Newsletter – Issue 3 – July 2009

Welcome! It is nice to be back in electronic print to let you know what the group has been up to and encourage further dialogue between readers. This Newsletter is intended to allow group members and others interested in electrostatics the opportunity to exchange thoughts and information, and as such it benefits us all when we can take part and contribute to it.

The Electrostatics Group aims to act as a hub and network to promote, support and help bring together academics, researchers, industrialists and building professionals working in this very diverse multi-disciplinary field, help disseminate knowledge, and publicise and support the work they are doing. It is also here to act as a means of contact for those who would otherwise work in relative isolation from their peers.

Electrostatics is everywhere, from the macro scale in the atmosphere to the nanoscale in the interactions between molecules and atoms. Examples of subjects with interests in Electrostatics include atmospheric electricity, aerosol technology, bioelectrostatics, MEMs, surface interactions, and so on. The Group organises a major conference, Electrostatics, every four years, and normally several one-day meetings every year on a wide range of subjects. We also publish group newsletters and are happy to accept articles of general and specific interest.

Electrostatics is one of the most important groups of physical phenomena, influencing the behaviour of nature on the extremely large and extremely small scales. Examples range in size from atmospheric electricity, through balloons sticking to your ceiling, all the way down to MEMs, biological interactions and the interactions of molecules. The worldwide community of researchers and industrialists who therefore "do" Electrostatics is not a small one.

Electrostatics also has wide technological importance, with electrostatic based processes such as electrostatic liquid and powder spraying, pollution control with electrostatic precipitators and electro-reprography. There is also a widening awareness of 'static' problems, owing mainly to the diversification of the use of insulating polymeric materials and to the extensive manufacture of electrically delicate electronic components such as field-effect transistors and integrated circuits. Problems and hazards as a result of unwanted static electricity, as well as exciting new technical possibilities, arise in a wide range of industries.

The Static Electrification Group was formed in 1967 to further interest in all aspects of static electricity: its generation, storage and dissipation, its measurements, its uses and hazards, and means of controlling it. As a result, the Group is truly multidisciplinary, with a membership drawn from industrial companies, universities and research associations. Many Group members are involved in the preparation of national and international standards concerning the control and measurement of static electricity. Over the intervening period, the Group has expanded to included representatives, both in the UK and abroad, with interests covering the wide range of fields that Electrostatics has an influence on.

For those of you who are not yet group members, but are interested in finding out more about what we do and possibly joining the group, please contact: membership@iop.org

Article

Electrical impedance measurements of cells

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A biological cell is the basic structural and functional unit of all living organisms; often called the 'building block of life'. Working at the cellular level is of fundamental importance for biomedical and clinical applications. Cellular analysis requires a combination of biophysical and technological approaches, including counting, manipulation (trapping / focusing / sorting / rotating) and identification (staining/ labelling) of cells. Traditional analysis is performed with bulk techniques, which are well established. However, measurements on large populations of cells only provide population averaged information. Individual cells, which may look identical, have different characteristics and behaviour. High throughput single cell analysis platforms offer the unique ability of characterizing large numbers of individual cells at high speed. Microscale devices can be used for single cell analysis. Standard laboratory processes, including sample preparation, chemical reaction and synthesis can all be integrated on a single Lab-on-a-Chip (LOC). Fluorescence spectroscopy is performed by binding antibody conjugated fluorescent probes to the cells and then performing analysis in a flow cytometer of FACS. Electrical measurement of cells are performed using high speed dielectric/impedance spectroscopy, a technique which is non-invasive and label-free.

