

Switching of surface plasmon resonance of a gold nanoparticle upon crystallization in a GeSbTe film

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Abstract

We have investigated surface plasmon resonance (SPR) shift of gold nanoparticles that are supported with GeSbTe (GST) by utilizing the phase change of this substrate. The phase change GST was chosen as the substrate since it has high contrast in dielectric properties between the crystal state and the amorphous state. We first carried out the experiment using white light illumination to measure the scattering spectra from a single gold nanoparticle on the phase change material of amorphous state. Next, we illuminated the same particle by a focused laser beam to induce the crystallization. As a result, we could observe the plasmon resonance shift of the nanoparticle due to the phase change of the GST substrate.

INTRODUCTION

Localized surface plasmon resonance (SPR) of a small metal particle is attractive for its widely potential applications including optical switching, chemical and biological sensing, and surface enhanced spectroscopy. It is well known and experimentally studied that SPR spectral features change as a function of dielectric constant of surrounding medium. If a significant change in the dielectric constant of the media can be induced by optical pulse excitation, we will achieve ultrafast SPR switching, which will be applied to photonic devices such as a buffer memory for optical telecommunications. We have been demonstrated that a GeSbTe (GST) thin film is amorphized by a single femtosecond laser pulse. By pump-probe measurements it is found that the reflectivity of a GST film abruptly drops within 500 fs and then remain almost constant. In this study we investigated SPR spectral shift of a gold nanoparticle supported on a GST film upon crystallization by laser annealing.

Figure 1 shows a dark field scattering micrograph of gold nanoparticles supported by an as-deposited thin film of GST with white light illumination. As it illustrated, single particles, particle pairs, and particle aggregates can be observed with different colors due to the position of their LSPR in the visible region of

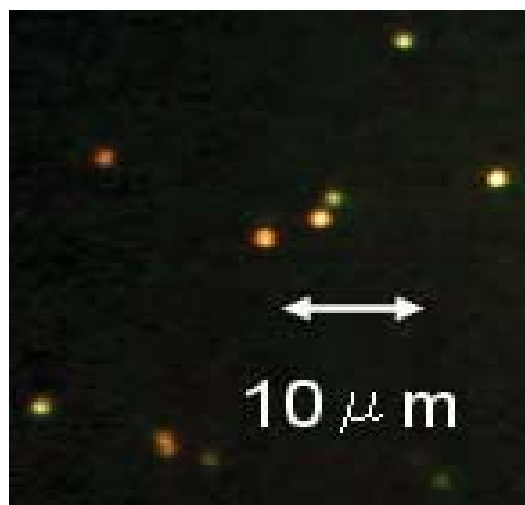


FIG. 1. Scattering light from gold nanoparticles (Diameter ~ 100 nm) on an as-deposited GST film (amorphous state).

the spectrum. Single particles have green color, particle pairs have orange color, and the color of particle aggregates is found at longer wavelengths (red-shifted).

MATERIALS AND METHODS

The phase change material $\text{Ge}_{10}\text{Sb}_2\text{Te}_{13}$ was chosen as a substrate material since it has high contrast in dielectric properties between the crystal state and the amorphous state. A thin film of GST (thickness = 20 nm) was deposited on a glass substrate (thickness = 0.6 mm). Gold nanoparticles (Diameter ~ 100 nm) were dispersed on the GST film. Measurements were carried out using an inverted optical microscope under dark-field illumination equipped with a color CCD camera.

The study was done by measuring the scattered light spectra from a gold nanoparticle dispersed on the GST of amorphous state under white light illumination. Phase change from amorphous state to crystal state was achieved by applying a second harmonic of Nd:YAG laser. Next, the scattered light spectra from the same gold nanoparticle was measured after the phase change took place.

RESULTS AND DISCUSSION

Figure 2 shows images of gold nanoparticles on GST before and after laser irradiation. As it is shown, we illuminated only one particle (center) in the measurement area. As stated earlier, LSPR of metal nanoparticles is sensitive to the environment, and hence, when the substrate in the vicinity of the particle changes from amorphous state to crystal state due to laser illumination, the illuminated particle changes color from green to orange while other particles in its vicinity does not exhibit color change.

Figure 3 shows typical scattering spectra from a gold nanoparticle due to laser irradiation in its vicinity. Before laser irradiation, gold nanoparticle was green in color and the plasmon resonance peak was approximately (~550nm). However, after irradiation, the particle changed color from green to orange and the resonance peak was approximately (~590nm). This shift in the LSPR is due to the change in the substrate (GST) from amorphous state to crystal state after laser irradiation. As a result, the resonance peak shift was approximately (~40nm) and we could observe several similar spectral shifts.

We obtained the scattering spectra by measuring both the spectra from the particle and from the GST in the absence of any particle and the final spectra was taken by subtracting the background spectra from the particle spectra.

