Plasma Science and Technology
Room: Galisteo - Session PS2+BI-ThA

Plasmas for Medical and Biological Applications
Moderator: S. Hamaguchi, Osaka University, Japan

2:00pm **PS2+BI-ThA1 Activation of Cell under the Atmospheric Pressure Plasma Irradiation**, ***T. Hirata***, *C. Tsutsui*, *A. Mori*, *T. Yamamoto, A. Taguchi*, Tokyo City University, Japan **INVITED**

The researches in the case of "novel plasma" have been widely conducted in the fields of chemistry, solid physics, and nanomaterial science. Such plasma uses a boundary reaction field in a liquid or gaseous-liquid phase based on application of liquid plasma, micro plasma, and atmospheric pressure plasma. In particular, atmospheric pressure plasma is indispensable not only for sterilization, disinfection, decomposition of hazardous materials, and surface modification but also for the cultivation and development of complex new areas which require a diverse perspective, involving biomedical science. From the above-mentioned background, we are conducting basic experiments on direct irradiation of cells using a micro-spot atmospheric pressure plasma source.

The device is a coaxial structure having a tungsten wire (1 mm I.D.) installed inside a glass capillary (plasma generation area: 8 mm I.D.; tip area: 1 mm I.D.), and a grounded tubular electrode wrapped on the outside. The high voltage for the plasma generation is provided by the high voltage power supply. The conditions of plasma generation are as follows: applied voltage: 5-9 kV, frequency: 1-3 kHz, helium (He) gas flow rate: 1 L/min, and plasma irradiation time: 1-300 sec. The experiment was conducted by preparing a culture medium containing mouse fibroblasts (NIH3T3) on a culture dish (made of polypropylene). A culture dish irradiated with plasma was introduced into a CO_2-incubator.

According to the dependency of cell numbers against the plasma irradiation time, when only He gas was flowed, the growth of cells was inhibited as the floatation of cells caused by gas agitation inside the culture was promoted. On the other hand, there was no floatation of cells and healthy growth was observed when plasma was generated. Therefore, it appears that the interaction due to ion/radical collisions on the culture surface causes a substantial effect on the proliferation of growth factors such as epidermal growth factor (EGF), nerve growth factor (NGF), and transforming growth factor (TGF) that are present in the cells.

2:40pm **PS2+BI-ThA3 Stability of Highly Functionalised Plasma Polymerised Acrylic Acid Thin Films in Aqueous Environments**, ***C.D. Easton***, *A. Pegalajar Jurado*, *A. Badri*, *S.L. McArthur*, Swinburne University of Technology, Australia

Plasma polymerisation provides a convenient one step method for creating a functionalised organic surface on virtually any substrate. This technique has attracted considerable attention in recent years for application within the biomedical field as a substrate for cell culture and as a surface functionalisation for polymer grafting and protein immobilisation *[1-4]*. Detailed stability studies of these coatings in aqueous solutions have focused on water rather than more biological relevant solutions including phosphate buffered saline (PBS). Critically, the interplay between coating stability and protein and polymer adsorption on the coating behaviours have rarely been examined.

Within this study, highly functionalised acrylic acid thin films have been fabricated via RF plasma polymerisation and the stability of these coatings in aqueous environments examined. The chemical and physical stability of these coatings in water and PBS were investigated using X-ray Photoelectron Spectroscopy (XPS), Atomic Force Microscopy (AFM) and Quartz Crystal Microbalance with Dissipation (QCM-D). The results have shown that the physical behaviour of the coatings changes significantly when they are exposed to water and buffers with differing pH and ionic strength. The significance of these stability observations in an application setting has been explored where the plasma polymerised acrylic acid coating has been used in the assembly of polyelectrolyte layers and biomolecule immobilisation.

References:

[1] K. S. Siow, L. Britcher, S. Kumar, H. J. Griesser, *Plasma Process. Polym.* **2006**, *3*, 392.

[2] R. Forch, A. N. Chifen, A. Bousquet, H. L. Khor, M. Jungblut, L. Q. Chu, Z. Zhang, I. Osey-Mensah, E. K. Sinner, W. Knoll, *Chem. Vapor Depos.* **2007**, *13*, 280.

[3] H. E. Colley, G. Mishra, A. M. Scutt, S. L. McArthur, *Plasma Process. Polym.* **2009**, *6*, 831.

[4] G. J. S. Fowler, G. Mishra, C. D. Easton, S. L. McArthur, *Polymer* **2009**, *50*, 5076.

3:00pm **PS2+BI-ThA4 Scalable Atmospheric DBD Device for Biomedical Processing**, ***S. Kitazaki***, *T. Iwao*, *G. Uchida*, *K. Koga*, *M. Shiratani*, Kyushu University, Japan, *N. Hayashi*, Saga University, Japan

Nonthermal atmospheric discharge plasmas have been employed for biomedical processing applications, because they offer low temperature processing [1-3]. We have developed a scalable atmospheric dielectric barrier discharge (DBD) device for biomedical processing in a large area. The device consists of 12 electrodes of a stainless rod of 1 mm in outer diameter and 60 mm in length covered with a ceramic tube of 2 mm in outer diameter. In principle, the device size can be extended to a large area by increasing the electrode length as well as the number of electrodes. The electrodes are arranged parallel with each other at a distance of 0.5 mm. The frequency of applied voltage was 10 kHz, and its peak-to-peak voltage was 10 kV. The peak discharge current was about 0.15 A and the duration of each current pulse was about 10 ns. To obtain information about radicals generated in the discharges, UV-Visible emission spectra were measured with a multi-channel spectrometer. Spectral lines of N_2 2nd positive band (280-400 nm) were observed in air DBD discharges. We apply the device to process seeds of radish sprouts. We compare germination and growth of seeds with one minute plasma irradiation to those of seeds without irradiation. While the germination periods of these two kinds of seeds are 2 days, being nearly the same with each other, the growth rate of irradiated seeds is 20-50% faster than that without irradiation. These results suggest that the DBD device is useful for such biomedical processing applications.