The dielectric properties of biological cells and tissues have been of interest for nearly a hundred years. The early work of Maxwell [1] and Wagner [2], Fricke [3], Cole [4] and Schwan [5], amongst others laid the foundations for this field of research; see [6] for a review. In dielectric/impedance spectroscopy, the dielectric properties of a system are determined by applying a frequency-dependent excitation signal and measuring the response. Conventionally, a small AC voltage, $\tilde{U}(j\omega)$, over a range of frequencies is used as the excitation signal. The electrical current response, $\tilde{I}(j\omega)$, is measured and the complex impedance of the system, $\tilde{Z}(j\omega)$, is given by:

$$\tilde{Z}(j\omega) = \frac{\tilde{U}(j\omega)}{\tilde{I}(j\omega)} = \tilde{Z}_{RE}(\omega) + j\tilde{Z}_{IM}(\omega)$$

where $\tilde{Z}_{RE}(\omega)$ and $\tilde{Z}_{IM}(\omega)$ are the real and imaginary parts of the complex impedance, respectively. The real part is called resistance while the imaginary part is called reactance.

The magnitude and phase angle of the complex impedance are:

$$\left|\tilde{Z}(j\omega)\right| = \sqrt{\left[\tilde{Z}_{RE}(\omega)\right]^2 + \left[\tilde{Z}_{IM}(\omega)\right]^2}$$

and

$$\angle\tilde{Z}(j\omega) = \arctan\left(\frac{\tilde{Z}_{IM}(\omega)}{\tilde{Z}_{RE}(\omega)}\right)$$

In impedance-based microfluidic cytometers, microelectrodes are fabricated inside a microchannel and the impedance signals of large numbers of cells are measured at high flowing speed, one cell at

a time (Figure 1). The first cytometer capable of measuring the electrical properties of single cells, was developed by Coulter [7]. The device measures the DC resistance between two electrically isolated fluid-filled chambers as cells pass through a small connecting orifice. For a fixed sized orifice, the change in electrical current can be used to count and size the cells. Recent chip designs now use AC signals at high frequencies to give information on cell dielectric properties as well as cell volume [8-10].

A typical example of on-chip single cell impedance measurement is shown in figure 1. Two pairs of microelectrodes are fabricated in a microchannel which is typically 40μm high and wide. The two electrodes allow a differential impedance measurement to be made. One pair is used for sensing the electrical signal fluctuation induced by the cell, the other measures the electrical signal passing through the unperturbed medium as an electrical reference. As the cell passes through the AC electric field in the channel (under pressure-driven flow), there is a change in the impedance which is indicative of the size, shape and dielectric properties of the cell. This impedance signal is sensed as a changing current signal by the bottom microelectrodes. A positive and negative peak is observed, as the cell passes though the channel – figure 1(b).

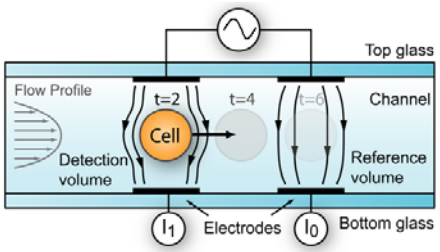

Figure 1 (a)

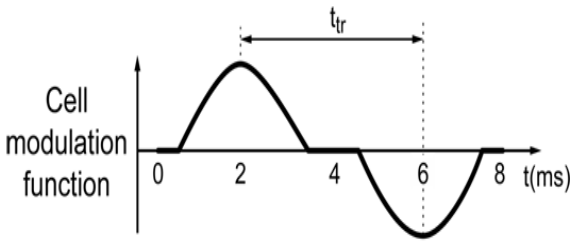

Figure 1 (b)

FIGURE 1: (a) Diagram showing the impedance analysis chip and a single cell flowing through the microfluidic channel. In the differential measurement scheme, the difference between the currents passing through the detection and reference volume is measured. The electrodes are typically 20μm wide and long. (b) Diagram showing the variation of the differential signal as the particle passes through the channel.