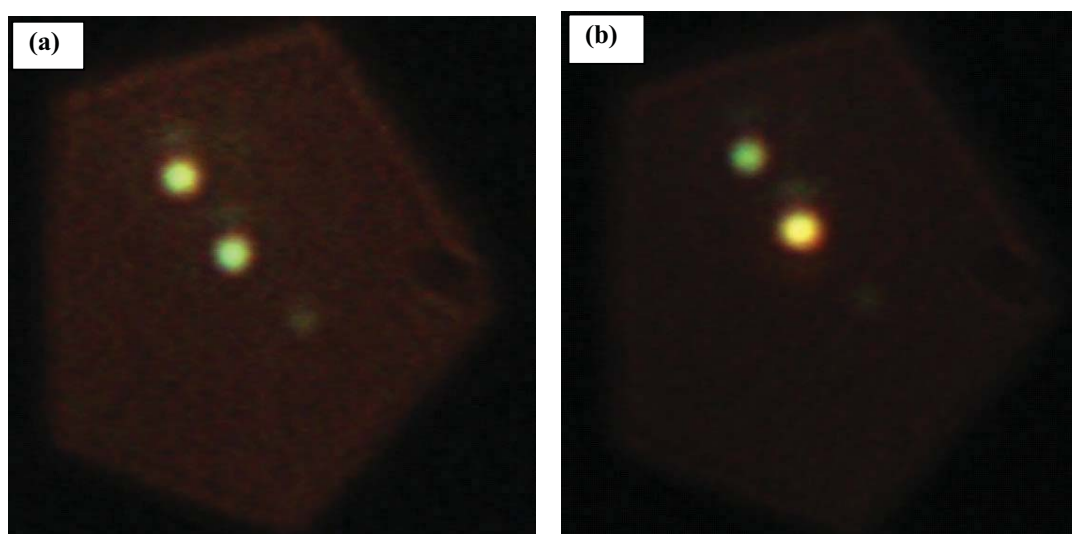


FIG. 2. Images of gold nanoparticles on GST substrate, (a) Before laser irradiation (b) After laser irradiation. Only the illuminated particle changed color from green to orange (center).

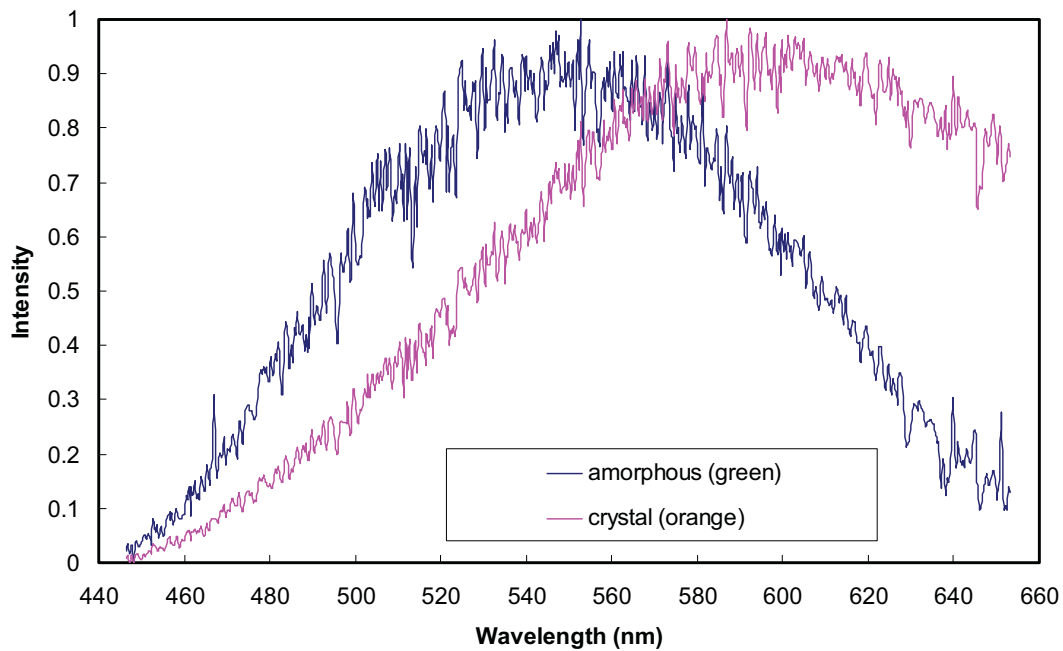


FIG. 3. Typical scattering spectra of a single gold nanoparticle on GST substrate before and after laser irradiation. The plasmon resonance peak is ($\sim 550\text{nm}$) in the amorphous state (Blue spectrum) while it was shifted to ($\sim 590\text{nm}$) in the crystal state (Red spectrum).

CONCLUSION

We carried out an experiment to measure the LSPR shift of gold nanoparticles supported by GST substrate that exhibit a phase change when irradiated by laser. Combining the significant properties of metal nanoparticles and phase change materials can find several applications such as ultrafast optical switching. In our future work we will perform calculations using Finite-Difference Time-Domain (FDTD) method to clarify experimental results.

ACKNOWLEDGEMENT

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