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Plasma technologies for a sustainable future: unique plasma processes for applications in biomedicine and space with opportunities in cellular agriculture and vaccine development

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Australia's enviable endowment of untapped solar energy renders it very attractive for investment in solar energy infrastructure. This is exemplified by Sun Cable Pty Ltd who are planning to build the world's largest solar power plant in outback Australia. The time is ripe to create advanced plasma-based manufacturing capabilities that leverage our vast renewable energy reserves and develop new plasma technologies to facilitate the transition to renewable energy economies.

Plasma technology is a Power-to-X (P2X) processing technology with inherent potential for coupling with renewable electricity to create value-added products. As plasmas do not require heating or pressurization of reaction vessels, they can be switched on and off rapidly, providing opportunities for materials synthesis and processing, that can take advantage of the peaks inherent in renewable electricity generation.

This presentation will describe unique plasma processes for applications in biomedicine and space, developed at the University of Sydney and currently being commercialized, as well as highlighting future opportunities.

Materials used in biomedicine are selected according to bulk properties, such as mechanical, electrical and optical, required for particular in-vivo and in-vitro applications. However, their surfaces almost always provide suboptimal biological microenvironments that do not promote the desired biological responses. To address this problem, we have developed sustainable and readily scalable plasma surface modification processes that enable resilient and easily tailorable biomolecule immobilization on all materials and structures, including the internal surfaces of multi-well plates, porous scaffolds and micro/nanostructures. This technology can be deployed to create bioinstructive cell microenvironments for cell culture (being commercialized by Culturon Pty Ltd), tissue integration, and nanomedicine. Typical time scales of cell culture and tissue integration necessitate covalent immobilisation to prevent interface instability due to desorption and exchange of the immobilized molecules with molecules in the surrounding aqueous environment. Our processes are suitable for a range of materials and structures and enable spontaneous, reagent-free, covalent functionalisation with bioactive molecules and hydrogels. Functional molecules that can be immobilised to create tailored biological microenvironments include but are not limited to, oligonucleotides, enzymes, peptides, aptamers, cytokines, antibodies, cell-adhesion extracellular matrix molecules, and histological dyes. The covalent immobilisation occurs on contact via radicals embedded in the surface by energetic plasma species. Strategies to immobilise biological microenvironment patterns and hydrogels onto the plasma-activated surfaces and to prepare multi-functionalisable nanoparticles will be described, together with strategies to control the density and orientation of surface-immobilised biomolecules. Potential opportunities in cellular agriculture, drug delivery and rapid vaccine development and deployment will be noted.

Plasma-deposited coatings to optimize surface properties outside of biomedicine are well established. Highly ionized plasmas in sources such as high-power impulse magnetron sputtering (HiPIMS) and cathodic arc are attractive as the depositing species'energies can be easily tailored to optimize microstructures. Recent examples in the development of electrochromic and high entropy alloy coatings will be presented, together with the application of our centre-triggered cathodic arc as a unique space thruster (being commercialized by Neumann Space Pty Ltd), which is capable of using space junk as fuel.

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