Cholesterol Crystals with Gold Nanoparticles: Photothermally Induced Effects

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Abstract: Gold nanoparticles embedded in cholesterol crystals promote localized heating under intense light illumination at the surface plasmon resonance absorption band, allowing material displacement from their original position, showing potential applications in cardiology.
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1. Introduction

Cholesterol is an extremely important biological molecule acting as precursor for the synthesis of the steroid hormones and bile acids. Nevertheless, heart attacks can be caused by cholesterol crystals in the blood stream that disrupt plaque found in arteries. The use of optics and nanotechnology in cardiology is promising to develop fundamentally new methods of diagnosis and treatment [1].

Gold nanoparticles optical and thermal properties are well characterized. They exhibit very high light absorption, show no cytotoxicity, and may easily be conjugated with many proteins and antibodies [1]. An intense light pulse rapidly heats gold nanoparticles, generating elevating lattice temperatures up to the melting point of bulk gold, resulting in dramatic effects in the particle and its surroundings [2, 3].

In this work we have studied the effect of the presence of gold nanoparticles in cholesterol crystals, under excitation by light at the nanoparticles plasmon resonance frequencies.

2. Materials and Methods

Pure cholesterol crystals were prepared heating 500 mg of cholesterol powder (Sigma 98%) until it melted, followed by fast cooling to room temperature. The cholesterol crystals with gold nanoparticles followed the same preparation, with the addition of 7 mg of $HAuCl_4$ (chloroauric acid) to the molten cholesterol. Polycrystalline structures were formed under this protocol.

Optical absorption spectra of the crystals were obtained with a Varian Cary 3000 UV-Vis-NIR spectrophotometer and micrographies of the samples were obtained using a Leica DMI6000 CS fluorescence microscope and a Hitachi TM3000 tabletop transmission electron microscope.

3. Results and Conclusions

Fig. 1 shows the optical absorption spectra of the pure cholesterol crystal together with the crystals synthetized with chloroauric acid, which exhibits a typical surface plasmon resonance (SPR) absorption band. This band peaking at 550 nm evidences that spherical gold nanoparticles, with diameters around 50 nm, were formed.

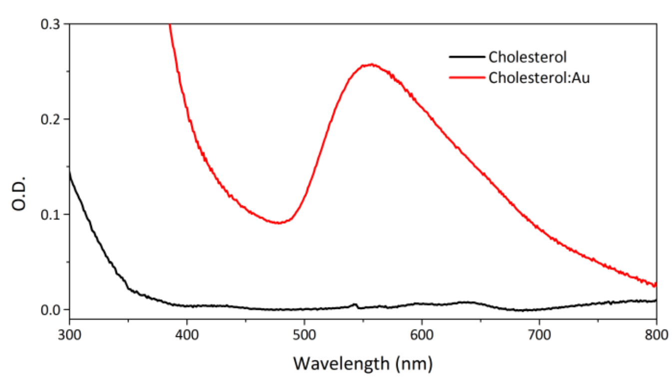

Fig. 1. Optical absorption spectra of the synthetized cholesterol crystals, pure and with gold nanoparticles.

Fig. 2a shows electronic micrographies of pure cholesterol crystals (up) and cholesterol crystals obtained with the with the chloroauric acid (down). Both images exhibit cholesterol crystals of ~100 μm, and the white dots in the lower image are likely to be gold nanoparticles incorporated within the cholesterol crystals. Fig. 2b presents the effect of intense illumination by the fluorescence microscope light using a 20× objective and the N2.1 filter (BP 515-560) (upper image). The same region is observed in the transmission electron microscope (lower image). The gold acts as a localized heat source due to the large absorption coefficient of the gold nanoparticles at the plasmon resonance (550 nm) and the small photoemission quantum yield for such particles [4]. The energy absorbed upon plasmon excitation creates phonons via nonradiative pathways, thereby heating the local surroundings inside the sample. These irradiation conditions produce a local temperature increase that softens the crystals without melting it, and allow its deformation, creating the circular region observed. Additionally, the radial heat flow in this softened region is appropriate to modify the geometry of the crystal, besides moving the supposed nanoparticles to the illuminated area periphery.

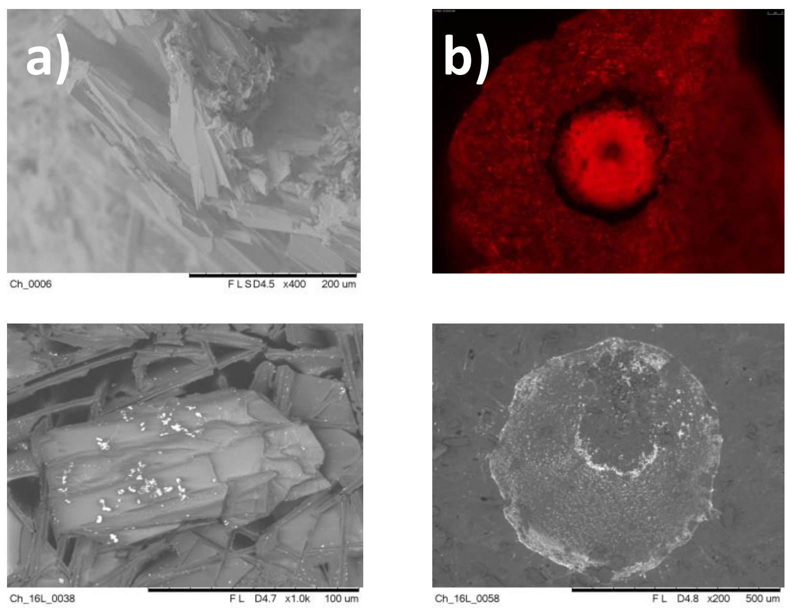

Fig. 2.a) Transmission electron microscopy of cholesterol crystals pure (up) and with gold nanoparticles (down). b) Fluorescence microscopy (up) and transmission electron microscopy (down) after photothermal effect.

In summary, we have demonstrated the ability of cholesterol crystals with gold nanoparticles to generate a photothermal effect that modifies these crystals geometry and moves material away from the irradiated area. The use of gold nanoparticles in cardiology is promising to develop fundamentally new methods of moving and destroying cholesterol crystals.

4. References

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