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Injectable Liquid Metal Coil for Magnetically Mediated Hyperthermia

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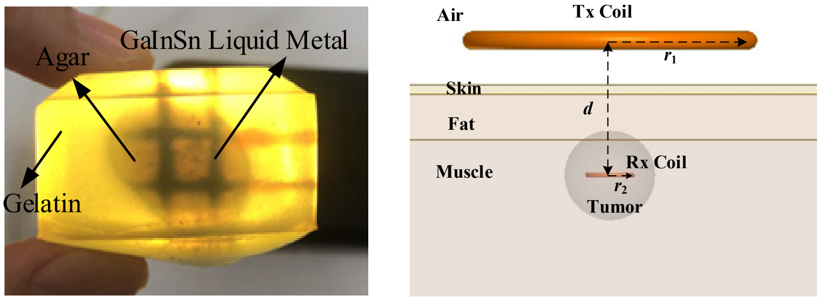
Abstract

Magnetically mediated hyperthermia (MMH) [1] is a promising technique to cure tumor by increasing the temperature of the targeted tissue region to a desired temperature range (typically from 41 °C to 46 °C) while keeping the tissue out of the targeted region almost constant. Because the biological tissue is almost non-magnetic and low-conductance, magnetic fields can be applied to heat up the implanted magnetic mediators in the tumor region. Magnetic nanoparticles (MNPs) are the most commonly used mediators through injection due to the minimal invasiveness advantage [2], [3]. However, the treatment temperature strongly depends on the dose of MNPs which will diffuse and even vanish in the human body thereby reducing the heating effectiveness. An alternative way is replacing the MNPs with metallic loops. Although metallic loops can be precisely located and will not be diffused over time, implanting them into the tissue is more invasive[4]. In this paper, we propse to use injectable metallic loop coils as the mediator by using liquid metal coatedg with biocompatible materials.

As a preliminary prototype, we use gelatin (25% consistence) to analog the human tissue. Agar solution mixed with konjaku flour (6% and 0.3% consistence, respectively) is injected into geltain with 1 ml/s speed by using a syringe needle. After about 5 seconds, the agar solution freezes and the syringe needle can be reomved. Four the syringe needles with 1.2-mm deameter are used to injected one by one to shape a square-shaped hole inside the agar. After removing the four syringle needles, the square-shaped hole is actually not hermetically-sealed. Additonal agar (red dye is mixed intendedly in order to let them be obvious) is injected to seal the square-shaped hole and form a sealed hallow tube. And then the liquid metal (GaInSn alloy with 0°C melting temperature) is injected into this hole with the help of a 0.5-mm diameter syringe needle. The final prototy flexible liquid metal coil is shown in Fig. 1a.



(a) (b)

Figure 1: (a) A prototype of square-shaped liquid metal coil and (b) a simplified diagram of the power coupling part of an MMH system.

Based on the prototype of liquid metal coil, a MMH system can be setup to analyze. It is important to optimize the heating efficiency so that the temperature increases only in the targeted region instead of impairing the healthy tissue. A simplified diagram of the MMH system is shown in Fig. 1b where the power transmitting part is represented by a single-turn cicular copper coil and the power receiving part is a single-turn square-shaped GaInSn coil. This is actually an inductive heating system which is similar to an inductively coupled wireless power transfer system.

In order to improve the heating efficiency, the operating freuqnency and the size of the transmitting coil are optimized with the help of analytical modeling of the system and full-wave electromagnetic simulation tools Ansoft HFSS. The simulated heating efficiency for different operating frequency is shwon in Fig. 2. The distance between the transmitting coil and the liquid metal coil is set to be 30 mm. The conductivity of GaInSn is 1.64 MS/m. The optimized tramsmitting coil has 30-mm radius and 5-mm copper wire radius. From Fig. 2, we can find that the heating efficiency can reach about 0.77% which is close to the maximum efficiency shown in [4] where, however, 1.5×10^5-S/m conductivity material is assumed (maybe not existed in reality) for the implanted coil and traditional implanted method have to be used.

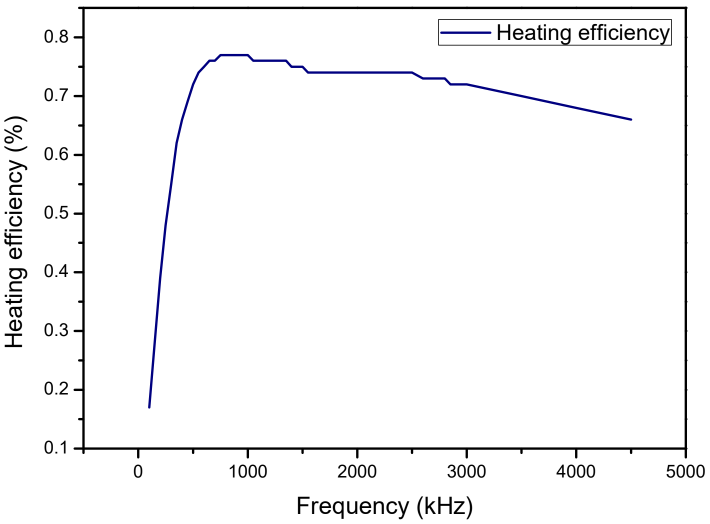


Figure 2: Heating efficieny of a MMH system by using square-shaped liquid metal coil.

References

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