

Properties of magnetic nanocomposites for biomedical applications

Polymer nanocomposites have been receiving a lot of attention in the field of biomedical engineering. These composite materials, which consist of a polymer as the matrix and nanoparticles (nano-sized particles) as fillers, offer the opportunity for the development of new biomedical devices. The nanoparticles enhance the physical properties of the polymer such as mechanical and hyperthermic.

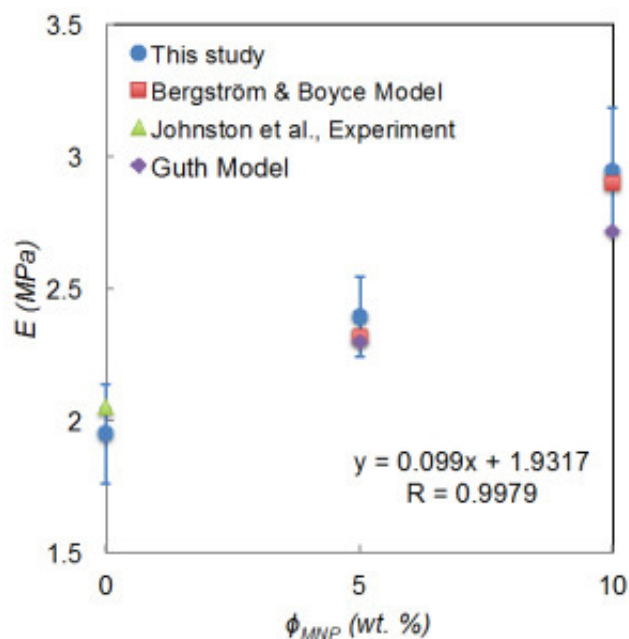


Fig. 1. Elastic modulus as function of the MNP wt. %. The error bars represent standard deviation of the data, assumed to be the experimental uncertainty of the measurements.

In an effort to explore the possibility of using such multifunctional materials in the design of biomedical devices such as cell-based biochips for disease diagnosis and heat sources for cancer treatment, we investigated the mechanical and hyperthermic properties of a poly(-dimethylsiloxane) (PDMS) based nanocomposite system. These were studied as a function of nanoparticle weight fraction (wt. %). Magnetic nanoparticles (MNPs), maghemite ($\gamma\text{-Fe}_2\text{O}_3$), were used for the study.

Cell-based biochips are miniaturized devices that allow many test to be performed simultaneously on a solid substrate. These devices are highly sort after because of their potential to be used in the several biomedical applications such as cancer identification. Current research efforts in the field are focused on finding new biocompatible materials that could be used as substrates. Their elastic

modulus, E , is one key property due to the effect it has on cell growth. Recently, various experimental results have shown PDMS to be a suitable substrate material because it is relatively easy to tune its E . Common approaches include varying the cross-linker concentration or curing time. However, our study explored the use of nanoparticles to tune E by varying the MNP wt. %. The results in Fig. 1 show that the E increases with increasing MNP wt. %. The range of the E obtained in this study agreed well with experimental results obtained in the literature using different techniques as well as predictions from Bergström-Boyce theoretical model.

