to other techniques. It has easy mode of operation and construction and allows deposition of wide range of materials. On the other hand, properties of the deposited layer (e.g. electric or heat conductivity, hydrophobicity) depend not only on the deposited material but also on the morphology of the produced layer, which is determined by the spraying conditions and difficult to control. To solve this drawback, we decided to study the process of nanoparticle deposition. Our goal is to clarify the influence of various effects taking place during the final stage of the particle motion on the morphology of the layer. A convenient way how to do that is mathematical modelling.

Presented first-principle model is based on the Discrete Element Method (DEM). In this approach, particle trajectory is computed as a consequence of the forces affecting the particle. An integral part of the model is evaluation of the electrostatic force which is a driving force of the particle motion. The resulting electric force affecting each charged particle depends on many effects: the electric field between the nozzle and the substrate, differently charged particles, the permittivity of the particles and the surrounding environment, etc. Therefore, the force has to be computed numerically.

We use the Finite Volume Method (FVM) to discretize the Poisson's equation and the electric force is evaluated from the resulting field of electric potential. The interparticle forces include non-contact van der Waals and contact elastic adhesive forces, while the drag force acts on a particle surrounded by a fluid (air). Morphology of the layers predicted by the developed model is qualitatively comparable to the experimentally obtained layers.

The results bring more insight into the complicated process of the nanoparticle deposition and allow us to compare the importance of various effects occurring in the system. For instance – apart from the phenomena affecting the particle motion – the model results clearly demonstrate the influence of the after-deposition processes on the final morphology of the layer. For this reason, the model has been extended by the particle discharging. The new results prove the importance of this extension and show that the morphology of the layer is altered when particles are discharging slowly.

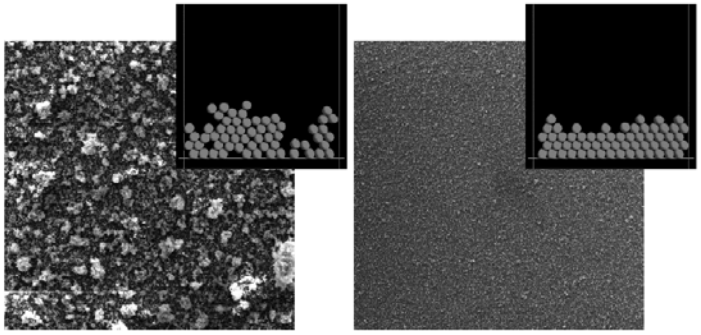

Fig. 1: Comparison of the morphologies obtained from the model and experiment.

Session 5: Lightning protection and hazards

Case study to determinate the angle-dependence during the risk determination in lightning protection

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To know the formation of the atmospheric discharge is one of the main starting point to create an accurate calculation model. In this paper a study will be discussed what kind of modifications are necessary improve PMAS [1, 2] calculation by taking into consideration the geometrical position of downward leader, especially the direction of the last step between the striking point and the point of strike.

The PMAS is a widely used method to calculate the probability of lightning strike for an object. Based on this calculation it is possible to get the expected number of strikes for a given object in a certain time-period. In the standard method, EGM (Electro-Geometry Method) the correlation between the current and the striking distance are proportional. In the paper [3], for the current distance-dependence was made a weighted solution, but it has no angle-dependence, also. This one was calculated by the help of different EGM.

The connection between the striking distance, lightning current and striking distance is not examined in the case of direction. In the work, the main question is this dependence, and the main goal is to define the context.

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A kinetic model for the electrostatic spark discharge in atmospheric pressure air

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This paper presents a 0-D kinetic model of electrostatic spark discharges consisting of the time-dependent Boltzmann equation of electrons, a discharge-circuit equation, and heavy particles' kinetic equations to investigate the energy-transfer mechanisms from the electrostatic energy given to the energy of gases by the spark discharge. In this report, the model is applied to the discharges in atmospheric-pressure air under optimum conditions corresponding for the minimum ignition energies of the typical ammable gases, hydrogen, ethylene and propane, in three types of explosion groups for gases.

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Session 6: Pharmaceutical

(Invited) Role of electrostatic charge on pharmaceutical aerosols

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Respiratory diseases such as asthma, COPD, etc. are treated by delivering medicament to the human lung in the form of aerosols generated by nebulizers, pressurised Metered Dose Inhalers (pMDIs) and Dry Powder Inhalers (DPIs). In the case of nebulizers, medical aerosols are generated using pressurised air to atomise the solutions or suspensions. Alternatively, ultrasonic energy is used to atomise the medicament. The mechanism associated with the process of disrupting the liquid film in either case, generates electrical charge. In the case of pMDIs, the medicament is contained in a pressurised metal can. When the device is actuated, the active ingredient suspended in hydrocarbon propellant with excipient, exits through an orifice in the valve stem. The mechanism that takes place is flash boiling and the liquid suspension passes through the orifice at very high velocities. Triboelectrification takes place at the orifice and the aerosol gets electrically charged. The level and polarity of aerosol charge will depend on the materials involved. In DPIs, the patient's inhalation flow rate will direct the gas dynamics within the device based on the internal structure of the device. The aerodynamics within the device mechanism will generate very high velocities that will carry the powder medicament through the mouthpiece to the lung. The exiting aerosol would have acquired electrical charge due to triboelectrification. Here again the polarity and level of charge acquired will depend on all the material properties and the velocity of air carrying the powder particles.

In this presentation, the significance of aerosol charge on lung airway deposition will be highlighted. A number of numerical models have been developed to study the aerosol deposition in human lung, which involve various mechanisms such as inertial impaction, gravity sedimentation, diffusion, interception and electrostatic forces (space charge and image charge). The model developed by the Brunel researchers will be presented, highlighting the importance of electrical forces. The drug aerosols generated by all these devices are known to exhibit bipolarity. The importance of bipolarity and the instruments available for detecting bipolar charge of aerosols will be critically reviewed. In addition, new generation of devices using pure electrical forces or hybrid systems to generate and control the desired level of charge for specific site deposition will also be reviewed.

Modelling electrostatic cohesion of pharmaceutical powders

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Respiratory diseases, such as chronic obstructive pulmonary disease (COPD) and asthma, continue to affect the health of hundreds of millions of people worldwide. Treatment of these diseases is generally performed via direct inhalation of the drug molecule, with newer devices using the aerosolisation of dry powders.

The pharmaceutical powders used for aerosolisation techniques are generally composed of both carrier particles (usually lactose) and the active pharmaceutical ingredients (APIs), with both components being dielectric materials. The dielectric nature of these materials leads to the accumulation of bipolar electrostatic charges due to triboelectric charging via particle-particle and particle-wall collisions during the blending process.

The bipolar charge within the powder may lead to an unwelcome aggregation of the powder particles while also having an effect on the homogeneity of the blend which could be positive (contributing to the formation

of an ordered mixture) or negative (poor mixing of the components). Following aerosolisation the charge may also have a positive effect, with the electrostatics improving the deposition of fine aerosol particles within the lungs.

In this presentation it is shown how recently developed theory on electrostatic interactions between charged, dielectric materials can be used to identify patterns of behaviour taking place during the aeroionisation of dielectric powders.

The electrostatic model used in this work was proposed by Lindgren et al. in 2018,[1] and is a generalisation of the solution, proposed in 2010 by Bichoutskaia et al.,[2] to the problem of accurately calculating the electrostatic interactions between charged spheres of dielectric materials. The model considers interactions between an arbitrary number of spheres of arbitrary size, charge, position and dielectric constant, embedded in a homogeneous dielectric medium. The solution accounts for the mutual polarisation of surface charge density on each sphere due to the presence of external charges.

In this work, we employ molecular dynamics techniques[3] that include a polarisable electrostatic force-field to run simulations which investigate the effects of bipolar charge on the interactions present in aerosolised pharmaceutical powders. A variety of systems have been studied, ranging from the simple case of predicting the outcome of a collision between two oppositely-charged bodies, to more complex problems such as investigating the charge scavenging of a bipolar cloud of particles by a larger charged particle.

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Session 7: ESD and Hazards

Hospital flooring - Why is that an issue today?

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Control of electrostatics has been considered important in hospitals since the advent of anaesthesia chemicals for surgical procedures. Now that anaesthetics are for the most part not flammable, hospital designers in the United States are rarely considering electrostatics. Since flammable situations are much less likely in hospitals, the US organization, the National Fire Protection Association (NFPA), has removed any mention of electrostatic control from the Health Care Facility Standard, NFPA 99[1]. This document had always been important for consideration in hospital design, especially surgical suites. The elimination of a requirement for conductive flooring and appropriate footwear have brought about serious consequences regarding electrostatic charge generation and accumulation. Accumulated charge has led to discharge issues resulting in personal injury, electronic equipment damage and loss of significant amounts of data. Figure 1 is an example of recorded voltage on a metal cart in the hospital discussed in Incident three below.

