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The biocompatibility and antibacterial properties of waterborne polyurethane-silver nanocomposites

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ABSTRACT

Nanocomposites from a polyester-type waterborne polyurethane (PU) containing various low concentrations (15–75 ppm) of silver nanoparticles (nano Ag, size ∼5 nm) were prepared. The PU–Ag nanocomposites exhibited good nanoparticle dispersion up to 30 ppm of nano Ag, confirmed by the transmission electron microscopy. Distinct surface morphology at different concentrations of nano Ag was shown by the atomic force microscopy. The oxidative degradation of PU–Ag was inhibited in all concentrations of nano Ag tested, especially at 30 ppm ("PU–Ag 30 ppm"). This may be related to the free radical scavenging ability observed for the nanocomposites. PU–Ag 30 ppm showed enhanced fibroblast attachment and endothelial cell response, as well as reduced monocyte and platelet activation, relative to PU alone or nanocomposites at the other silver contents. The rat subcutaneous implantation confirmed the better biocompatibility of the nanocomposites. The adhesion of *Bacillus subtilis, Escherichia (E.) coli* or Ag^+-resistant *E. coli* on PU–Ag nanocomposites was significantly lower at all concentrations of nano Ag tested. Besides, the nanocomposites demonstrated microbiostatic effect while pure PU did not. The commercial catheters coated with PU–Ag 30 ppm were inserted into rat jugular veins for evaluation. The results showed milder inflammation for PU–Ag after 3 months compared to the non-coated catheters or pure PU-coated catheters. The enhanced performance of PU–Ag over that of pure PU was a result of extensively modified surface morphology in the presence of a very small amount of nano Ag. The dispersion of nano Ag was highly associated with the overall performance.

1. Introduction

Polyurethane (PU) is one of the most attractive synthetic elastomers and is extensively used in biomedical applications due to the good biocompatibility and mechanical properties [1]. The continuous reduction in costs and the control of volatile organic compounds have driven the expansion of waterborne PU formulations. The resultant waterborne materials possess many of the features related to the traditional organic solvent-borne PU with the benefit of low viscosity at high molecular weights, non-toxicity, and good applicability [2]. However, the properties of waterborne PU need to be further improved for biomedical applications.

Silver (Ag) is regarded as one of the noble metals with high biocompatibility. Silver nanoparticles (nano Ag) are known to have antimicrobial properties. When coated onto PU foams, the interaction between nano Ag and PU made the coating resistant to wash and the nano Ag coated PU could serve as a water filter to remove bacteria from water [3]. Bone cements loaded with 1% of nano Ag revealed high antibacterial activity against many strains including methicillin-resistant *S. aureus* and methicillin-resistant *S. epidermidis* [4]. On the other hand, nano Ag in liquid medium were found to cause only the growth delay of *E. coli*, even when nano Ag was used in high concentrations [5]. Recently, we have reported that nano Ag in low concentrations did not activate macrophages [6].

Nano Ag have been doped in polymer films by a variety of chemical and physical methods in which the formation of nano Ag was usually performed first, and then the nanoparticles were doped in polymer solution to prepare Ag/polymer nanocomposite films. It is extremely difficult to disperse nano Ag homogeneously

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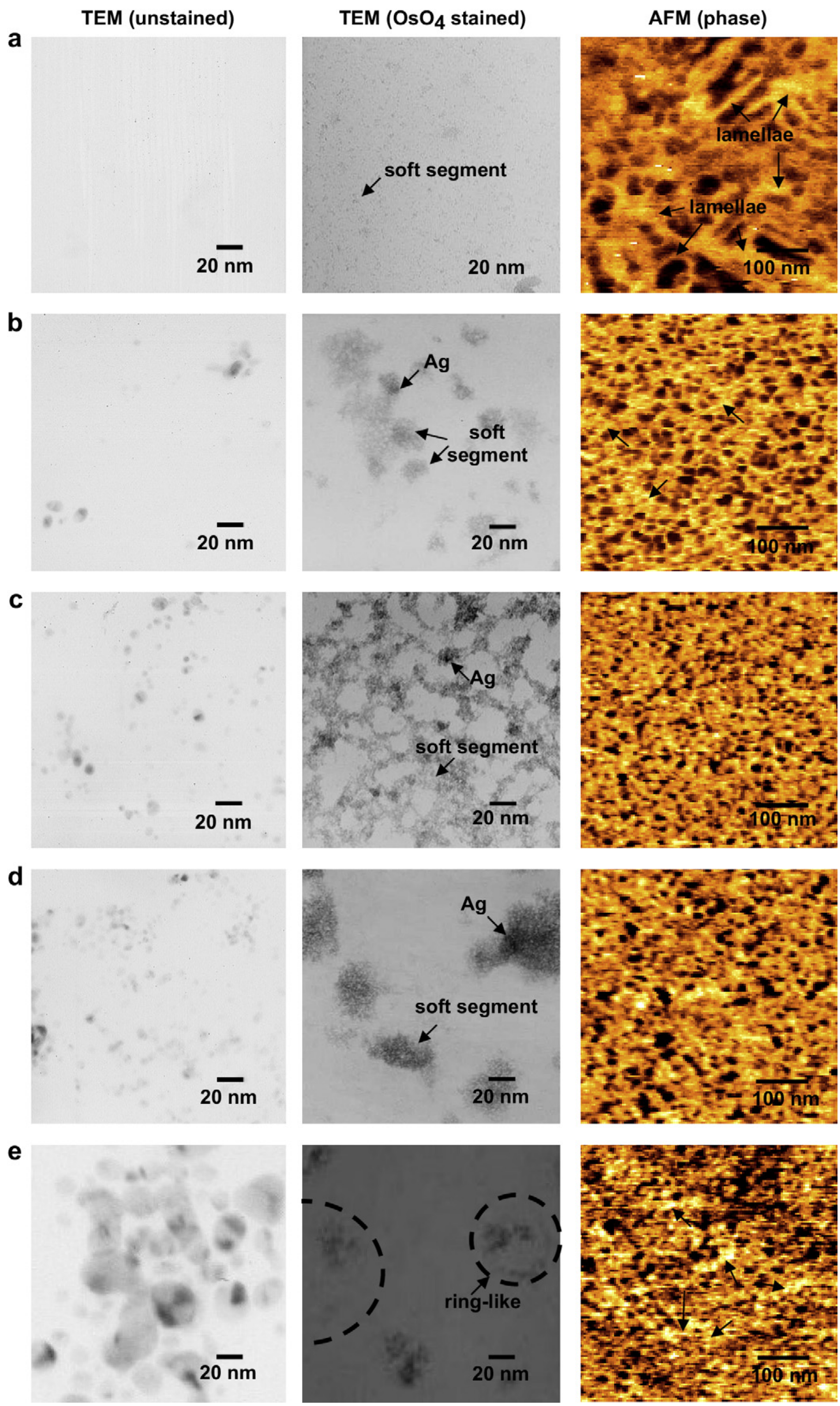

Fig. 1. TEM images of unstained or OsO_4 stained samples and AFM phase images for (a) the pure PU as well as the PU–Ag nanocomposites containing (b) 15 ppm, (c) 30 ppm, (d) 50 ppm or (e) 75 ppm, of nano Ag. Arrows in AFM phase images indicate the presence of lamellae.