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Magnetite Nanoparticles for Composite Coatings with Patterned Roughness

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Extended Abstract

Wettability control on solid surfaces is currently intensely studied due to its importance in many fields, such as self-cleaning coatings for solar energy panels, satellite dishes, automobile windshields, ice-repellant and anti-corrosion surface treatments for aircrafts, high performance materials for biomedical applications, to mention just a few. The strategies for engineering synthetic coatings with water/ice repellant properties have been inspired by naturally occurring superhydrophobic materials and involve an optimum combination of hierarchical surface roughness and low surface tension, as concluded in recent comprehensive reviews (Yan et al., 2011). A textured surface facilitates air pocket entrapment underneath the water drops resting on it, thus minimizing the effective contact area (Boinovich and Emelyanenko, 2013). Among the various approaches for creating patterned surfaces with hierarchical roughness, nanoparticle aggregation within polymeric matrices is known to be relatively facile and cost effective.

This study aims to develop a method to prepare iron oxide nanoparticles that are capable of mutual magnetic interaction during the curing stage of a polymeric support to create micro-scale surface protuberances in a controlled manner.

Materials and Methods

The Fe_3O_4 particles were obtained by partial oxidation of ferrous ions in alkaline solution and were characterized by transmission electron microscopy (TEM), X-ray diffraction (XRD) and magnetization measurement. They were subsequently functionalized in aqueous suspension using either sodium oleate or mixtures of non-ionic surfactants (Span80 and Tween80) with various hydrophilic to lipophilic balance (HLB) values.

Chitosan was used as a model film-forming polymeric support. Functionalized particles were suspended in acidic chitosan solution. The obtained nanoparticle-polymer dispersions were deposited by spraying on glass slides and subsequently cured by drying under a static magnetic field (strength range 3 to 6 mT) generated with the aid of an electromagnet, to yield composite films.

Results

The Fe_3O_4 particles obtained by the optimum procedure had a mean size of 14 nm as estimated from the TEM micrographs, an XRD pattern that is characteristic to highly crystalline magnetite and a saturation magnetization of 88.3 emu/g that is close to the theoretical value.

Magnetic field generated surface roughness was evidenced in the composite films by optical and scanning electron microscopy. The film morphology varies depending on the surfactant nature and the strength of the applied magnetic field. The rate of the particle movement in the curing stage and therefore their aggregation degree is a result of the equilibrium between the aligning effect of the magnetic field and the drag force acting upon them. The optimum texture was produced with the sodium oleate functionalized nanoparticles, assembled in chain-like structures, thus forming ordered protuberances within the polymeric film.

The results show that textured surface composite coatings may be prepared in a relatively simple manner with the aid of a magnetic field. Moreover, the versatility of the method is demonstrated by the possibility to choose the surfactant combination with the appropriate HLB value, depending on the support properties, to encourage the desired surface patterning.

A polymeric matrix modified with a low surface energy reagent will be synthesized in the next stage of the project in order to produce composite films with ice-phobic properties.

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