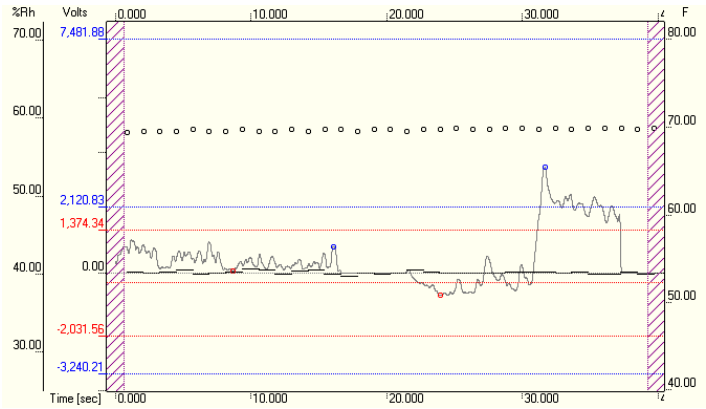

Fig.1: Walking voltage recorded in surgical suite – while pushing cart

[1] NFPA 99 – *Health Care Facilities*, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101, www.nfpa.org

[2] IEC61340-6-1 – *Electrostatic control in health care facilities* – International Electrotechnical Commission,3, rue de Varembe', Geneva, Switzerland, www.iec.ch

Energy released by brush discharges from the fabric with conducting fibers

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Fabrics containing regularly spread conductive fibres introduced into their structure may storage an electric charge, which results in a characteristic surface potential distribution. The brush discharges (ESD) may occur when the grounded conductive object approaches to the charged fabric surface. A simplified, charged fabric-grounded object model is proposed. A metal sphere as the conductive object and a synthetic fabric with conductive yarn (forming regular cells) are considered. The analytical model allows to connect the energy W, that can be released during the ESD, with geometry of the fabric-object system and with the density of the uniform surface charge $\sigma s0$ deposited initially on fabric. The model has led to the power type relation between the energy W and the cell with a diameter a, $W=K\cdot an$, where K – const, $n\approx3$.

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Can ESD sensitive devices be damaged by electrostatic fields?

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In recent years the susceptibility of ElectroStatic Discharge Sensitive devices (ESDS) to electrostatic fields has been questioned. This paper proposes that very high impedance voltage sensitive ESDS such as MOSFETs or MOS capacitors can be damaged due external field changes without making contact with other conductors in the presence of the field. A simple electronic model is proposed. In a practical evaluation of this risk, discharges are demonstrated to occur due changing external fields, as a result of breakdown of a voltage sensitive structure in a high impedance circuit with one terminal continuously grounded.

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Charge distribution and discharge current analysis with charged connector pins

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Electronic components and electromechanics can get static charges during handling and discharge on a printed circuit board when assembled. This study focuses on charged connector metal pins with less than 2 pF source capacitance. A charge distribution, rise time, and shape of the discharge current waveform is studied by using co-simulations between frequency domain finite element method and SPICE time domain circuits. Results show that the current rise time can be less than 10 ps and mainly depends on the inductance of the discharge path when the initial charging voltage is constant. The frequency response of the 3D object defines the shape of the discharge current waveform together with the series inductance and resistance of the discharge path.

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Ignition risks associated with migratory antistatic liners at the point of use

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Dissipative plastics are often used to reduce risks of static ignition sources in explosive atmospheres. Migratory agents which diffuse to the surface can aid dissipation. The agent attracts ambient moisture to the surface thus decreasing the electrical resistance. In tests it has been found that surface resistance of migratory liners can take around 24 hours to become dissipative. This brings into question whether conditioning periods recommended for surface resistance tests could be masking the ignition risk of materials. Surface resistance, transferred charge and gas probe ignition tests have been carried out to investigate the ignition likelihood further. Rubbing tests indicated that a protective lubricating film formed at around 1 hour that could prevent charge transfer events but subsequent rubbing removed the film leading to charge transfer events. Liner filling tests were set up similar to IEC 61340-4-4. This testing recorded charge transfer events of over 60 nC for all liners even after 24 hours exposure. Liner filling tests with the gas ignition probe produced ignitions with standard insulating liners (no migratory agent) but produced no ignitions or measurable charge transfers for migratory liners. A question remains over the use of charge transfer values to evaluate ignition risks for migratory static dissipative materials and more guidance is sought to help industry manage these risks.

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Session 8: Industrial, applications and charge control

Electrodynamic dust shield for particle repulsion in solar energy applications

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Electrodynamic dust shield (EDS) has been proposed as a potential anti-dust solution for terrestrial solar PV power generation in dusty environments. Substantial research effort has been invested in moving the EDS technology from laboratory into real-world applications in the field. It has been found that dust removal efficiency of EDS is affected by many factors, each of which can play an important role in the viability of the EDS technology. It is first found that the EDS efficiency is a function of the dust loading level, i.e., mass of dust per unit surface area. Then a laboratory study reveals that EDS efficiency decreases significantly when operating in cyclic mode, which is the expected mode of operation in the field. Field test then shows a similar trend of EDS efficiency decrease when operating in cyclic mode, and the removal efficiency is strongly dependent on the "age" of dust particles. Most recently a field study suggests that EDS does provide some significant "anti-dust" benefits, but the beneficial effect needs to be amplified before EDS may be considered economically viable. Details of the state-of-the-art EDS technology and potential future development will be given in the presentation.

Experimental study of collisional charge transfer between particles for the development of a CFD model on electrostatic effects in gas-solid flows

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Triboelectric charging is an ongoing operational challenge in gas-solid fluidized bed reactors. Particularly in polyethylene production, this phenomenon can lead to significant wall fouling that forces prolonged and expensive shut-downs for reactor maintenance. Studies on triboelectric charging in gas-solid fluidized beds will lead to the development of electrostatic charging models for use in simulations, which are a cost-effective alternative to performing pilot-scale fluidization experiments. In this research group, an Euler-Euler CFD model for gassolid flows that incorporates the effects of triboelectric charging is under development [1].

Since triboelectric charging occurs due to particle-wall and particle-particle collisions, both mechanisms must be carefully considered in any charging model. A particle-wall charging model was implemented into a CFD model for gas-solid flows, and particle-wall collision experiments were performed to verify its applicability with polyethylene particles [2]. Triboelectric charging due to particle-particle collisions, however, has received limited attention. As such, systematic experimental studies are needed to better understand the charge transfer mechanisms between two colliding particles. In this work, a novel apparatus was constructed that provides the magnitude and direction of charge transfer between two colliding particles.

The design focus for this apparatus was to mitigate any external influence on the system, thereby ensuring that the charge transfer would solely be due to particle-particle collision. The apparatus consists of three sections: an initial drop section where the charge on each particle is measured using Faraday cages; an induced collision section where the two particles achieve an elastic collision; and a particle capture section where the final charge of each particle is independently measured. A high-speed video recorder, linked to a particle-tracking program, was used to detect whenever an elastic collision occurred. Using this apparatus, elastic collisions between same-sized particles were confirmed at high frequency, and a measurable transfer in particle charge was detected between these colliding particles. These experiments have indicated that the initial charges of the particles play an important role in the magnitude and direction of charge transfer.

For particles with small initial charges, the direction of charge transfer may be dependent on the local charge difference of the particles at the point of impact, rather than the overall charge of each particle. The apparatus will be modified to also consider the charging tendencies of particle-particle collisions between particles of varying sizes, materials, and/or densities.

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Study on charge neutralization effect by electron cyclotron resonance plasma source in high vacuum

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Electric charge deposition is cause of failures in a variety of in-vacuum manufacturing processes. Therefore, high efficient charge neutralization method is required. The goal of our study is to improve the charge neutralization speed in vacuum. Our research aims to the application of an electron cyclotron resonance (ECR) plasma source as neutralizer in vacuum. ECR neutralizer has been developed to neutralize ions emitted by ion thrusters, preventing the spacecraft from charging. We improved the neutralization current and investigated the charge neutralization of insulating film as an application for roll-to-roll system. Conveying films at high speed in vacuum, the films are entangled with each other because of friction charging. By placing the ECR neutralizer at 1.5m from a roll-to-roll system, we can convey the film roll at 1000m/min, the highest speed currently used in the industry. Our neutralization system runs at a gas ow rate of just 0.05mg/s of xenon. The 10W class ECR neutralizer is hence proved to be an effective charge neutralization method also for non-propulsion applications in high vacuum.

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[2] Nishiyama K, Hosoda S, Ueno K, Tsukizaki R and Kuninaka H 2016 *Trans. Japan Society for Aeronautical and Space Sciences Aerospace Tech* **14** Pb131-Pb140
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Characterizing the electrostatic charging and discharging processes of sprayed conductive liquids in free jet or in a conductive vessel

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The process of spraying liquids generated electrical charges. The question therefore arises as to whether this electrostatic charge represent an ignition hazard when an explosive mixture is present. This hazard occurs when cleaning vessels, in which an explosive mixture is formed by residues of easily flammable liquids or the cleaning medium itself. Although measurement techniques and methods exist for detecting this electrostatic charging process, they have not been sufficiently scientifically proven. The Chilworth JCI 131 *adverse conditions field meter* is to be used to measure the electrostatic charging of spraying liquids. It is to be validated by measuring the electric field strength of a spray jet charged by a modified, insulated arranged electrostatic spraying system (up to 90 kV) in low-pressure range (8 bar). A flat-jet nozzle is selected which atomizes the spray jet, which serves as the measuring surface, sufficiently large. This arrangement is further investigated in a 1 m^3 stainless steel IBC. The investigations presented are part of a project aiming to extend the scope of the German Technical Rules for Hazardous Substances (TRGS) of TRGS 727, which regulate avoiding ignition hazards resulting from electrostatic charging. The aim is to reach an understanding that

allows provisions for safe cleaning of “small” and “medium-sized” containers up to 50 m³. This project is funded by DGUV (German Social Accident Insurance) and partners from the industry.