For small cells (low volume fraction), the complex permittivity of a cell in suspension is determined by Maxwell's mixture theory [1]. This approach works well for volume fractions less than 10%; the analysis was extended for higher volume fraction by Bruggeman [11] and Hanai [12]. The characteristics of the impedance spectrum of the suspending system can identified over different frequency ranges. A cell has a thin insulating membrane, and the measured permittivity of a suspension of cells has a high value at low frequencies due to charging of this membrane. As the frequency increases, the value of the permittivity decreases, approaching that of the suspending medium. Using a differential measurement scheme, and for a cell suspended in physiological medium, the cell size is determined at low frequencies (< 1MHz). The cell membrane capacitance can be determined in a frequency window between 1-10 MHz and at even higher frequencies; the properties of the cell cytoplasm are probed. The technique can be used to discriminate between different cell types (e.g. sub-populations of leukocytes), measure the effects of chemical agents on cells, or probe changes in cell structure.

In summary, impedance measurements of single cells gives information on cell size, membrane capacitance and cytoplasm conductivity. It allows the identification and differentiation of cells sub-populations at high speed. It is non-invasive and label-free, and has a wide range of biotechnological and biomedical applications.

References

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Past Conferences

Electrostatics 2007

For those not aware of it, the Electrostatics Group organises a major international conference on Electrostatics every four years, the last of which was held at St Catherine's College Oxford, and co-sponsored by ESDA, ISSA Electricity Section and the Journal of Electrostatics.

The event itself was a huge success, with Plenary talks from Dr Martin Glor, Professor Greg Rutledge, Professor Andreas Stemmer and Professor Tom Jones.

Among the topics discussed were: atmospheric electrostatics; bioelectrostatics; environmental electrostatics; fluids; hazards; nanoelectrostatics; planetary electrostatics; powders and aerosols; and modelling and stimulation. The proceedings of this event are available online at:

http://www.iop.org/EJ/toc/1742-6596/142/1

Electromagnetic Phenomena and Health - A Continuing Controversy?

Another, slightly more recent, international event organised by the group was "Electromagnetic Phenomena and Health - A Continuing Controversy?" which took place on 10 September 2008 at 76 Portland Place, London.

This event was also well attended and a great success, with many high profile world-speakers, and our own group secretary, providing a number of thought provoking presentations over the course of the day.

Professor Derek Clements-Croome, the Vice-President of the Chartered Institute of Building Service Engineers (CIBSE), Professor of Construction Engineering at Reading University, editor of the book "Electromagnetic Environments and Health in Buildings" (Spons 2004), and Chairman of the CIBSE Intelligent Buildings Group, was the able Chairperson for a stimulating morning session.

The keynote speech was given by Professor Michael Repacholi from the University of Rome, who was previously Radiation Specialist in Occupational and Environmental Health and the Protection of the Human Environment for the WHO, coordinator of the WHO EMF Project (1996-2006), and Inaugural Chairman of the International Commission on Non-Ionizing Radiation Protection (ICNIRP).

After Professor Repacholi's talk, a presentation was given by ICNIRP member Professor Paolo Vecchia, who is the Head of the Non Ionizing Radiation Section of the Physics Laboratory of ISS, President of the European Bioelectromagnetics Association (EBEA) and Past President of the Italian Radiation Protection Association (AIRP). Part of his responsibilities relate to giving suitable advice to health and environmental authorities on any health problems that may be related to non-ionising radiation, and his informed and heartfelt presentation was able to help correct a number of possible misconceptions about the role of such bodies in advising on standards, the difficulties that are faced, and how the need for good science was paramount.

Following on from that presentation was Professor Yury Grigoriev, the Chairman of the Russian National Committee on Non-Ionizing Radiation Protection, who amongst his many positions is also a member of the Russian National Commission on Ionising Radiation Protection, and a member of the International Advisory Committee of the WHO on their International Program EMF and Health. Whilst agreeing with the first two speakers on many points, Professor Grigoriev opened the scientific debate further on possible non-thermal effects of electromagnetic radiation, and suggested that there may be many benefits in actively adopting lower exposure guidelines, such as those presently recommended by the Russian Federation.

