Austin Journal of Nanomedicine & Nanotechnology

Austin Publishing Group

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Editorial

Water in Nanomedicine & Nanotechnology

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Received: January 04, 2014; Accepted: January 08, 2014; Published: January 14, 2014

When 157 years ago Michael Faraday reported on the preparation of colloidal gold in nanometer size and of thin films of gold – *Experimental Relations of Gold (and Other Metals) to Light* [1] – nobody believed that his findings would be of any practical value. Indeed, Faraday's discovery did not preoccupy the scientific community for almost 100 years. The explosion in applications of gold nanoparticles in nanotechnology in general, and in nanomedicine in particular, illustrates the big picture before and after the nanotechnology revolution, which was actually propelled by Feynman's $1,000 invitation "think small". The extraordinary momentum of the progress can be understood when we realize that the technological advance proceeds simultaneously in a multitude of fields, which are topically totally different. Practical exploitation of the potential of this trend demands for unprecedented multidisciplinary diversity.

Therefore, "think small" has to be logically extended by "think big". Following this approach, we recently directed the attention of the nanotechnology community to nanoscopic interfacial water layers, found to uniformly mask both hydrophilic and hydrophobic surfaces. Hydrophilic surfaces exposed to air are known to be wetted with a thin water layer. The prevalence of a wetting layer on hydrophobic surfaces was indicated by the measurements of James et al. [2], thereby confirming our earlier results on the subject [3]. To better understand the importance of nanoscopic interfacial water layers in both nanotechnology and nanomedicine, it is instructive to recapitulate here the results of recent atomic force acoustic microscopy (AFAM) experiments, which explored nanoscopic interfacial water layers under ambient conditions on a variety of substrates, including nanocrystalline diamond. The importance of diamond in investigating nanoscopic interfacial water layers is clear: Diamond is inert both chemically and biologically. Other materials are showing corrosivity and the release of ions, thereby perturbing the intrinsic molecular organization of the nanoscopic interfacial water layers on their surfaces. The principal result of the AFAM experiments was that 670 nm laser light applied at intensities as low as 50 Watt · m^{-2} was capable to tune (modulate) the structure of the water masks in the contact space between the atomic force microscope tip and the ultrasonically excited substrates beneath [4]. Interestingly, nanoscopic interfacial water layers on hydrogen-terminated nanocrystalline diamond showed less susceptibility to the laser light than those masking the non-hydrogenated species, reflecting a pronounced bond stability of the water films on hydrogenated diamond [5]. We explained the bond stability in terms of an ordering effect caused by vertical hydrogen bonds – polarizing the water molecules on the surface of hydrogenated diamond. This effect is virtually absent on the non-hydrogenated species. Concomitant with the picture of a layer of polarized water molecules on hydrogen-terminated diamond, and the low friction coefficients resulting from the electrostatic repulsion between two such surfaces in contact (cf. Fig. 2 in ref 5), we obtain design principles for the reduction of the friction and wear between micromechanical components, e.g., in mechanical watches [6].

In a study which explored the interplay between nanoscopic interfacial water layers and their contact environment we suggested that order is not only imposed on the water layers by the substrate, but that the ordered water layers themselves possess the potential to induce order, for instance, to biological structures. With emphasis on the nature of water layers masking living cells, and at the interface between differently polar structures in the body, such as hydroxyapatite crystallites and the organic matrix, it was predicted that biomineralization and biocrystallization processes are controlled by the order of nanoscopic interfacial water layers [3]. Recently, the prediction received partial validation [7]. Furthermore, the analysis of nanoscopic interfacial water layers provided intuitive hints, which justified their consideration in evolutionary modeling, nanotechnology and nanomedicine. Starting from the capacity of nanoscopic interfacial water layers to impose order, we established an origin-of-life model, offering a simple explanation to the facilitated self-assembly of primordial amino acids to the first polymers on naturally hydrogenated natural diamonds covered with nanoscopic interfacial water layers [8]. The catalytic capacity of the nanoscopic interfacial water layers, and its interplay with laser light, has been recently exploited in the production of extremely ordered body-centered cubic carbon nanocrystals from a meta stable carbon phase [9], a modification predicted by Johnston and Hoffmann [10].

Earlier, we demonstrated that the results obtained from the modulation of nanoscopic interfacial water layers on model surfaces could be applied to biology. We could show that intermittent irradiation with 670 nm laser light applied at non-destructive levels was capable to modulate the interfacial water layers presumed to mask the myriads of macromolecules in the crowded space [11] in the interior of living cells. For instance, we used moderate levels of 670 nm laser light to force cancer cells to uptake cytostatic/cytotoxic drugs *in vitro* [12]. Using a similar protocol we reduced amyloid-β concentrations in neuroblastoma cells [13]. However, relevant non-destructive biological effects of low levels of irradiation are not limited to the visible spectrum of light [14].

Notably, surfaces exposed to air or covered with water are not necessarily masked with nanoscopic interfacial water layers. The data presented in previous work [15] leave room to the possibility

Citation: Sommer AP, Fecht H-J. Water in Nanomedicine & Nanotechnology. Austin J Nanomed Nanotechnol. 2014;2(2): 1012.

that certain biomaterial surfaces, e.g., polystyrene, convert interfacial water to interfacial reactive oxygen species (ROS). This insight motivated the design and development of a new generation of cell-friendly diamond-coated Petri dishes [16]. We hope that this brief overview will inspire further research.

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Austin J Nanomed Nanotechnol - Volume 2 Issue 2 - 2014
ISSN : 2381-8956 | www.austinpublishinggroup.org

Citation: Sommer AP, Fecht H-J. Water in Nanomedicine & Nanotechnology. Austin J Nanomed Nanotechnol. 2014;2(2): 1012.