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Session 9: Measurements

Electrostatic risk and specification of field and voltage limits for insulating web materials

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Evaluation of electrostatic risk in production insulating web systems rely on electrostatic field or voltage measurements. Field meter measurement at the centre of a web span gives a direct evaluation of electrostatic risk from net web surface charge density. Surface voltage measured on the web against a grounded conductor can reveal the distribution of charges on each web film surface independently. Considerations for measurement instruments are given.

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Measurement of total electric charge of submicrometer particles using a DBD charger coupled with a capacitive sensor

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The objective of this experimental research work is to evaluate the efficiency of a capacitive system for particles charge measurement. The obtained results are used to assess the performance of an aerosol DBD charger based on the particle losses. The charge measurement system consists of a sensitive electrometer that determines the total charge of the particles flowing through a capacitive sensor, and a DBD charger that is used to charge particles at elevated levels. The results are compared to that obtained using an Electrical Low Pressure Impactor (ELPI+). Experimental results show similar behavior of both detection instruments employed in this study. In particular, equivalent trend, order of magnitude and polarity of total charge are obtained for different status of the DBD charger (different frequency, voltage and geometry).

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Characterization of ESD shielding materials with novel test methods

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Electrostatic discharge (ESD) shielding effectiveness of materials used to protect ESD sensitive devices was evaluated with a coaxial electrode and ESD generator. Attenuation of a continuous low power signal and a high power transient was measured. Electromagnetic far field shielding does not necessarily address ESD protection performance. High impedance on a discharge path reduces energy coupling efficiently. Therefore the prevention of conductive and capacitive coupling is the key factor for designing protective packaging for transportation of ESD sensitive devises. Due to the effect of breakdown field strength, low power signals shall not be used alone to assess ESD shielding characteristics. A coaxial electrode and an ESD generator was found a useful combination for the evaluation of ESD shielding effectiveness. As a final outcome, adequate ESD protection can be achieved even without the far field shielding, depending on application.

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[2] IEC 61340-4-8:2014 Standard test methods for specific applications - Electrostatic discharge shielding – Bags
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[6] IEC 61000-4-2:2008 EMC, Electrostatic discharge immunity test

Session 10: Environment and agriculture

(Invited) Electron beam induced diesel off gases desulfurization and denitrification

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Air pollution is an important issue among present day society. Recently, there has been significant concern with the pollution from marine sources which currently utilize low quality diesel fuels. As a result, research and development projects have focused heavily on creating cost effective technology that can clean off gases with a high level of efficiency. The Electron Beam Flue Gas Treatment (EBFGT) is one of the most popular non-thermal plasma techniques used due to its high efficiency and has attracted a lot of scientific interest in the environmental protection sector. The exhaust gas is irradiated with the Electron Beam from the accelerator, which causes interactions between the fast electrons and the molecules from the gas, which creates new species such as ions, radicals and excited states. A new emerging hybrid technology that couples the Electron Beam with the reduced size wet scrubbing methods may provide an answer to the reducing emissions from the marine shipping industry (Fig.1).

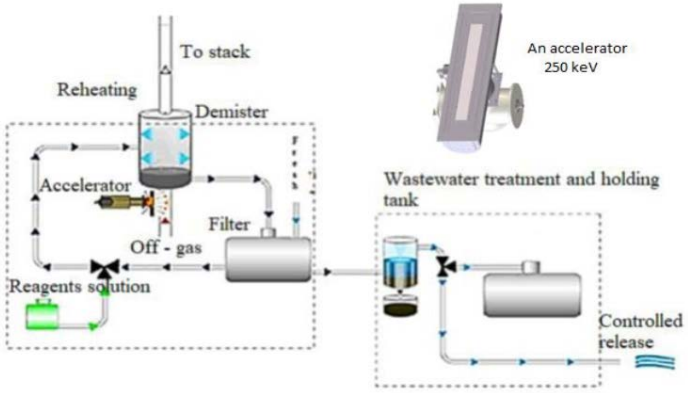

Fig.1: Hybrid EB – sruber system for Diesel off gases treatment.

There are two main stages involved: 1) SO_2 and NOx oxidation during irradiation by the Electron Beam from the accelerator and 2) the pollution products absorption into aqueous solution[1,2].. Application of droplet spray in the irradiation zone[3] will remove oxidation products to avoid back reactions. The organic pollutants (VOC, PAH) may be destroyed in eb formed plasma as well. The results of the present modeling and experimental studies are discussed in the paper.

Acknowledgments

This work was partly financed by the project TANGO 2 (Agreement number TANGO2/341079/NCBR/2017, Plasma technology to remove NO_x from off-gases") funded by NCBiR (National Centre for Research and Development), and co-financed by European ARIES project GA No 730871 WP3 (Accelerator Research and Innovation for European Science and Society) and by Polish ministry of Science and Higher Education (grant Nr 3697/H2020/2017/2).

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Optimization of parameters of designed and developed hand-held electrostatic sprayer and its performance evaluation for herbal pesticides

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Electrostatic force field has been exploited in the design and development of a handheld air-assisted electrostatic sprayer for herbal pesticides. Electrostatic spraying is a novel approach for agricultural pesticides applications to increase the mass transfer efficiency, pesticide bio-efficacy, uniform deposition, maximum canopy coverage and liquid pest to reach the hidden areas and underside of the target by reducing the drift of active ingredients of pesticides from the target. A new air-assisted electrostatic sprayer has been designed and developed for small scale farms with a specific focus on rural developing economies. In this work, experiments were carried out with four types of herbal pesticides and one chemical pesticide to evaluate and compare the performance of developed electrostatic sprayer. The results are characterized in terms of depended variable i.e. charge-to-mass ratio by varying independent variables such as applied voltage, air pressure, conductivity and density of liquid. The droplets are charged more than 8 mC/kg with an applied voltage of 1.5 kV at a flow rate of 110 ml/min and air pressure of 40 psi which is more than desirable to achieve the wraparound effect. This nozzle is light weight, highly efficient, reduces pesticide use and human health risks, and eco-friendly.

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Influence of ESP collector configuration on reduction of particulate emission from biomass combustion facility

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Development of compact electrostatic precipitators (ESPs) for reduction of particulate emissions from small scale biomass combustion is an actual task. Particle mass collection efficiency of an ESP depends from combustion conditions, geometry of ionizer, collector stage configuration and precipitator operation parameters. The investigation of the influence of collector stage configuration on particle mass collection efficiency of a pilot space charge ESP was in the focus of the study. It was shown that the use of tube collector with integrated grounded plates enhanced particle mass collection efficiency. The loading of plates with aerosol provoked particle re-entrainment and decreased long-term ESP collection efficiency. The use of grounded brush electrodes ensured effective reduction of particle emissions but resulted in increase of pressure drop in the precipitator. The optimization of cleaning intervals of the ionizer and collector increased particle mass collection efficiency. It was shown, that the integration of automatic systems for ionizer and collector cleaning into the space charge ESP enhanced long-term operation stability and ensured effective reduction of particulate emissions form small scale biomass combustion.

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Session 11: Modelling and simulation

Simulations and comparative study: the performance of various active devices in an AIA

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This paper presents a comparative study of various active device types inserted in an active integrated antenna (AIA) for the resonant frequency of 4GHz. Three terminal devices which can be BJT, HBT, MESFET or HEMT are integrated within the patch antenna through a microstrip transformer. We are using ADS simulator tools for designing and analysis. We have discussed the performance of the AIA by calculating its input impedance, reflection coefficient and current density distribution.

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Modeling of agglomeration of electrostatically charged particles

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The agglomeration of particles during the handling of powders results in caking, lumping or the local accumulation of electrostatic energy. In the case of dry powders the attraction in-between particles can be mainly attributed to van der Waals and electrostatic forces. In this paper we present a novel numerical approach which is based on an algorithm developed by Erleben [1] in the field of computer graphics. This algorithm is extended to compute binary and multiple particle interaction with each other and solid surfaces. The herein presented results demonstrate that this algorithm allows to accurately and efficiently predict whether particles agglomerate or separate depending on their kinetic parameters. Simulated test cases reveal how electrostatic and van der Waals forces lead to the growth of structures in case the particle restitution coefficient is sufficiently low.

Acknowledgments

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Monte-Carlo simulations of electrostatic self-charging of tritiated dust

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The electrostatic self-charging rate of tokamak dust is investigated using Geant4, a toolkit for the simulation of the passage of particles through matter. To do so, the particles geometrical characteristics, the β disintegration energy spectrum and the deepness of tritium infusion are taken into account. The investigated materials are tungsten and beryllium, the plasma facing components (PFC) of ITER, considered as spherical particles from 20 nm to 200 µm in diameter, both tritiated. Two cases of tritium distribution in the particles are examined. On the one hand, tritium is homogeneously distributed over the whole sphere; on the other hand, tritium is homogeneously distributed within the external 100 nm layer of the sphere. The self-charging rate is assessed through the calculation of the particle exiting electron rate. Based on a tritium inventory of 10 GBq/g, relevant for ITER tokamak environment, our results show that, for a single tungsten or beryllium

particle of 10 μm in diameter, the self-charging rate when tritium is homogeneously distributed is respectively 2.4 and 1.9 positive elementary charges per second.

