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Citation: AIP Conference Proceedings **1731**, 040002 (2016); doi: 10.1063/1.4947638
View online: http://dx.doi.org/10.1063/1.4947638
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Enhancement in Biological Response of Ag-Nano Composite Polymer Membranes Using Plasma Treatment for Fabrication of Efficient Bio Materials

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Abstract. Biomaterials are nonviable material used in medical devices, intended to interact with biological systems, which are becoming necessary for the development of artificial material for biological systems such as artificial skin diaphragm, valves for heart and kidney, lenses for eye etc. Polymers having novel properties like antibacterial, antimicrobial, high adhesion, blood compatibility and wettability are most suitable for synthesis of biomaterial, but all of these properties does not exist in any natural or artificial polymeric material. Nano particles and plasma treatment can offer these properties to the polymers. Hence a new nano-biomaterial has been developed by modifying the surface and chemical properties of Ag nanocomposite polymer membranes (NCPM) by Argon ion plasma treatment. These membranes were characterized using different techniques for surface and chemical modifications occurred. Bacterial adhesion and wettability were also tested for these membranes, to show direct use of this new class of nano-biomaterial for biomedical applications.

Keywords: Ag nanoparticle, Plasma Treatment, High adhesion, Wettability, Surface modification, Nano-Bio Material.
PACS: 87.85.jj, 87.85.Qr, 87.85.Rs, 78.67.Sc, 82.35.Gh, 81.65.Kn

INTRODUCTION

Polymers have become a very important class of materials in modern manufacturing processes offering a wide variety of chemical, mechanical & elastic properties in addition to lightweight, flexibility and process-ability: applicable in numerous applications like gas filtration [1], bactericidal & biological systems [2] and mechanical applications [3] etc. Although these polymers are receiving great interest due to their increasing applications for synthesis of biomaterial and addition of many peculiar properties which can be of a great help in the field of biological systems [in-vivo or in-vitro]. Biomaterials are widely used in medical devices, intended to interact with biological systems [in-vivo]. Medical devices based on poly methyl methacrylate (PMMA) being used for the preparation of bone cement, intraocular lenses, contact lenses, fixation of articular prostheses, dentures, adhesives, artificial hearts and skin and blood contacting devices, various catheters synthesis [4]. In order to use polymers as a biomaterial, some peculiar properties such as antibacterial, antimicrobial, high chemical functionality, low surface energy and geometries, blood compatibility, high adhesion and wettability have to be provided to it or generated within, which can be achieved only *via* reinforcement of the nanoparticles and further treatment with the plasma beam. Here, in this study the authors report embedding of the Ag nanoparticles into PMMA and further treating the so prepared NCPM with argon plasma to achieve high adhesion and wettability to develop a new class of nano-biomaterial.

EXPERIMENTAL

Synthesis of Ag nanoparticles were carried out at room temperature using a simple chemical precipitation route as described by B. Sadeghi *et al*. [5] and characterized by TEM (Fig. 1), the size of Ag particles was observed to be about 20-25 nm.

DAE Solid State Physics Symposium 2015
AIP Conf. Proc. 1731, 040002-1–040002-3; doi: 10.1063/1.4947638
Published by AIP Publishing. 978-0-7354-1378-8/$30.00

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Poly methyl methacrylate (PMMA) granules and 2 wt. % Ag nanoparticles [weight percent method] were used to prepare nanocomposite polymer membranes of thickness 20μm using solution cast method in dichloromethane [2]. Plasma chamber set up consists of source with power supply which is connected to a vacuum system. The argon gas was used for generating plasma is filled in the source chamber using a flow controller and DC glow discharge has been generated. Argon plasma in the chamber is used for the surface modification of PNCM.