[1] J. Raiser and M. Zenker, J. Phys. D, 39, 3520 (2006).

[2] M. G. Kong, et al., New J. Phys., 11, 115012 (2009).

[3] A. Helmke, et al., New J. Phys., 11, 115025 (2009).

3:40pm **PS2+BI-ThA6 2010 AVS Medard Welch Award Lecture - Controlling Plasma Sources: Nano to Bio**, *N.Yu. Babaeva*, *S.-H. Song*, University of Michigan, Ann Arbor, *J. Shoeb*, *M. Wang*, Iowa State University, *Y. Yang*, Applied Materials, Inc., ***M.J. Kushner****, University of Michigan, Ann Arbor **INVITED**

4:20pm **PS2+BI-ThA8 Spectral Signatures of Amine Species at Aminated Surfaces Prepared by using Plasma Techniques, Self Assembling of Thiols and Silanization**, ***W.E.S. Unger***, *N. Graf*, *P.M. Dietrich*, *H. Min*, *P.-L. Girard-Lauriault*, *A. Lippitz*, *T. Gross*, BAM Federal Institute for Materials Research and Testing, Germany

The determination of amines on surfaces capable of binding biomolecules is important for the understanding and optimization of technologically relevant coupling processes. Different relevant types of amino-functionalized model surfaces have been investigated by complementary tools of surface analysis: XPS, NEXAFS spectroscopy and ToF-SIMS with Principal Component Analysis. Amino-terminated surfaces have been prepared from aliphatic and aromatic aminosilanes and aminothiols by self assembly, plasma polymerization of allyl amine and plasma activated polyethylene foils reacted with 1,2-diaminoethane. The determination of those amino groups which are available to serve as attachment sites for biomolecules in technical applications by wet chemical derivatization (CD) XPS using 3,5-bis(trifluoromethyl)phenyl isothiocyanate was a special issue of interest. In another experiment the in-depth homogeneity of a pulse plasma polymerized allyl amine film after derivatization with 4-trifluoromethyl benzaldehyde (TFBA) was investigated by using variable excitation energy XPS. Finally, effects of aging in air and damage by X ray radiation on aminated surfaces are addressed.

Problems of the CD XPS approach for a determination of amines will be discussed with a focus of comparability of results obtained in different labs.

4:40pm **PS2+BI-ThA9 Correlation of Properties of Polymeric Organic Layers with Plasma Parameters**, *S. Umrath*, *F. Schamberger*, ***G. Franz***, Hochschule Muenchen, Germany

For exact deposition of thin films out of the vaporous phase (cvd), an entire knowledge of the process parameters such as flows, pressure and gaseous temperature is required. In the case of pecvd, this means the extension on influencing plasma variables like plasma density and electron temperature, in particular in large reactors for production purposes to meet the demands

***** Medard W. Welch Award Winner

for flat layer qualities (growth and composition) over the whole reactor volume.

In an almost cubical reactor 80 l in volume, the microwave power is coupled into the volume via a quartz window which exhibits approximately 1/10 of the sidewall area. The spatial compilation of these plasma quantities along with plasma potential has been accomplished with a bendable Langmuir probe. To isolate the tungsten wire against its grounded housing tube, it was coated with polyparylene. After having compared this construction with our Langmuir probe which has been now in use for more than a decade, we have taken data of the whole reactor with argon and with mixtures of monomers of parylene and argon or oxygen in a pressure range between 10 mTorr and 150 mTorr (1 1/2 Pa to 20 Pa) applying a new evaluation procedure [1]. Over the covered range, the plasma density remains in the dielectric regime (plasma degree less than 100 ppm).

Compared to discharges through pure argon, the plasma parameters exhibit opposing behavior: at same discharge pressure and power input, the plasma density is lower, whereas the electron temperature goes up. The layers are highly transparent with a slightly yellow color. Ftir measurements reveal that the ring structure still remains intact. Adding oxygen to the ambient to the monomeric vapor leads to hydrophilic surfaces which is caused by the formation of CO bonds and OH bonds. The creation of these features is confined by power input. If it is raised beyond 4 W/l, the reaction mechanism drastically changes from surface polymerization to volume polymerization leading to thick, low-density films which can be easily be scratched away. This change has been traced by plasma diagnostics and mass spectrometry. At a threshold density of about $1 \times 10^{10} cm^3$ (plasma degree about 1000 ppm), all peaks beyond 44 (CO_2) vanish. In the resulting mass spectrum, no CH vibrations beyond 3000 cm^{-1} can be detected indicating the complete destruction of the aromatic system.

[1] Peter Scheubert: Modelling and Diagnostics of Low Pressure Plasma Discharges, PhD thesis, Bochum, 2002

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