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NOx reduction from diesel engines using DBD assisted adsorption and desorption-reduction

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The study presented in this paper is NOx abatement from diesel engine using non-thermal plasma (NTP) and granular activated carbon (GAC). We proposed a system based on the adsorption of NOx on GAC followed by a GAC desorption and reduction by NTP in N_2. This multi-stage process of NOx abatement was carried out in a continuous process using two units in parallel (adsorption/GAC regeneration). NTP was generated using AC dielectric barrier discharge (DBD) and used for two purposes; one was to assist the desorption process of NO from GAC and to the reduction process of desorbed NO (in N_2) into N_2 and O_2. The main purpose of this kind of set-up was to eliminate the presence of O_2 in the reduction process as presence of O_2 would not allow NO to be reduced into N_2 rather it would lead to further production NO_2. A number of parameters (voltage and frequency of AC voltage, residence time/ velocity of gas and concentration of NO) were investigated and reported in this paper. We also investigated the regeneration capacity of GAC in term of number of cycles of use and it was found that a typical GAC can be used to for as many as 30 cycles. The key results was that more than 99% of NO was reduce with the proposed multi-stage process for a gas concentrating of 250 ppm in air at the velocity of 0.1 m/s.

Session 12: Atmospheric and Lightning

(Invited) Lightning on other planets

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More than 3800 planet are known that orbit stars other than our Sun. Many harbour a dynamic atmosphere that is cold enough that cloud particles can form in abundance. The diversity of exoplanets leads to differences in cloud coverage depending on global system parameters. Some planets will be fully covered in clouds, some have clouds on the nightside but are free of clouds on the dayside. We argue that these clouds can easily be charged and lightning discharges will occur in cloudy, exoplanet atmosphere. Lightning supports a global electric circuit (GCE) on Earth, and we argue that also exoplanet may develop a GCE if parts of the exoplanet atmospheres can remain cloud free.

Atmospheric potential gradient measurements from a rooftop in Bangkok

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The atmospheric potential gradient (APG) arises through global thunderstorm activity transporting charge to the ionosphere, which is then dissipated back to ground through the atmosphere. The atmosphere is weakly conducting due to the presence of air-ions caused by ground-based radiation and cosmic rays. APG measurements are often used to provide information about atmospheric physics and meteorology [1,2] but have also been used to infer information on pollution due to the reduction in atmospheric conductivity caused by atmospheric air-ion attachment to aerosol [3,4].

APG measurements at 1 Hz (averaged to 1 minute samples) were taken on the roof of a 6 floor building, approximately 100 m from a busy toll road in Lak Si, northern Bangkok. The measurement period was from March 8th 2018 until September 12th 2018, covering the transition from hot season into rainy season. The heavy monsoon rains and the heavy traffic can both be significant disruptors of the fair weather atmospheric electric field. Heavy traffic will increase APG due to aerosol loading, while rain storms can increase the magnitude, but also change sign of the field due to charge processes within clouds.

During the APG measurements, there were 8 weeks of particle number count and 3 6-days of measurements of aerodynamic size distribution in March and April 2018. Aerosol count and APG should be well correlated [2,3,4] with the relationship dependent on size distribution. If measured alongside meteorological data, APG can provide information on the hygroscopicity of local aerosol [3]. Separating the APG by wind direction can provide insights into the nature of aerosol content without direct aerosol measurements or sampling. Measurements of the time series of APG in the time domain and the frequency domain can provide information on aerosol loading and sources in the atmosphere by identifying cyclic behaviour. Frequency domain analysis of APG can identify a diurnal cycles that can be indicative of traffic rush hours.

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Session 13: Energy and environment applications

Study of electrohydrodynamic phenomena in high temperature high pressure nitrogen

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The study of corona discharge current-voltage characteristics (CVC) in high temperature high pressure (HTHP) gases is important step in development of compact HTHP electrostatic precipitators and heat exchanges. The scope of current work was the study of corona discharge CVCs in HTHP nitrogen. Corona discharge ionizer was installed inside of a HTHP casing. Ionizer included a heated grounded tube electrode and star-shaped high voltage (HV) electrodes. Tests were carried out for various gas pressure and temperature. The CVC-direct and CVC-indirect were measured for positive and negative polarity of applied voltage. For the same voltage, current for negative corona was higher than for positive one. Increase of gas pressure stabilized corona discharge and increased breakdown voltage. Corona discharge CVCs were characterized by a hysteresis loop. The area of hysteresis loop depended on gas pressure and temperature. At the same applied voltage, CVC-indirect have shown higher currents than CVC-direct. Operation at CVC-indirect ensured stable corona discharge and heat transfer.

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Electrostatic charging of water spray by induction

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Results of experimental investigation of electric charging of water spray produced by several commercially available single-fluid pressure swirl atomizers, with cylinder induction electrode are presented in this paper. The process of induction charging of water spray is analysed in terms of specific charge and droplet size distribution, for water flow rate, water pressure, induction electrode voltage and inter-electrode distance as process variables. It was found that the specific charge of water droplets increases with increasing voltage applied to the induction electrode, but only to a certain voltage magnitude. The decrease in the specific charge for higher voltages is caused by corona discharge from the induction electrode and the shielding effect of space charge due to electric field produced by the charged droplets. The optimal inter-electrode distance maximizing the specific charge was determined for each of the tested nozzles.

Acknowledgements

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Joint session 1: Dielectrics and Electrostatics I

Influence of electrode spacing on a symmetrical washer-type electrohydrodynamic conduction pump

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Electrohydrodynamic (EHD) pumping is an attractive method that can be applied to drive a fluid in mass transport and heat transfer enhancement applications, and more particularly for microfluidic applications. EHD pumps are very interesting because they do not require moving parts. The electric energy is directly converted into kinetic energy via the Coulomb force. Three modes can generate this fluid motion: conduction, induction, and injection. This paper presents the experimental results of a parametric investigation on EHD conduction pumps with washer-type electrode geometry. Only symmetrical electrode configuration is investigated in order to highlight the influence of the positive/negative charge mobility ratio. The working fluid is a dielectric liquid (HFE-7100). The pumping mechanism is examined with several washer-type electrode geometries and different types of spacers. For each configuration, pressure and current time variations are recorded and compared.

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Time resolved measurement of dielectric particles velocity in standing wave electric conveyor using PTV technique

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The interaction between micro-sized dielectric particles and standing wave electric field is investigated experimentally in this paper. The particles are deposed on a conveyor made of a series of copper electrodes on a dielectric surface and moved by an electric field. The standing wave electric field is generated by applying 2-phase voltage signals to the electrodes. Particles motion is recorded using high speed camera, and then a Particles Tracking Velocimetry (PTV) based post-processing is carried out in order to track each particle and evaluate its velocity. The main results indicate that the particles move toward both directions perpendicular to the electrodes close to the surface and their velocity increases. Some of them can reach a synchronism velocity equivalent to the velocity of the electric wave. However, most of the particles cannot reach this velocity because of the contribution of adhesion and drag forces.

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Dielectric measurements for the examination of electrostatic charging of powders

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The electrostatic charge accumulation of extremely pure substances usually makes the manufacturing technology more difficult. The electrostatic behaviour of the materials can be examined by the measurement of charge decay time, but the conductivity of pure materials is very low, therefore they show very long charge decaying times. Hence, this quantity is not applicable for reliable electrostatic characterisation of pure powders. In this investigation, dielectric and charge accumulation measurements were executed on extremely

pure powders. The results of leakage current and voltage response methods show significant difference between the powders according to their electrostatic behaviour. The result of dielectric measurements is confirmed by the charge accumulation measurement. The findings reveal the importance of the investigation of slow polarisation mechanisms in the charge accumulation processes of powders.

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Phased-array metasurface modeling using the MoM-GEC method

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Phased array metasurfaces are the new classes of diffractive elements through spatial phase engineering. In this article, we proposed a new design of a graphene plasmonic metasurface based on the concept of phased array antennas. Our investigation demonstrates the capability of dynamically achieve full range 360° phase modulation using graphene doping technique. This dynamic modulation is a viable solution compared to tuning the phase by varying the element length because it offers a full 2π transmission phase control.

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(Invited) **Electrical capacitance tomography for dielectric measurement**

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Electrical capacitance tomography (ECT) is based on measuring capacitance from a multi-electrode sensor surrounding a subject, and reconstructing the permittivity distribution in the surrounded cross section. Obviously, ECT is a type of dielectric measurement. Various other industrial tomography techniques or modalities have been developed based on different sensing principles, such as x-ray, -ray, optical, Laser, Terahertz, microwave, electrical resistance, electro-magnetic and ultrasonic. Among all industrial tomography modalities, ECT is the most mature and has been used for many challenging industrial applications. The internal information obtained by ECT is valuable for understanding complicated phenomena, verifying CFD models and simulation results, measurement and control of complicated processes. Compared with other tomography modalities, ECT has several advantages of no radioactive, fast response, both non-intrusive and non-invasive, withstanding high temperature and high pressure and of low-cost. Because of very small capacitance to be measured (down to 0.0001 pF) and the “soft-field” nature, ECT does present challenges in circuit design, solving the inverse problem and re-engineering. Our latest AC-based ECT system can generate online images at 300 frames per second with a signal-to-noise ratio (SNR) of 73 dB. Examples of industrial applications include the measurement of gas/oil/water flows, wet gas separation, pneumatic conveyors, cyclone separators and fluidised beds for pharmaceutical manufacturing and clean use of coal by circulating fluidised bed combustion and methanol-to-olefins conversion. During this talk, ECT will be discussed from principle to industrial applications, together with a demonstration of an AC-based ECT system.