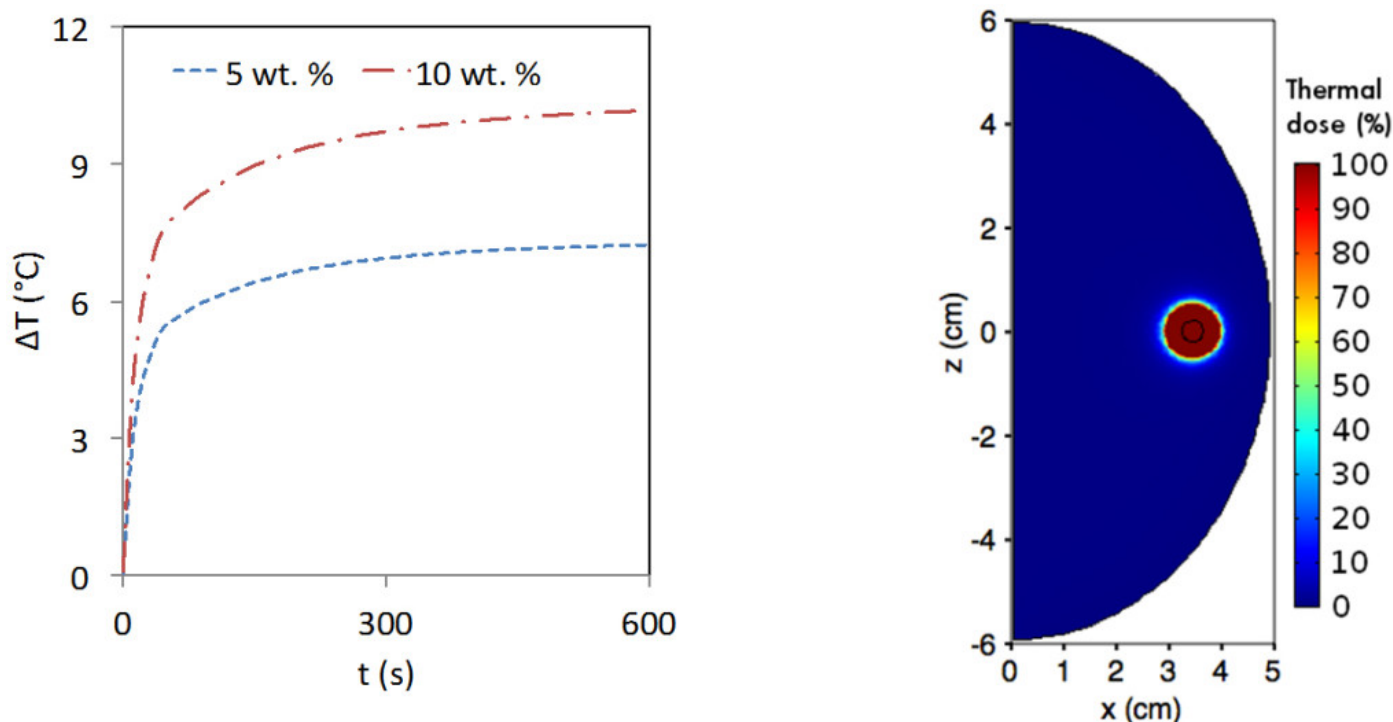


Fig. 2. (a) Temperature as a function of time and (b) Thermal dose coverage when breast tissue is subjected to heating by the nanocomposite structures for 5 mins.

Furthermore, MNP wt. % required for the range of E obtained in the study is enough to generate heat within the nanocomposite substrates when it is exposed to an alternating magnetic field. Table 1 shows a summary of results of heat loss predictions as function of nanoparticles and alternating magnetic field (AMF) strength. It is evident that heat loss increases with both parameters.

The most frequently occurring cancer in women is breast cancer. For such small breast cancers, mastectomy is an aggressive form of treatment. Therefore, treatment methods that can enhance the use of lumpectomy by eliminating residual cells are needed. Hyperthermia, which involves the use of elevated temperatures to kill cancer cells, has been documented as a treatment modality with fewer side effects. To access the feasibility of using heat produced from structures fabricated

from nanocomposite to eliminate residual cells using human-safe AMF parameters, we simulated the heating of breast tissue after surgical removal of a tumor using a 3D finite element model.

Sample name	H_{max} [mT]	σ_s [$Am^2 kg^{-1}$]	A_{exp} [$mJ g^{-1}$]
PDMS-0		0	0
PDMS-5	5	2.43	0.013
PDMS-10		3.40	0.018
PDMS-10	10	3.40	0.037
PDMS-10	15	3.40	0.050

Table 1. Summary of results of hyperthermic predictions: H_{max} , AMF amplitude at which experiments were conducted; σ_s , saturation magnetization; A_{exp} , experimental hysteresis loop.

The results in Fig. 2a show that both hyperthermic (≈ 46 ; 5 wt. %) and ablative (≈ 52 , 10 wt. %) temperature levels can be achieved for the range of MNP wt. % used in our study when breast is exposed to human-safe AMF for 5 mins. Fig. 2b shows the corresponding thermal dose coverage. The region where 100% thermal damage occurred was measured to be 0.62 cm and 0.80 cm for 5 wt. % and 10 wt. % respectively.

Put together, the results suggest that this simple nanocomposite system with nanoparticle controlled Young's modulus and hyperthermic properties have the potential to enhance the efficacy of cancer diagnosis and treatment.

Publication

[Mechanical and hyperthermic properties of magnetic nanocomposites for biomedical applications.](#)

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