Professor David O. Carpenter from the Institute for Health and the Environment at the University of Albany, NY, who was co-editor of the 2007 "Bioinitiative Report", two 1994 volumes entitled "Biological Effects of Electric and Magnetic Fields", and Executive Secretary of the New York State Powerlines Project in the 1980s, was next to speak and aired similar views to Professor Grigoriev, adding momentum to the debate, as did the last speaker for that session Professor Olle Johansson, a Professor at The Royal Institute of Technology in Stockholm, Sweden, and an Associate Professor, and Head of the Experimental Dermatology Unit at the Karolinska Institute's Department of Neuroscience.

Whilst the views of some of the morning speakers were sharply contrasting, what was perhaps most striking in this generally good natured and thought provoking debate was the shared desire of all parties to use good, rigorous scientific research to clarify the true need for precaution that may exist.

The potential benefits of gaining such understandings were examined further during the afternoon session chaired by Professor Repacholi.

The first speaker for that session was Professor Henry Lai, from the University of Washington, who discussed the biological effects of non-ionizing radiation from extremely-low-frequency to radiofrequency electromagnetic fields and the exciting prospects of using suitably adapted electromagnetic fields for the treatment of various diseases, such as malaria and cancer.

Professor Lai's presentation appeared particularly important in indicating a range of benefits that might be achieved through greater knowledge being gained in this field, and that beneficial effects can be noted through exposures to appropriate field protocols.

This possibility was then spoken about further by the next speaker (the present writer) examining examples of possible benefits, and pitfalls to avoid, when seeking to employ the 'precautionary principle' and As Low As Reasonably Acceptable (ALARA) regimes to create 'healthier' electromagnetic environments indoors in home, office and healthcare facilities, and why there may often be a need to proceed with caution when seeking to design such environments.

The penultimate speaker was Dr. John Swanson, scientific advisor to the UK National Grid, and advisor on electric and magnetic fields for the Electricity Association and stakeholder of SAGE (Stakeholder Advisory Group ELF EMF), with some personal views on the work he does, and how important it is to consider the individual. His words were very much appreciated and again indicated the difficulties that can arise in this field.

Professor Emeritus Michael J. O'Carroll from the University of Sunderland, who is also a UK Stakeholder Advisory Group ELF EMF (SAGE) stakeholder member, gave the final presentation speaking about possible ways ahead in this scientific debate and the need for proper dialogue between all parties, before the matter was thrown open to the floor by Professor Repacholi for a question and answer session with the audience.

Perhaps what was most apparent from this whole day, and the civilised discussions of the matters in hand, were the complexity of the scientific challenges we face, the benefits that might be achieved in this field by further trying to see things from the scientific viewpoints of others, and the insights that such approaches may provide.

Dr Isaac Jamieson

Forthcoming Conferences/Seminars

Electrostatics 2011

Planning is now underway for the 13th International Conference on Electrostatics. The first announcement and call for paper will be released soon.

Events of Interest

Whilst we try to keep our fingers on the pulse of current events, there is always the chance that some events of interest may slip under the radar unless we are informed of them by members, so do get in touch if you feel there are events out there that group members may be interested in taking part in.

Ideas for Future Conferences/One Day Meetings

The group always welcomes constructive ideas on possible topics for meetings from members, so do get in contact with the Chair (Paul Holdstock), or Secretary (Isaac Jamieson), if you feel there is a topic related to electrostatics that you believe would be worthy of turning into an event. This particularly holds true if you would like to get involved in helping to put it together!

Your Electrostatics Group Committee 2008-2009

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Items for Newsletter

Feedback and contributions are always welcomed, particularly if they are of the sort we are able to print! So if you would like your work, or work of others to be better known, or wish to discuss challenges within the field, please consider sending us an article. They are normally quite painless to write - usually being of up to 300 words in length - and can often help greatly with networking to let others know what you are up to, or your present areas of interest.

Items can include, but are no means limited to, news articles, photographs, conference/meeting reports, events of interest, cartoons, etc. Additionally, the more that you contribute, the more often we can issue this newsletter!

In order to reflect the diversity of the group's membership, we would especially welcome articles from the female and student members of our group who are currently under represented.

Please send items to:

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Closing date for submissions for next issue: 4th September 2009.