Joint session 2: Dielectrics and Electrostatics II

Oxide based memristive devices: Current status of understanding and future prospects

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Forschungszentrum Juelich, Germany

Transition metal oxides exhibit a reversible, non-volatile change in electrical resistance upon electrical stimulus, a phenomenon known as resistive switching. In the simplest case resistive switching memory cells, or so called memristive devices, can be switched between a low resistance state (LRS) and a high resistance states (HRS) which can be interpreted as the logical "1" and "0", respectively. However, it is important to note that resistive switching cells often show multiple resistive states rather than only two logical states.

Based on the current knowledge, resistive switching in memristive elements based on transition metal oxides can be ascribed to electrically induced redox-processes at the oxide/electrode interface, which occur either in a spatially confined switching filament, multiple filaments or in a spatially homogeneous, area-dependent manner. In most cases, the redox-process in the metal-oxide goes along with a change in the valence state of the metal ion modifying the Schottky barrier at the oxide/electrode interface.

In this talk, we will present the current knowledge about microscopic mechanisms which drive electroforming and resistive switching in different variants of redox-based memristive elements. In particular, we will show direct experimental evidence of the redox-processes gained by in-operando spectroscopy and microscopy. Using the quantitative numbers gained from these experiments as input for existing nanoionic device simulations offers a route to less empirical and more predictive design of future memory cells. We will present detailed experimental studies and simulations of the strongly non-linear switching kinetics based on the drift-diffusion processes of oxygen vacancies in VCM-type systems. Finally, a brief overview about the current and future fields of application will be presented.

Poster programme

Poster Session 1

(P1.1) Fabrication of hollow carbon nanofiber containing metaloxide catalyst via electrospinning and thermal treatment for atmospheric VOCs removal and water treatment

S Kang

Yonsei University , South Korea

We propose a novel material which has high VOCs removal performance as an adsorbent and also as a catalytic oxidation agent. In addition, we propose a methodology of fabricating this material. By ejecting a PMMA solution containing manganese oxide (Mn3O4) precursor through the inner part of a dual nozzle while a PAN solution is delivered through the outer part, nanofibers impregnated with Mn3O4 (denoted as Mn3O4/NFs) are fabricated after the co-axial electrospinning (outer layer: PAN, inner layer: MnAc/PMMA). The Mn3O4/NFs are carbonized, become a hollow structure, and are activated (Mn3O4/HACNFs). Mn3O4 fabricated in this study are the most widely studied metal oxides due to the high activity, stability, relative low toxicity and redox properties. The fabricated Mn3O4/HACNFs are then tested for VOCs removal. The VOCs removal performance of is evaluated at low temperature (below 100°C) and high temperature (150~280°C), respectively, as a toluene adsorbent and a toluene oxidizing agent. The fabrication of Mn3O4/HACNFs using the dual nozzle co-axial electrospinning process is introduced for the first time, to the best of our knowledge.

A series of $Co_xMn_{3-x}O_4$/HCNFs were also synthesized, and their catalytic performance in oxidative degradation of organic dye compounds in water was investigated. The results showed that, as an oxide composite of Co and Mn elements, $CoMn_2O_4$/HCNFs showed much stronger catalytic activity in peroxymonosulfate (PMS) oxidation than Co_3O_4, Mn_3O_4, and their physical mixture. Typically, the uses of 0.2 g/L $CoMn_2O_4$/HCNFs and 0.3 g/L PMS yielded a nearly complete removal of Rhodamine B (50μM) in 80 min at 25°C. The efficiency of Rhodamine B decomposition increased with increasing temperature (15–55°C). Furthermore, $CoMn_2O_4$/HCNFs could maintain its catalytic activity in the repeated batch experiments. Moreover, hydroxyl and sulfate radicals participating in the process were evidenced using quenching experiments, and a rational mechanism was proposed. PMS oxidation with $CoMn_2O_4$ is an efficient technique for remediation of organic contaminants in wastewater.

The surface morphology and structure of the all nanofibers were characterized by field emission scanning electron microscopy (FESEM), energy-dispersive X-ray spectroscopy (EDX), transmission electron microscopy (TEM), powder X-ray diffraction (XRD), and X-ray photoelectron spectroscopy (XPS).

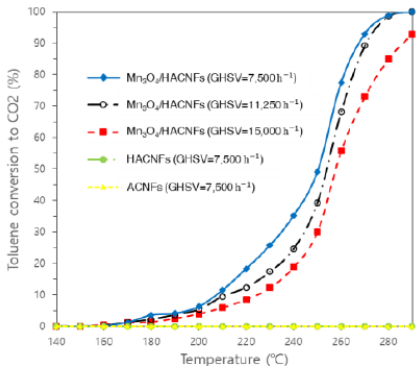

Fig. 1: Catalytic results of the different ACNFs for the total oxidation of the toluene at different gas hourly space velocities (GHSV) as a function of the reaction temperature.

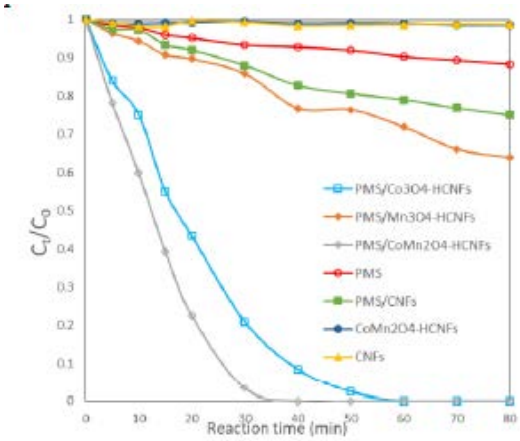

Fig. 2: Comparison of the photocatalytic performance of samples under different conditions.

This work was supported by Railroad Technology Research Program (18RTRP-B082486-05) funded by Ministry of Land, Infrastructure and Transport of Korean Government. Yao, Yunjin, et al. "Sulfate radicals induced from peroxymonosulfate by cobalt manganese oxides (CoxMn3− xO4) for Fenton-like reaction in water." Journal of hazardous materials 296 (2015): 128-137. Morales-Torres, Sergio, et al. "Coupling noble metals and carbon supports in the development of combustion catalysts for the abatement of BTX compounds.

(P1.2) Stability of charged nanoclusters: a case of fullerenes and polyoxometalates

A Miller

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Electrostatic interactions are vital in numerous natural and anthropogenic phenomena: from larger scale cases such as the behaviour of volcanic ash clouds and the formation of clouds to everyday activities including food processing and printing. Although many different electrostatic models exist for studying such effects between charged particles, many fail to account for the dielectric nature of the materials present.

In 2010, Bichoutskaia et al.[1] introduced a model which presented a new mathematical solution to calculate the electrostatic interactions between charged, dielectric, spherical particles which shows stability until the point of the particles touching. A particularly interesting feature is its demonstration of the charge-induced interactions that occur between two dielectric particles of like-charge being attractive. Since then, the model has grown beyond the two-body problem and many-body solutions [2] have been added to enable the investigation of the electrostatic interactions that occur in short range proximity for a large amount of charged particles. The many-body solution is general, and it can be used for charged particles ranging from a small collection of atoms through to milli-scale particles. In this work, we model the behaviour of charged nanoparticles, specifically C60 clusters and polyoxometalates (POMs).

Although the energetics determining the fragmentation of large and charged C60 structures have previously been examined [3], the forces driving the stability of C60 clusters are less well known. By treating highly charged C60 molecular clusters as dielectric particles we can investigate both their stability and fragmentation in a new light to give an accurate description of C60 clusters holding high positive charges. This allows us to assess various configurations including geometry and surface charge density distribution in order to find stable cluster structures.

Similarly, in this work the many-body solution [2] is used to model the behaviour of POMs, which are known to self-assemble in solution to form giant spherical hollow 'blackberry' macrostructures. Formation of these 'blackberries' is not observed at low pHs – where the amount of charge on the POMs is low – indicating that the formation is electrostatically driven. We investigate the formation of the most basic oligomer (a dimer) via one proposed driving force for the self-assembly – counterion-mediated attraction – in which the counterions in the solution create the attractive interaction between two POMs.

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(P1.3) Fluid viscosity and corresponding effects on fluid flow, velocity magnitude and electric field distribution in electrohydrodynamic jetting

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The phenomenon of electrohydrodynamic (EHD) jetting is affected by both the flow and electric properties of the dietetic fluid. A computational fluid dynamics (CFD) approach has been used to analyse the resultant effect of fluid viscosity on EHD flows. This study looks at the unique effect of fluid viscosity on Taylor formation, velocity magnitude and the electric field distribution. It is very difficult to experimentally study these relationships, but CFD provides insights into them that can open the world of Electrohydrodynamics to a new level of application; as this will give an idea of how to manipulate the fibre formation from the angle of solution parameters. Jaworek et al [1], highlighted viscosity as one of the key parameters that aid jet elongation and stability. Therefore, the necessity to study its role. Most studies have been carried out experimentally, but this paper provides computation insights.

