
Fabrication of Magnetic Iron Oxide Nanoparticle Doped Phosphate Glasses

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Abstract

The inert, transparent, and amorphous nature of glasses has highlighted these materials as promising candidates for the fabrication of novel multi-functional materials. Doping glasses with nanoparticles has the potential to design new materials where the advantages of a glass matrix can be maintained, while adding the functionality of nanocrystals. In order to achieve such materials, the challenges are (i) prepare functional nanocrystals suitable for doping into a glass, (ii) coat the nanocrystals to provide a protective and wetting layer to facilitate doping, and (iii) carry out glass making using low melting temperature glasses to preserve the coated nanocrystals, and improving sustainability. In this study, superparamagnetic iron oxide (Fe₃O₄) nanoparticles were synthesised using a co-precipitation method, due to its high yield and use of inexpensive materials. The particles were coated in a silica shell via a 'sol-gel' method, using sodium silicate as a silica source, a cheaper alternative to silicon alkoxides. Both bare and coated nanoparticles are magnetic and their powder XRD analysis displayed characteristic Fe₃O₄ peaks, with coated samples also showing a broad halo in the region of 20-30° 2

theta, corresponding to the presence of amorphous silica. The average size of the Fe₃O₄ nanocrystals was calculated with the Scherrer equation, showing nanocrystals to be in the 13 nm range, in both bare and coated samples. TEM imaging showed particles were spherical in shape for both types of sample. Phosphate based 45P₂O₅-10Ca-45Na₂O glass, with a low melting temperature, was synthesised via a melt quenching process. XRD analysis showed no crystalline peaks, confirming the amorphous glass structure. The incorporation of the nanoparticles into a glass matrix was attempted by remelting mixtures of nanoparticles and glass matrix. In order to maintain the favourable properties of both materials, preventing the dissolution of iron oxide particles, which could alter both the glass structure and nanoparticle functionality, is needed. A balance between the nanoparticle to glass ratio is vital. High doping levels could influence both the optical transparency, and amorphous structure of the glass matrix, while low levels may diminish the superparamagnetic properties of the nanoparticles within the glass. Methods to achieve a homogeneous dispersion of nanoparticles within the glass are also being explored.

Keywords: Multi functional material, low melting temperature, phosphate glasses, nanocrystal, doping

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