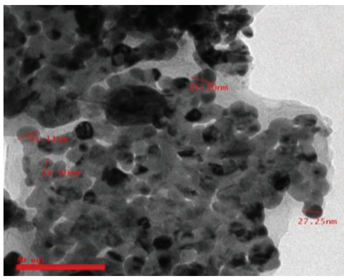

FIGURE 1. TEM image of Silver Nanoparticles, Particle size ranging 20-25 nm.

RESULTS AND DISCUSSIONS

At low pressure accelerated ion of Ar has sufficient energy to induce cleavage of the chemical bonds, graft copolymerization, modify polymer surface, functionalization, valuable tool to improve their adhesion properties and wettability. The effect of Ar plasma treatment/modification on the surface of membrane is primarily investigated by SEM (Fig 2) it is found that surface roughness of NCPM is increased after plasma treatment. The similar trend is also observed in 3D surface profile study of NCPM by surface profile-meter at much higher resolutions (Fig 3).

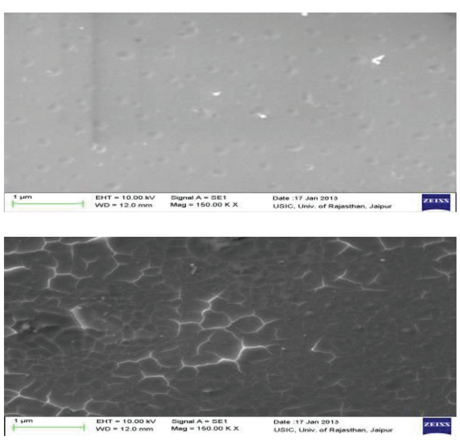

FIGURE 2. SEM images of NCPM before and after plasma treatment.

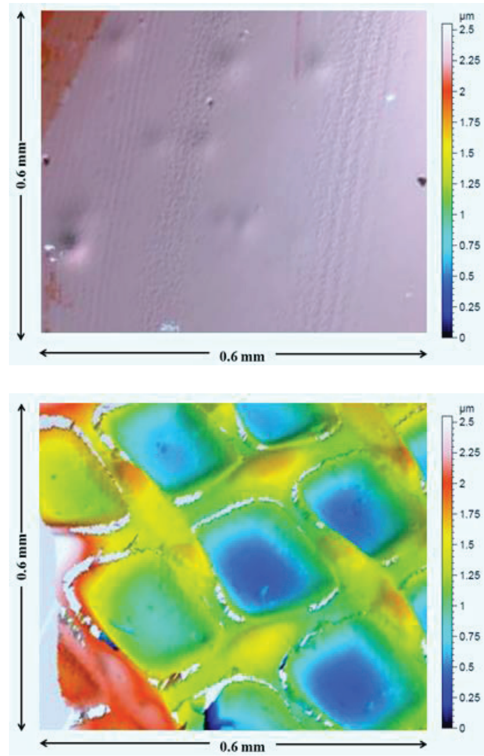

FIGURE 3. Surface profile of NCPM before and after plasma treatment taken by surface profilometer (Taylor Hobson).

Bacterial adhesion

To observe the adhesion of bacteria on membrane, E. coli bacteria was chosen as it is relatively easy to handle, nontoxic, readily available and shows clear colonies within 24 hrs. Standard E. coli inoculums having E. coli (≈ 115 cfu/mL) were inoculated in 100 mL sterilized normal saline. Next, few drops of standard E. coli inoculums were dropped on autoclaved NCPM (treated or untreated) which already have liquid nutrient agar media mounted on it. These NCPM were kept at 37 ºC in the incubation chamber. Clear colonies of bacteria were observed after 24 hrs. Then these membranes were washed in running water for 10 minutes and studied under optical microscope. Results shown in fig 4 shows, very high bacteria content on plasma treated NCPM comparative to untreated NCPM i.e. bacteria/cells adhered poorly to the control/untreated surface and are found to be better adhered to plasma-treated NCPM which shows better adhesion and hydroxylation properties of these NCPM. Hence it shows Plasma treatment provides excellent adherence/adhesion to NCPM may be due to hydrogen bonding between the hydroxyl groups on the polymer surface and the polar groups on the bacteria surfaces.