To solve the multiphase problem, a finite volume based CFD package, CFD-ACE+ (ESI Group, Paris, France) was used for the investigation. The leaky dielectric model which describes the process solves the combination of the Charge Transport Model Navier-Stokes equations simultaneously. The transient liquid-gas interface tracking is achieved by solving simultaneously with the other governing equations, using the VOF technique. Central differencing scheme with second-order piecewise linear interface technique construction (PLIC) scheme was used to explore the interface shape from the value of fluid fraction in each cell. The surface tension effect along the liquid-gas interface was treated by the continuous surface force (CSF) scheme. Finite volume method (FVM), using structured quadrilateral cells was used to discretize the volume. The resulting flow characteristics observed had striking similar profiles to the physical process. Three solutions of varying viscosity magnitudes have been modelled to study the effects of fluid viscosity on EHD flows.

Among many other features observed, the results showed that it takes more time for the electric field to overcome the opposing surface tension of the solution at higher viscosity than at lower viscosity. Higher electric field magnitudes/strength were observed for the fluid of lower viscosity than that of the higher viscosity. Also, an increase in the viscosity reduces the droplet size/jet diameter just as reported in experimental results from [1]–[3]. The length of the jet increases with an increase in viscosity.

(P1.4) Nanoparticle deposition during electrospraying: discrete element model

A Zítková

University of Chemistry and Technology Prague, Czech Republic

Nanostructured materials became an integral part of the customer market and so did the products based on nanoparticle layers (e.g. electrodes in supercapacitors, superhydrophobic coating). For the production of nanostructured layers, electrospraying is a suitable method offering several advantages compared to other techniques. It has easy mode of operation and construction and allows deposition of wide range of materials. On the other hand, properties of the deposited layer (e.g. electric or heat conductivity, hydrophobicity) depend not only on the deposited material but also on the morphology of the produced layer, which is determined by the spraying conditions and difficult to control. To solve this drawback, we decided to study the process of nanoparticle deposition. Our goal is to clarify the influence of various effects taking place during the final stage of the particle motion on the morphology of the layer. A convenient way how to do that is mathematical modelling.

Presented first-principle model is based on the Discrete Element Method (DEM). In this approach, particle trajectory is computed as a consequence of the forces affecting the particle. An integral part of the model is evaluation of the electrostatic force which is a driving force of the particle motion. The resulting electric force affecting each charged particle depends on many effects: the electric field between the nozzle and the substrate, differently charged particles, the permittivity of the particles and the surrounding environment, etc. Therefore, the force has to be computed numerically.

We use the Finite Volume Method (FVM) to discretize the Poisson's equation and the electric force is evaluated from the resulting field of electric potential. The interparticle forces include non-contact van der Waals and contact elastic adhesive forces, while the drag force acts on a particle surrounded by a fluid (air). Morphology of the layers predicted by the developed model is qualitatively comparable to the experimentally obtained layers.

The results bring more insight into the complicated process of the nanoparticle deposition and allow us to compare the importance of various effects occurring in the system. For instance – apart from the phenomena affecting the particle motion – the model results clearly demonstrate the influence of the after-deposition processes on the final morphology of the layer. For this reason, the model has been extended by the particle discharging. The new results prove the importance of this extension and show that the morphology of the layer is altered when particles are discharging slowly.

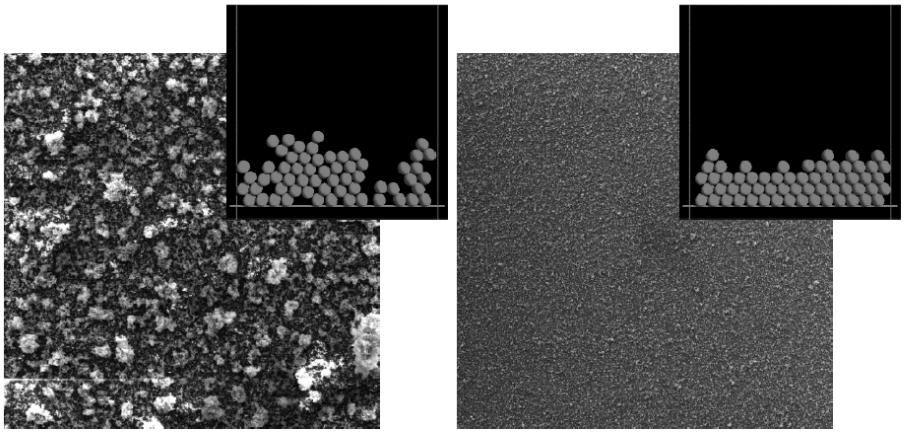

Fig. 1: Comparison of the morphologies obtained from the model and experiment.

(P1.5) Triboelectric charging of polyethylene powders: experimental and modelling study of bipolar charging

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University of Chemistry and Technology, Prague

The manufacturing and handling of polyethylene (PE) powders is associated with undesired charging, resulting in agglomeration of charged particles and wall sheeting that can eventually lead to the plugging of reactors/conveyors. In the processing and transport of insulator powders (for example, polymers, drugs, pigments or flour) collisions occur both among powder particles and between particles and a device wall. During such collisions, charge carriers are redistributed asymmetrically among the particles, which results in charging. Many theories have been proposed aiming to describe the triboelectric charging. However, these are mostly specialized on one type of charging and are rarely useful for the quantitative prediction of charging. Because the mechanics of electrostatic charging is still not fully understood, our predictions of which and how parameters affect the charging are limited, which underlines the importance of experimental research in this area.

Thus, we measured the particle-particle and particle-wall charging of PE particles and a metal wall simultaneously to provide results relevant to industrial processes. The crucial part of our equipment is a free fall electrostatic separator, which separates the pre-charged sample particles according to the charge density and afterwards we directly measure the charge of separated particles in the Faraday pail connected to an electrometer. In our work, we focused mostly on the effect of following parameters on charging Volume fraction and particle size distribution significantly affects the charging behaviour. Similar results were predicted also by our Discrete Element Method model that incorporates the balance of transferable charged species participating in the charging mechanism. Moreover, the effect of temperature and impact velocity on charging was studied. The results indicate that the effect of these parameters on the saturation charge of PE particles is associated with the properties of the particles; namely Young modulus significantly affects the saturation charge at elevated temperatures. The saturation charge of PE particles decreases with increasing air humidity. Moreover, experiments with controlled rapid change of humidity showed a rapid change in the saturation charge, but only in the case when charged PE particles collided with other particles or metal wall. The repeated experiment showed no hysteresis, excluding the role of adsorption dynamics in the charging. Such observations suggest that the common interpretation of humidity-dependent charging, namely the effect of adsorbed water leading to the reduced surface resistivity, or the charge decay in humid air, are not sufficient to explain the humidity-dependent charging of PE particles.

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Poster Session 2

(P2.1) Study of the effect of plasma treatment on the triboelectric properties of polyethylene (PE) and polypropylene (PP) slabs

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Pprime Institute, France

The dielectric barrier discharge (DBD) is a convenient way to modify the surface properties of polymers. The aim of this study is to evaluate the effect of atmospheric DBD treatment on the triboelectric properties of polymers in sliding contact. The experiments were carried out on two polymers that were rubbed against each other: PP and PE. The pairs of samples were exposed to the DBD, and then taken to a triboelectric test bench for friction charging. The distribution of electric potential at the surface of the tribocharged samples was measured by an electrostatic voltmeter. The triboelectric behavior of the considered polymers depends on the conditions of DBD treatment: thickness of the dielectric barrier and duration of the exposure to the non-thermal plasma.

Acknowledgments

This work was partially funded by the French Government program “Investissements d’Avenir” (LABEX INTERACTIFS, reference ANR-11-LABX-0017-01) and by a FEDER-CPER program, financed by the European Union and by the Nouvelle Aquitaine Regional Council.

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(P2.2) The importance of the electro-dynamic field in the pilot production of homogeneous nanofibrous layers for potential use in wound healing and cosmetics

M Pokorny

Contipro a.s., Czech Republic

In the few last years in our company, the production of nanofibrous layers containing the main component of hyaluronic acid was scaled-up from the research phase. Based on our experience with the development of technology of the laboratory apparatus with the commercial name 4SPIN LAB, a larger pilot plant was developed. A new device was designed to produce nanofibrous layers on an application-acceptable substrate material of at least 50 cm wide. The uniformity of the nanofibrous layer in a weight tolerance of

maximum ±10 % in the production of layers with an areal weight up to 20 g/m^2 was also requested. During the development of the equipment, it has been shown that the continuous roll-to-roll production in electrostatic deposition does not achieve the required quality of the layers, therefore the deposition method has been extensively modified.

