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PEG-coated ZnO/Fe3O4 nanoparticles: design, stability, and potential in cancer therapy

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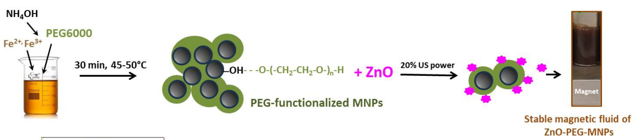
The study of various inorganic oxide nanoparticles is a crucial aspect of modern nanomedicine, particularly in the field of cancer therapy. Magnetic nanoparticles (MNPs), Fe_3O_4, for instance, are highly effective in theranostics, providing the necessary magnetic properties for applications such as magnetic hyperthermia. Similarly, ZnO nanoparticles demonstrate great potential for controlled drug delivery and the selective destruction of cancer cells, emphasizing their significance in combined therapeutic strategies. However, their clinical use is often limited by poor colloidal stability. This study explores a multifunctional nanocarrier composed of Fe_3O_4 and ZnO oxides. To enhance aqueous stability, MNPs were first stabilized with a polyethylene glycol coating (PEG-MNPs), followed by the incorporation of flower-like ZnO nanoparticles (ZnO-NPs) into the magnetic fluid (ZnO-PEG-MNPs). HRTEM revealed spherical MNPs (8–12 nm) and flower-like ZnO-NPs (30 nm). DLS confirmed hydrodynamic sizes of 80–250 nm and helped optimize ZnO/PEG-MNP ratios. PEG-MNPs showed high pH/thermal stability. PEG coating slightly reduced magnetization (74 to 60 emu/g) while maintaining superparamagnetism. FTIR, TGA, and XRD confirmed successful coating and coexistence of Fe_3O_4 and ZnO phases. The magnetic hyperthermia performance of PEG-MNPs and ZnO-PEG-MNPs was evaluated under alternating magnetic field (1050 kHz, 5.9 kA/m) in water and agarose dispersions. The concentration of MNPs in dispersions was 10.1 mg/ml. Both nanomaterials exhibited efficient heat generation, with PEG-MNPs showing slightly higher heating efficiency than ZnO-PEG-MNPs, likely due to the presence of the non-magnetic ZnO NPs. Only a minor decrease in heating efficiency was observed in the viscous agarose medium, suggesting that Néel relaxation is the dominant heat generation mechanism. Utilizing an innovative combined coprecipitation-ultrasonication approach, we successfully produced highly stable magnetic fluids that can serve as platforms for the further loading of various agents or drugs.



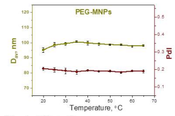


Fig. 1: Effect of temperature on z-average of PEG-MNPs.

Table 1: Estimation of the hyperthermia effect of the prepared nanomaterials.

Sample	Water dispersion		Agarose dispersion	
	Heating rate, °C/min	**SLP, W/g**	Heating rate, °C/min	**SLP, W/g**
PEG-MNPs	7.8	54 ± 5	6.5	47 ± 1
ZnO-PEG-MNPs	6.9	47 ± 6	5.9	43 ± 6

Acknowledgements

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