FEM Simulation of Magnetically Triggered Hydrogel Micro Particles As Advanced Drug Carriers

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Abstract

Thermally responsive microgel Poly (N-isopropylacrylamide), or PNIPAM, particles are interesting candidates for advanced drug delivery methods [1,2,3]. In this work, we embed iron oxide nanobeads into PNIPAM microparticles, creating magneto-thermally responsive microparticles (MTMs). The particles have mono disperse size distribution and a diameters ranging from 20 to 500 µm. The magnetic losses in the nanobeads activate the PNIPAM by heating it up to its lower critical solution temperature (LCST), which is approximately 32°C. The MTMs were filled with Rhodamine B [4] acting as a model drug by diffusion. Applying an AC field of 80 Oe, a release of 7% was achieved. Repetitive application of the AC field enabled a release of up to 80%. The COMSOL Multiphysics® software with Heat Transfer Module is used to study the heat generation and propagation inside and outside of the MTM. Thereby, the temperature dependent volume of the MTM was modeled by designing an interpolation function for the swelling ratio of the droplets and setting up a power density function for the heat distribution inside the droplet. The transient equation of the simulation was adapted for the total time of the experiment and the simulation results confirmed the experimentally observed non linear dependence of the size and the heat dissipation inside of the MTM.

Both the experimental and simulation temperatures saturate after 400 seconds, which means the MTM has reached its maximum shrinking ratio. Bellow 4 mg/ml concentration of MTMs, no release was observed and between 6.5 to 10 mg/ml a linear release was achieved. By simulating different concentrations of nanobeads inside the MTMs, those results could be explained by the maximum temperature obtained inside the MTMs. A higher concentration (12 mg/ml and more) was negatively affecting the polymerisation of the microgel.

The experimental results obtained are very promising for further developing improved drug carriers. By the help of the COMSOL simulations, a thorough understanding of the results has been obtained, and the influence of various parameters has been clarified. This enables tailoring of the properties of the MTMs for specific applications.

Reference

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Figures used in the abstract

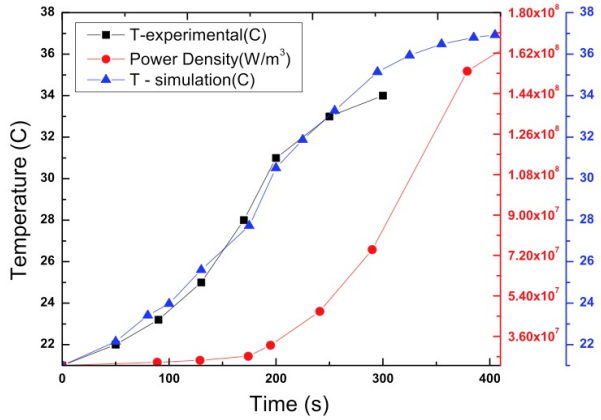

Figure 1: LCST in PNIPAM for difference concentration proven by simulation.