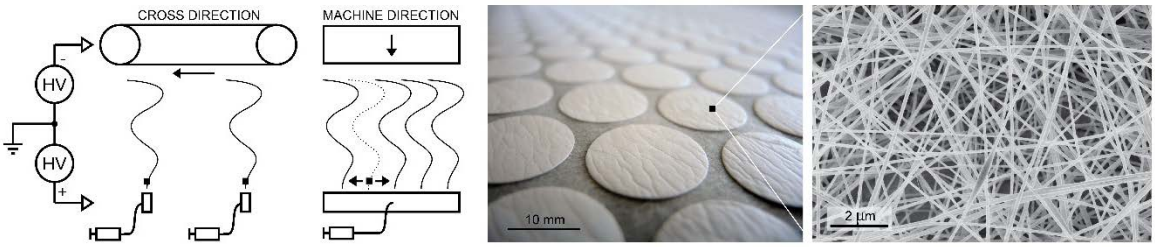

Fig. 1: Illustration of the spinning process in the electrically dynamic field. Processed layers and their morphology are shown.

The device uses two parallel needleless electrodes and a rotating collector in the form of an endless belt with a voltage difference of up to 120 kV (see Figure 1). To achieve the desired thickness homogeneity, two parameters were shown to be highly critical. The first of these parameters is the surface velocity of the substrate material, which was increased from the original 2 cm/min up to a hundred-fold. For this reason, the roll-to-roll system was replaced by an endless belt. Secondly, the movable mechanism near the nozzles destabilizing the position of the Taylor cones led to the overall elimination of the resulting patterns and stripes in the thickness of the layer. Thus, the modified deposition process can be characterized as highly electrodynamic, and not clearly electrostatic as is known from the standard electrospinning method arrangement.

The produced nanofibrous hyaluronic acid-based layers are prepared within 130 minutes with a surface area of (110 x 55) cm^2. The thickness of the nanofibrous layer weighing 18 g/m^2 is uniform in the above-mentioned tolerance to more than 95 % of the usable area. The validation of the manufacturing process was verified by two independent measuring methods, i.e. by weighing and analyzing the images produced by passing light. The layers prepared after further processing, e.g. cutting, then separation from the substrate material, packing, meet high-quality requirements and then can be distributed and used in applications in dermatology and cosmetics.

(P2.3) Optimization of parameters of designed and developed hand-held electrostatic sprayer and its performance evaluation for herbal pesticides

M K Patel

CSIR-Central Scientific Instruments Organisation, India

Electrostatic force field has been exploited in the design and development of a handheld air-assisted electrostatic sprayer for herbal pesticides. Electrostatic spraying is a novel approach for agricultural pesticides applications to increase the mass transfer efficiency, pesticide bio-efficacy, uniform deposition, maximum canopy coverage and liquid pest to reach the hidden areas and underside of the target by reducing the drift of active ingredients of pesticides from the target. A new air-assisted electrostatic sprayer has been designed and developed for small scale farms with a specific focus on rural developing economies. In this work, experiments were carried out with four types of herbal pesticides and one chemical pesticide to evaluate and compare the performance of developed electrostatic sprayer. The results are characterized in

terms of depended variable i.e. charge-to-mass ratio by varying independent variables such as applied voltage, air pressure, conductivity and density of liquid. The droplets are charged more than 8 mC/kg with an applied voltage of 1.5 kV at a flow rate of 110 ml/min and air pressure of 40 psi which is more than desirable to achieve the wraparound effect. This nozzle is light weight, highly efficient, reduces pesticide use and human health risks, and eco-friendly.

Acknowledgements

Authors are thankful to SRISTI and Honey Bee Network, Ahmedabad to provide the herbal pesticides for conducting the experiments on developed electrostatic sprayer at CSIR-CSIO, Chandigarh. Authors are also thankful to Dr. Sakshi and her team for helping in conducting laboratory experiments.

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P2.4 Development of an electrospraying device - theoretical study

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InoCure s.r.o., Czech Republic

Nowadays, nanoparticles are of high interest for pharmaceutical and biomedical use, especially for drug delivery applications. However, due to many limitations (e.g. difficulties in controlling particles size and morphology), the production of nanoparticles is a challenging task and takes a big attention from scientists. Recent developments in micro- and nanofabrication techniques [1]have shown a great potential in needleless electrospraying as one of the most efficient method for large-scale manufacture. Besides incontestable advantages of the process (simplicity, high production rate, low cost, …),

electrohydrodynamic atomization technique still requires improvement, especially of uniformity and purity of obtained particles [2].

Processing parameters and electrospraying apparatus play crucial role in optimization of the nanoparticles-based formulation. In our study we have examined the impact of the geometry of the needleless emitter on the process features. We present a comprehensive theoretical analysis of the electric field profile depending on the design of the elements.

The 3D-model has been prepared with COMSOL Multiphysics software by finite elements method.

Our study will greatly help to select the proper emitter, as well as scale-up the particles fabrication in needleless electrospraying.

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(P2.5) Electrostatic agglomeration of fly ash particles for hybrid gas cleaning devices.

A Sobczyk

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The paper presents experimental results of the investigation of agglomeration of PM2.5 fly ash particles with larger particles in an electrostatic agglomerator. SEM micrographs of the obtained agglomerates shown that a single particle of the size of 10-20 μm can collect more than 20-50 PM2.5 particles in this type of agglomerator. The experiments were carried out in a semi-industrial scale channel of a cross section of about 600 mm height and 1100 mm width. The agglomerator can be used as a particle precharger in a hybrid system or as the first stage in a two-stage electrostatic precipitator, in order to increase their total collection efficiency.

Acknowledgements

The paper was supported by the National Centre for Research and Development (NCBiR) of Poland within the project No. POIR.04.01.04-00-0096/17, "HYBRID system for emission reduction of the acidic compounds and fly ash from flue gases", HYBRYDA+ within the call No. 1/4.1.4/2017/POIR, co-financed by the European Union through the European Regional Development Fund within the Operational Programme Smart Growth.

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(P2.6) Modelling Electrostatic Cohesion of Pharmaceutical Powders

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Respiratory diseases, such as chronic obstructive pulmonary disease (COPD) and asthma, continue to affect the health of hundreds of millions of people worldwide. Treatment of these diseases is generally performed via direct inhalation of the drug molecule, with newer devices using the aerosolisation of dry powders.

The pharmaceutical powders used for aerosolisation techniques are generally composed of both carrier particles (usually lactose) and the active pharmaceutical ingredients (APIs), with both components being dielectric materials. The dielectric nature of these materials leads to the accumulation of bipolar electrostatic charges due to triboelectric charging via particle-particle and particle-wall collisions during the blending process.

The bipolar charge within the powder may lead to an unwelcome aggregation of the powder particles while also having an effect on the homogeneity of the blend which could be positive (contributing to the formation of an ordered mixture) or negative (poor mixing of the components). Following aerosolisation the charge may also have a positive effect, with the electrostatics improving the deposition of fine aerosol particles within the lungs.

In this presentation it is shown how recently developed theory on electrostatic interactions between charged, dielectric materials can be used to identify patterns of behaviour taking place during the aeroionisation of dielectric powders.

The electrostatic model used in this work was proposed by Lindgren et al. in 2018,1 and is a generalisation of the solution, proposed in 2010 by Bichoutskaia et al.,2 to the problem of accurately calculating the electrostatic interactions between charged spheres of dielectric materials. The model considers interactions between an arbitrary number of spheres of arbitrary size, charge, position and dielectric constant, embedded in a homogeneous dielectric medium. The solution accounts for the mutual polarisation of surface charge density on each sphere due to the presence of external charges.

In this work, we employ molecular dynamics techniques3 that include a polarisable electrostatic force-field to run simulations which investigate the effects of bipolar charge on the interactions present in aerosolised pharmaceutical powders. A variety of systems have been studied, ranging from the simple case of predicting the outcome of a collision between two oppositely-charged bodies, to more complex problems such as investigating the charge scavenging of a bipolar cloud of particles by a larger charged particle.

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Poster Session 3

(P3.1) Monte-Carlo simulations of electrostatic self-charging of tritiated dust

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The electrostatic self-charging rate of tokamak dust is investigated using Geant4, a toolkit for the simulation of the passage of particles through matter. To do so, the particles geometrical characteristics, the β disintegration energy spectrum and the deepness of tritium infusion are taken into account. The investigated materials are tungsten and beryllium, the plasma facing components (PFC) of ITER, considered as spherical particles from 20 nm to 200 µm in diameter, both tritiated. Two cases of tritium distribution in the particles are examined. On the one hand, tritium is homogeneously distributed over the whole sphere; on the other hand, tritium is homogeneously distributed within the external 100 nm layer of the sphere. The self-charging rate is assessed through the calculation of the particle exiting electron rate. Based on a tritium inventory of 10 GBq/g, relevant for ITER tokamak environment, our results show that, for a single tungsten or beryllium particle of 10 µm in diameter, the self-charging rate when tritium is homogeneously distributed is respectively 2.4 and 1.9 positive elementary charges per second.

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(P3.2) Removal efficiency increase in electrostatic precipitation for surrogate particles via electrical coagulation

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Nowadays, people use subways as a means of transportation. However, the concentration of airborne particulate matter (PM) on subway platforms has been reported to be higher than the outdoor PM concentration. Subway dust are iron-containing particles which is more harmful to human body than street dust particles. As one method of removing subway tunnel particles, a conventional electrostatic precipitator has been used. However, the electrostatic precipitator showed lower efficiency in the nano-sized region than in the microsized region. One of the most effective and economical methods for improving the collection efficiency of ESP is the agglomeration in an alternating electric field [1] In this study, the real dust collected at the electrostatic precipitator from subway of the Dae-Gu, Republic of Korea was used on the lab scale. The generated particles enter the duct with a cross section of 4x4 cm and are charged bipolar by the wire to rod type charger. The charged particles enter the coagulator. The coagulator consists of two iron plates up and down at intervals of 4 cm, and an AC electric field is applied to both plates, and the charged particles oscillate therein. The vibrating particles collide with each other. Particularly, particles having a large charge and large size sweep out small particles due to a larger vibration. At the end of the duct, the particle size distribution and concentration are measured through SMPS and APS. In order to compare the theoretical charge value with experimental charge value, we have also conducted experiments to measure the charge number. The I-V curve of the charger was measured to determine the proper DC voltage and the current value of the voltage was obtained. The current value of the charged particles was measured using an electrometer, and the concentration of the charged particles was measured using CPC.

