53

Tuning the Curie Temperature of Mn-Substituted Iron Oxide Nanoparticles for Self-Regulated Magnetic Welding of Thermoplastics

Author: Dnyandevi Dileep Deorukhkar[1]

Co-authors: Andrey Kuznetsov [2]; Arjan Houtepen [3]; Clemens Dransfeld [4]; Emma Chiavelli [4]

[1] *Optoelectronic Materials Section, Faculty of Applied Sciences, Delft University of Technology, 2629HZ Delft, The Netherlands*

[2] *Computational and Soft Matter Physics, University of Vienna, 1090 Vienna, Austria*

[3] *Optoelectronic Materials Section, Faculty of Applied Sciences, Techinical University of Delft, Van der Maasweg 9, 2629 HZ Delft, The Netherlands*

[4] *Aerospace Structures and Materials, Faculty of Aerospace Engineering, Delft University of Technology, 2600 GB, Delft, The Netherlands*

Magnetic nanoparticle-mediated heating is emerging as a promising approach for welding of thermoplastic polymers. Magnetic nanoparticles, when subjected to a magnetic field, can generate heat through Néel and Brownian relaxation mechanisms. As heat generation under an alternating magnetic field sharply decreases above Curie temperature (T_c), this specific T_c of magnetic nanoparticles provides an intrinsic mechanism for self-regulated heating. The study focuses on systematic investigation of tuning the Curie temperature of magnetite (Fe_3O_4) nanoparticles through controlled substitution of Fe^{2+} and Fe^{3+} ions with manganese ions to be matched to the processing window of a polymer. Mn-substituted iron oxide nanoparticles were synthesized via a co-precipitation method with varying Mn:Fe ratios and characterized in detail using X-ray diffraction (XRD) and transmission electron microscopy (TEM), revealing a composition-dependent structural transition from cubic spinel to tetragonal phases. A thermogravimetric analysis (TGA)-based methodology was developed to reliably determine the Curie temperature, enabling fast and reliable assessment of magnetic phase transitions of synthesized magnetic nanoparticles. By varying the Mn:Fe ratio, the Curie temperature was systematically tuned from above $500°\mathrm{C}$ to below $200°\mathrm{C}$, spanning the processing window of technologically relevant thermoplastics such as poly (ether ether ketone) (PEEK). These findings establish the potential use of Mn-substituted magnetite nanoparticles with their tunable T_c as self-regulating heat sources for their application in magnetic welding of thermoplastic materials.

Type:

Oral