Focused Microwave Cancer Therapy Using Lithographically Defined Nanoparticles

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In recent years, the destruction of solid tumors via hyperthermia has seen increased use in cancer therapy. However, it is difficult to achieve highly localized heating on the target inside human body without unwanted heating of intervening tissues. Recent work has demonstrated that gold nanoparticles with a peak optical absorption in the NIR can be injected to enhance heating selectivity[1]. Unfortunately, this technique is only effective at treating near-surface cancers due to significant scattering and attenuation of IR light by biological tissues.

This study for the first time presents lithographically defined nanoparticles to achieve enhanced absorption at microwave frequencies. Nanoparticles were designed using Ansoft HFSS to have optimal microwave absorption efficiency. We compared the electromagnetic volume loss density of different structures. The HFSS predicted electromagnetic loss was then used as heat source in COMSOL to study the thermal effects. Temperature distribution in blood with particles inside was then explored to demonstrate the suitable heating performance.

Figure 1 shows the electromagnetic loss density of several types of structures at 2.45 GHz. Although the most efficient structure is the gold microring with nickel core, one single gold microdisk has almost the same absorption efficiency, and it is much simpler for fabrication. For real case simulation, microwave were focused in a $(2cm)^3$ blood cube as the heat source with nanoparticles inside, with surrounding a 1L blood cube. To reduce the mesh quantity in COMSOL, the heat effect of blood and particles were averaged over volume. Within concentration of particles 1.6 pmol/L and 1500s illumination in microwave with power density 120 mW/cm^2, the temperature increased from 37℃ to 51.2℃ (Figure 2). Figure 3 shows the diagram of the fabrication process. One layer of photoresist was first spin-coated on substrate. After defining the nanoparticle patterns (Figure 3(a)), O_2 plasma was exploited to etch polymer support and photoresist (Figure 3(b)). Then, the sample was immersed into acetone ultrasound vibration to dissolve the photoresist and to release the particles (Figure 3(c)). Figure 3(d) shows the SEM image of released nanoparticles with 350nm thick gold and 1.6um thick polymer support. The polymer support is used to monitor the heating effect, which actually will be melted at certain temperature. Those particles can be fabricated at large volume and low cost using roll-to-roll nanoimprint lithography (Figure 4).

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[1] Day, Emily S., Jennifer G. Morton, and Jennifer L. West. Nanoparticles for Thermal Cancer Therapy. *Journal of Biomechanical Engineering* 131.7, 2009.

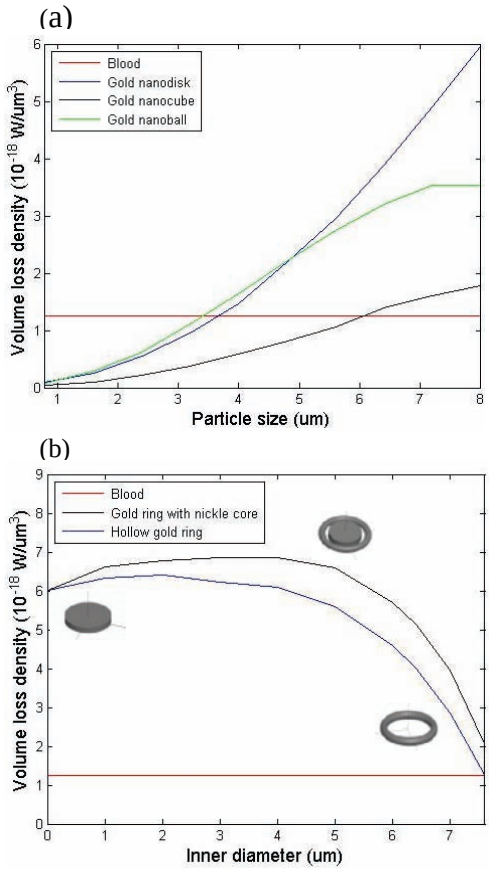


Figure 1: Electromagnetic absorption in different structures at 2.45GHz. a) Difference between nanodisk, nanocube and nanoball. b) Difference between microrings with different inner diameters but the same outer diameter 8um.

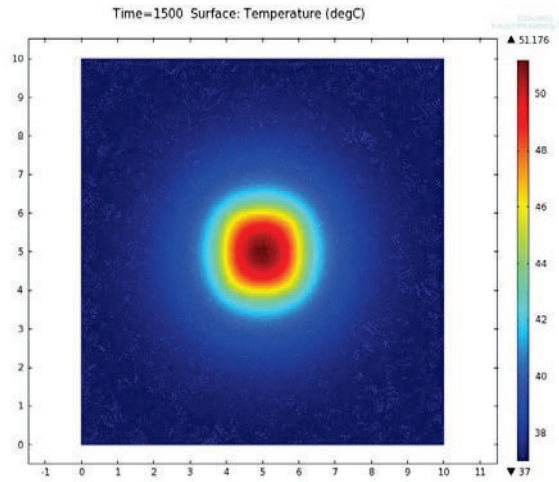
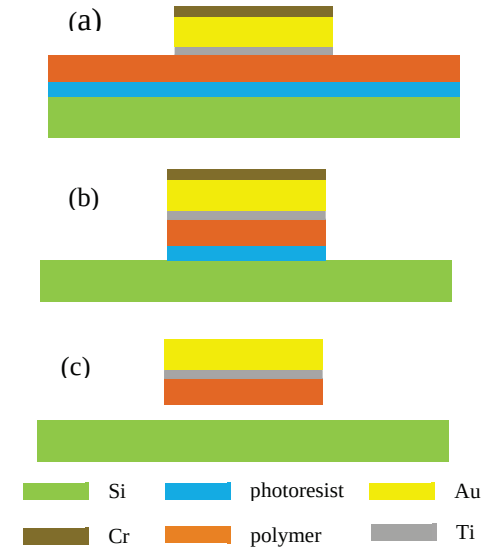


Figure 2: Temperature distribution at the cross section of a 1L blood cube. Heat source is confined in a 8cm^3 cubic region. All of the six boundaries and the initial value are set to be 37℃.



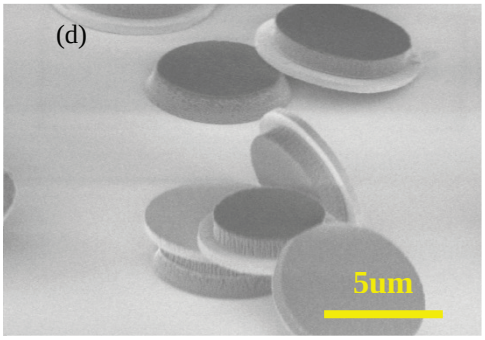


Figure 3: Diagram of the fabrication process and the fabrication result of released nanoparticles with 350nm thick gold cap and 1.6um thick polymer support

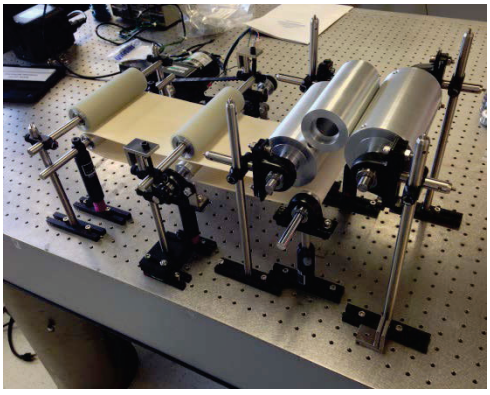


Figure 4: Roll-to-roll imprint machine for large quantity nanoparticle releasing.