The experimental results showed that the charge number tended to increase as the particle size increased, and the theoretical value was similar to that of the experiment. In the AC electrical agglomeration experiment, as the AC field strength increased, the total number concentration of particles decreased and the particle distribution tended to increase gradually from left to right. We are going to carry out the experiment to measure the number concentration and charge number in micro area as well as in nano-sized area.

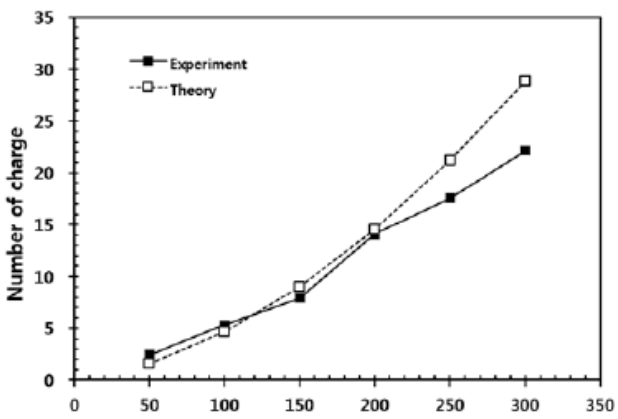

Figure 1. Comparison between theory and experimental data of positive charge number by particle size

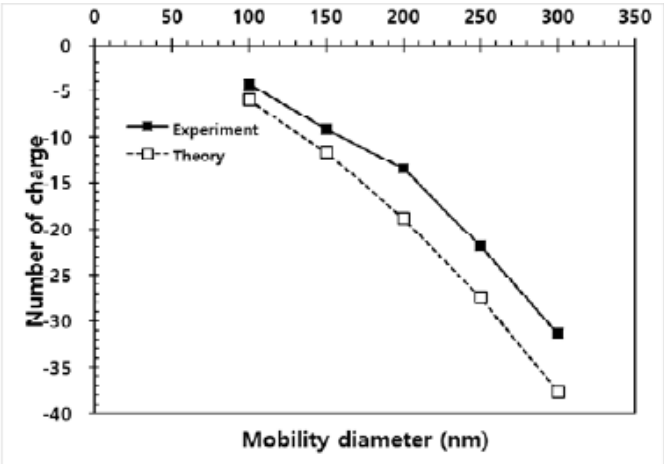

Figure 2. Comparison between theory and experimental data of negative charge number by particle size

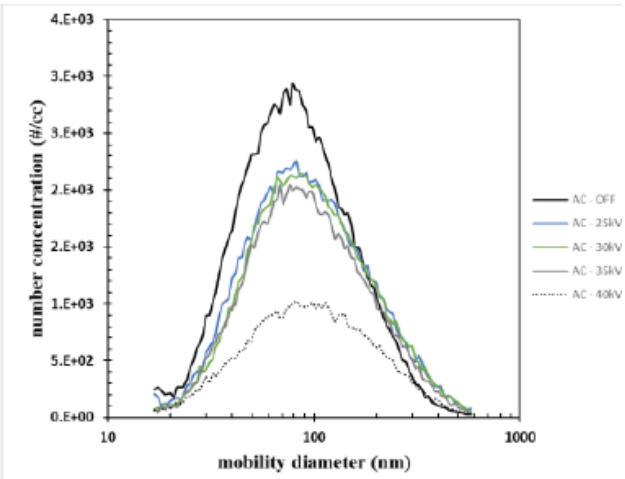

Figure 3. Particle size distribution by AC electric field This work was supported by Railroad Technology Research Program (18RTRP-B082486-05) funded by Ministry of Land, Infrastructure and Transport of Korean Government. Thonglek, V., and Kiatsiriroat, T. (2014). Agglomeration of sub-micron particles by a non-thermal plasma electrostatic precipitator. Journal of Electrostatics, 72(1), 33-38.

(P3.3) Improved mathematical model of particle trajectories in multimodal electrostatic separators

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The multimodal electrostatic separator has been designed to facilitate the feasibility assessment of corona-, tribo-, or purely-electrostatic processes of selective sorting of the constituents of granular mixtures. The versatility of the separator has imposed the development of an equally-agile simulation program for modelling the particle behaviour in each of the operational configurations of the machine. Thus, the paper discusses the numerical models that describe the various specific physical phenomena: corona-charging at the surface of the belt conveyor; induction charging of the conductive particles in contact with the grounded electrode; impact of particles with the rotating-roll high-voltage electrode. An example of conductive and

insulating particles trajectories computation is given. The simulated results are compared with the experimental observations.

(P3.4) Development of an electrostatic wind driven generator (EWICON-R)

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For this type of electrostatic generator firstly the wind flow is converted into a circulating flow resembling a mini cyclone in a special flow chamber. Secondly, small expanded polymer spheres are introduced that rotate with the circulating flow. While the air escapes from the middle, the particles remain in the system due to the centrifugal force. The particles are electrostatically charged by a tribological interaction with the outer wall. The power extracted from multiple electrodes is converted with a DC-DC convertor into common voltages. Because of the absence of moving parts, and reduced noise level, the electrostatic generator is especially suited for application in the built environment. The power output I still a subject of investigation and at present, too low for practical applications.

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(P3.5) Study on charge neutralization effect by electron cyclotron resonance plasma source in high vacuum

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Electric charge deposition is cause of failures in a variety of in-vacuum manufacturing processes. Therefore, high efficient charge neutralization method is required. The goal of our study is to improve the charge neutralization speed in vacuum. Our research aims to the application of an electron cyclotron resonance (ECR) plasma source as neutralizer in vacuum. ECR neutralizer has been developed to neutralize ions emitted by ion thrusters, preventing the spacecraft from charging. We improved the neutralization current and investigated the charge neutralization of insulating film as an application for roll-to-roll system. Conveying films at high speed in vacuum, the films are entangled with each other because of friction charging. By placing the ECR neutralizer at 1.5m from a roll-to-roll system, we can convey the film roll at 1000m/min, the highest speed currently used in the industry. Our neutralization system runs at a gas ow rate of just 0.05mg/s of xenon. The 10W class ECR neutralizer is hence proved to be an effective charge neutralization method also for non-propulsion applications in high vacuum.

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(P3.6) Fabrication of gas removal filter with metal oxide nanoparticle using electrostatic precipitator method and performance evaluation

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Nowadays, Recently, large buildings such as high-rise buildings tend to reduce the number of ventilation to save energy. This tendency cause not only the number of bacteria and fungi in the indoor space, but also the odor concentration of indoor air such as VOCs As a result, the indoor air quality deteriorated. Until now, most of the deodorization techniques for removing such odors have been using activated carbon (AC) filters for adsorbing gaseous pollutants.

However, this technology has a disadvantage that the life of the filter is short due to the difficulty of reusing these filters because the pollutants are simply transported from the gas phase to the solid phase, and secondary pollution occurs when the gas is buried or incinerated. Therefore, techniques for reducing odorous substances without using activated carbon have been studied, In particular, deodorization filters using metal oxide catalysts can oxidize odorous substances at room temperature and have a long life span (Liotta. 2008). In the case of the deodorization filter of the refrigerator, the deodorization performance of the filter treated with the metal oxide catalyst was higher than that of the adsorption filter using the activated carbon.

In this study, metal oxide nanoparticles are produced by spark discharge method. Spark discharge is an environmentally friendly process that does not require a chemical process to generate metal nanoparticles by applying a strong voltage to two metal electrodes. The resulting metal oxide nanoparticles were coated on the porous filter media using an electrostatic precipitated aerosol coating technique.

Electrostatic precipitated aerosol coating is a method in which particles are charged and an electric field is applied to the filter to attach the charged particles to the filter. The particle coating efficiency was evaluated according to the type of metal oxide, electric field type and intensity. Respectively.

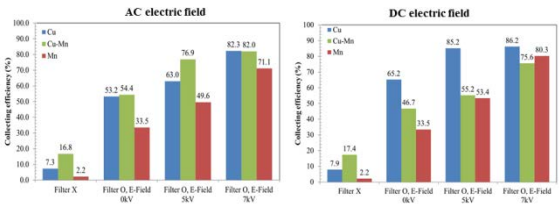

Figure 1. Coating efficiency by electric field

In result, As the electric field increased, the coating efficiency increased and the coating efficiency was about 80% at 7 kV. The deodorization performance of VOCs was evaluated by using the metal oxide deodorizing filter and the deodorization efficiency of VOCs such as formaldehyde, ammonia, and acetic acid was about 30%.

This research was supported by Korea Ministry of Environment (MOE) as “Advanced Technology Program for Environmental Industry”.

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