Investigation of laser heating effect of metallic nanoparticles on cancer treatment

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Abstract. Metallic nanoparticles can be applied for hyperthermia therapy of cancer treatment to enhance the efficacy because of their high absorption rate. The absorption of laser energy by metallic nanoparticles is strongly dependent on the concentration, shape, material of nanoparticles and the wavelength of the laser. However, there is no systematic investigation on the heating effect involving different material, concentration and laser wavelength. In this paper, gold nanoparticles (AuNPs), silver nanoparticles (AgNPs) and silver nanowires (AgNWs) with different concentrations are heated by 450nm and 532nm wavelength laser to investigate the heating effect. The result shows that the temperature distribution of heated metallic nanoparticles is non-uniform.

1. Introduction

Nanomaterials have been widely investigated for biomedical applications, such as drug delivery, bioimaging, photothermal cancer treatment[1-5]. Metallic nanoparticles, due to their nature of good biocompatibility, being easy of preparation, and strong absorption and scattering effect of light laser, are ideal candidates for photothermal cancer treatment.[6-7] A laser is an important tool for metallic nanoparticle heating.[8] There are many factors affecting the heating efficiency of metallic nanoparticles, such as the wave length of the laser, the shape, concentration, and material of metallic nanoparticles.[9-10] However, there is no comprehensive study regarding different materials, concentration, and morphology. To narrow this knowledge gap, a preliminary experimental scheme for investigation of the heating effects of 450nm, 532nm laser of different concentration AuNPs, AgNPs and AgNWs from 25μmol/L to 150μmol/L in the interval of 25μmol/L has been designed.

2. Experimental Procedure

The experimental setup for laser heating is illustrated as figure 1. A cuvette was placed in a chamber with two 50mm by 50mm square holes. The laser was aligned to metallic nanoparticle dispersion through the top hole, and the lateral was left for thermal imager detection. A fiber optical temperature meter monitored the temperature change of dispersion. The optical fiber was attached to the inner wall of the cuvette to avoid the direct illumination with an accuracy of ±0.1℃.
The experimental procedure is as follows:
- Drop 4ml sample into the cuvette with a dropper;
- Put the cuvette in the chamber for 10 mins to achieve thermal equilibrium;
- Record the temperature of the original sample by using the fiber temperature meter and thermal imager respectively;
- Illuminate the sample for 10 mins with the 450nm/532nm laser;
- Record rise in temperature of the sample by using the fiber temperature meter and thermal imager respectively.

3. Results and Discussion
The original samples are shown in figure 2 (a), (b) and (c). The temperature profiles of dispersion recorded by thermal imager are presented in figure 2 (d). As for AgNPs and AuNPs, it clearly shows that non-uniform temperature distribution can be observed for high concentration samples, while relative uniform heating can be found for low concentration samples. However, in the AgNWs samples, the temperature distribution is always uniform whatever the concentration is. Taking the AgNPs samples heated by 532nm laser as an example, the temperature distributions of samples with the concentration of 25, 50, and 75μmol/L are uniform, as can be seen from the temperature profile. For higher concentrations, 100, 125, and 150μmol/L, however, layered temperature distribution can be observed. In light of this phenomenon, the temperature measurement was conducted with the sensor placed at the top, middle and bottom layers, respectively. The temperature rises of dispersion with different concentration were plotted in figure 3.

For AgNPs samples, the temperature increases with the concentration whatever the concentration is. However, the bottom layers are always less heated than their upper layers. In comparison, for AuNPs, the temperature rises in the upper area increase with the concentration. However, the middle layer and bottom layer show a turning point depending on the wave length of the laser. The rise in temperature of AgNWs is less than that of either the AgNPs or AuNPs.

It is seen that the AuNP dispersions are more heated than AgNP samples with the same concentration. For instance, samples at the concentration of 100 μmol/L, heated by 532nm laser, the temperature rise of the upper, middle and bottom layer of AuNPs are 9.3, 7.3 and 4.9℃, which are stronger than the rise of AgNPs, 5.6, 5.2 and 4.3℃ respectively. The AgNP samples are more heated than AgNW dispersions with the same concentration. For instance, the maximum temperature rise of AgNWs samples heated by 450nm laser is 1.9℃, which is even weaker than the minimum, 2.1℃, of
AgNPs under the same condition. It seems AuNPs are better for photothermal therapy. However, from the layered temperature, we can make the conclusion that AuNPs with worse penetration depth are more absorptive than AgNPs.

Figure 2. (a) AgNPs original samples (b) AuNPs original samples (c) AgNWs original samples (d) Temperature profiles recorded by the thermal imager.
4. Conclusion
The laser heating effect of metallic nanoparticles with different concentrations has been investigated in this paper. The conclusion is that the rise temperature of AgNPs and AuNPs with high concentrations are layered. The AuNP dispersions are more heated than AgNP and AgNW samples with the same concentration. The AuNPs with worse penetration depth are more absorptive than AgNPs.
5. Acknowledgments
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