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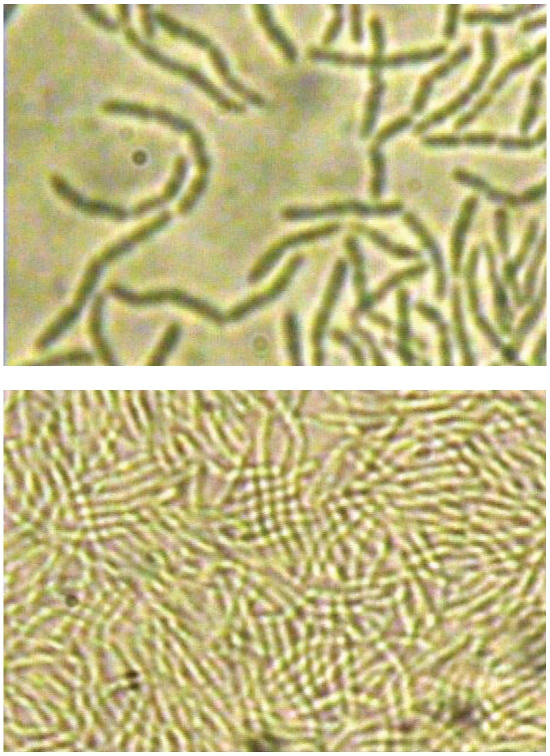

FIGURE 4. Bacterial adhesion study on NCPM before and after plasma treatment.

Surface Wettability and Energy

Hydrophobic polymers are not favorable for cell, bacterial attachment and proliferation over the surface. Hence surface wettability and effect of process parameters on surface energy is measured by measuring water contact angles for NCPM. A 2 µl droplet of ultra-pure water (Milli Q) was placed on a horizontal NCPM surface and observed the contact angle. Results (Fig 5) show that water contact angles for untreated membranes changed from 120º to 45º for plasma treated NCPM. Thus, plasma treatment also provides high wettability to NCPM. Polar and dispersion components of surface energy were calculated using the Owens–Wendt method [4]. Untreated NCPM have almost a non-polar surface with a polar component γ^p_s = 0.8 mJ/m^2 and dispersion component γ^d_s = 19.2 mJ/m2 which makes its surface energy γ_s = 20.0 mJ/m^2. But after Plasma treatment polar component becomes γ^p_s = 8.0 mJ/m^2 and dispersion component γ^d_s = 20.0 mJ/m^2 which makes its surface energy γ_s = 28.0 mJ/m^2. i.e. the plasma treatment shows significant increase in the polar component of surface energy and thus in the polarity after plasma treatment.

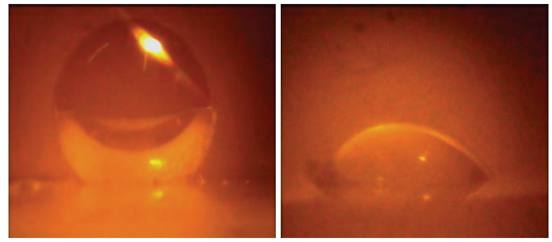

FIGURE 5. Wettability study on NCPM before and after plasma treatment.

SUMMARY & CONCLUSION

Low pressure Argon plasma treatment increase surface activation, roughness & wettability by lowering surface energy. The observations and results of this investigation suggest that plasma processing is an extremely useful technique to enhance Bio/bacterial adhesion for NCPM. In general conclusion, it is important to highlight that low pressure Ar plasma treatment provide necessary properties to NCPM required for synthesis of Nano-bio materials and medical device in environment friendly & efficient method by improving adhesion & other technical properties.

ACKNOWLEDGMENTS

The authors are thankful to University of Rajasthan for providing characterization facilities. Authors are also thankful to Taylor Hobson, Ametek for providing the surface profilometer characterization facilities.

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