High contrast optical switching of localized surface plasmon resonance in a single gold nanosandwich using a GeSbTe film

Kenta Kuwamura, Takashi Hira, Takayuki Uchiyama, Yuya Kihara, and Toshiharu Saiki
Graduate School of Science and Technology, Keio University
3-14-1 Hiyoshi, Kohoku, Yokohama, Kanagawa 223-8522, Japan
kenta.kuwamura@saiki.elec.keio.ac.jp

ABSTRACT

Localized surface plasmon resonance (LSPR) switching in a Au/GeSbTe/Au nanosandwich was investigated as a key active element in plasmonic integrated circuits and devices. Single-particle spectroscopy was conducted to examine the interaction of a Au nanorod and Au film, between which a GeSbTe layer was incorporated as a phase change active media. When two metal particles are coupled, two plasmon modes are hybridized and split into symmetric and antisymmetric modes. The nanosandwich is advantageous to enhance the LSPR switching contrast upon phase change because the LSPR peak position of the hybridized modes drastically changes with the refractive index of the dielectric material employed. Experimental demonstration of the switching operation was performed by alternate irradiation with a picosecond pulsed laser for amorphization and a continuous wave laser for crystallization. Stable and repeatable modulation with a high contrast was obtained.

Key words: GeSbTe, Localized surface plasmon resonance, plasmonic devices

1. INTRODUCTION

Active control of localized surface plasmon resonance (LSPR) supported by metal nanostructures has attracted increasing attention for the implementation of dynamic switching and tuning functionality in plasmonic devices [1,2]. In most approaches the mechanism of LSPR control relies on the sensitivity of LSPR to changes in the local dielectric environment due to dielectric screening and mode hybridization. Recently phase change materials have been extensively utilized due to significant changes in their dielectric properties upon phase change. In this paper, we present an experimental study on the LSPR modulation of a Au nanorod (AuNR) on a Au film, between which a GeSbTe thin layer is inserted. This configuration is equivalent to the nanosandwich structure and is technically easier to prepare. We demonstrated stable and repeatable LSPR switching with high contrast by alternate irradiation from two different lasers for the amorphization and crystallization of GeSbTe.

2. EXPERIMENTS

After deposition of a Au thin film with a thickness of 50 nm on a glass substrate, a 20 nm GST film was formed by sputtering. A colloidal solution of AuNRs (140 nm long, 50 nm diameter) was used; the AuNR dispersion in ethanol solution was drop-cast onto the GST film. The substrate was heated to rapidly evaporate the ethanol and prevent the aggregation of AuNRs.

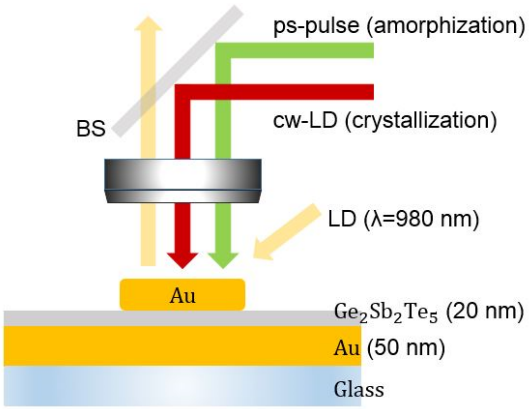

Fig. 1. Schematic diagram of the sample structure and experimental setup for dark-field scattering measurements.

The optical setup for single AuNR spectroscopy is illustrated in Fig. 1. For the amorphization of GST, a picosecond pulse from a diode pumped solid state laser (λ=532 nm and pulse width of 300 ps) was delivered through a microscope objective. For crystallization, a laser diode (LD) of λ=830 nm was used under cw operation. To monitor the switching behavior of a single AuNR at the LSPR band around 1000 nm, the AuNR was illuminated with a LD of λ=980 nm under the dark-field configuration and the scattered light was detected through the objective.

3. RESULTS AND DISCUSSION

Figure 2 shows a time trace of the scattered light intensity. Starting with the GST layer in the crystalline phase, amorphization and crystallization was repeated by alternate irradiation with picosecond laser pulses and a cw LD. LSPR switching with good stability and repeatability was observed. The switching contrast of 1.5 obtained was also sufficiently large.

At the initial stage of the switching operation, a gradual increase in the modulation contrast was observed. Although it is difficult to determine what happens from the optical measurement alone, one possible explanation for the result can be given as follows. The modification of the surface morphology due to volume expansion of the GST film may be different after each amorphization process. There is a volume expansion of approximately 10% upon amorphization from crystalline GST. There may be a slight change in the position or configuration of the AuNR at the initial stage that eventually becomes stabilized.

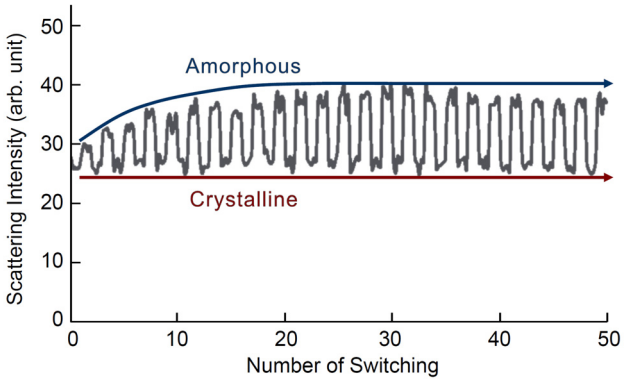

Fig. 2. A time trace of scattering light intensity (λ=980 nm) from a AuNR/GST/Au nanosandwich demonstrates repeatable modulation of the LSPR band by alternate irradiation with a femtosecond pulsed laser for amorphization and a cw LD for crystallization.

4. CONCLUSION

Single particle spectroscopy of a Au nanosandwich, where a GST thin layer is sandwiched between interacting AuNRs and a Au film, was conducted. A significantly large band shift was obtained for the hybridized modes between the AuNR and Au film upon phase change of the GST layer. An experimental demonstration of LSPR modulation was performed for the LSPR band around 1000 nm. A stable and repeatable switching with a contrast of 1.5 was obtained. Interestingly, at the initial stage of switching operation, a growth in the modulation contrast was observed.

ACKOWLEADGMENT

This work was supported by a Grant-in-Aid for Scientific Research on Innovative Areas “Optical Science of Dynamically Correlated Electrons” from the Ministry of Education, Culture, Sports, Science and Technology of Japan. We would like to thank T. Shintani for providing the GeSbTe thin film sample.

REFERENCES

1. Y. Leroux, J. C. Lacroix, C. Fave, V. Stockhausen, N. Fe´lidj, J. Grand, A. Hohenau, and J. R. Krenn, “Active Plasmonic Devices with Anisotropic Optical Response: A Step Toward Active Polarizer,” Nano Lett. **9**, 2144-2148 (2009).
2. N. A. Mirin, K. Bao, and P. Nordlander, “Fano Resonances in Plasmonic Nanoparticle Aggregates,” J. Phys. Chem. A **113**, 4028-4034 (2009).