Thermo-optical properties of polydimethylsiloxane (PDMS) doped with metallic nanoparticles

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Abstract-The thermo-optical response of polydimethylsiloxane (PDMS) doped with metallic nanoparticles is theoretically studied. The temperature dependence of the effective refractive index of the mixture has been analyzed through the spectral evolution of the output power ratio of a beam crossing a sample. Both the nanoparticle size and the concentration effects have been analyzed to design a potential temperature sensor.

Polydimethylsiloxane, also called PDMS or dimethicone, is a mineral-organic polymer of the siloxane family. It belongs to a group of polymeric organosilicon compounds that are commonly referred to as silicones. PDMS is the most widely used silicon-based organic polymer. It is specifically known for its unusual properties. PDMS is transparent at optical frequencies, it has low autofluorescence and is considered bio-compatible (with some restrictions). The PDMS sticks tightly to glass or another PDMS layer but at the same time is also flexible. In addition, it is possible to mold nanostructures. Finally, PDMS is a very cheap material. For all these reasons, PDMS is present in several applications, such as contact lenses, medical devices and flexible microsystems.

The use of PDMS with embedded metal nanoparticles (NPs) is currently a hot research topic [1] [2] [3]. These works reported the possibility to obtain homogeneous samples of colloid NPs in a PDMS. The advantageous properties of the NPs, like their plasmon resonances, and those of PDMS, like the extraordinary large and linear thermo-optic coefficient (dn/dT) [4], can be used for many applications. For this reason, a detailed study of the properties of the mixture is required.

In this work, the thermo-optical response of polydimethylsiloxane (PDMS) doped with metallic NPs is theoretically studied. The different optical properties of PDMS under different temperatures induces a shift of the plasmon resonances of the metallic nanoparticles. This effect can be also observed in a spectral shift of the effective refractive index of the compound, in particular in its absorption. A study of the output power ratio of the light beam passing through the PDMS doped with NP layer can show this phenomenon. Fig. 1 and Fig. 2 summarize some of the previous results, considering a silver nanoparticles (radius=5 nm), as some concentrations.

As a summary, the variation of the effective refractive index of the considered compound produced by a temperature change can be easily observed through the output power ratio of the beam crossing a sample. The high thermo-optic coefficient of PDMS along with the resonant phenomena in the absorption of NPs produce remarkable changes in the output power ratio. In addition, the broad range of working temperature, the linearity and high sensitivities make this compound a good candidate to work as an optical sensing element.

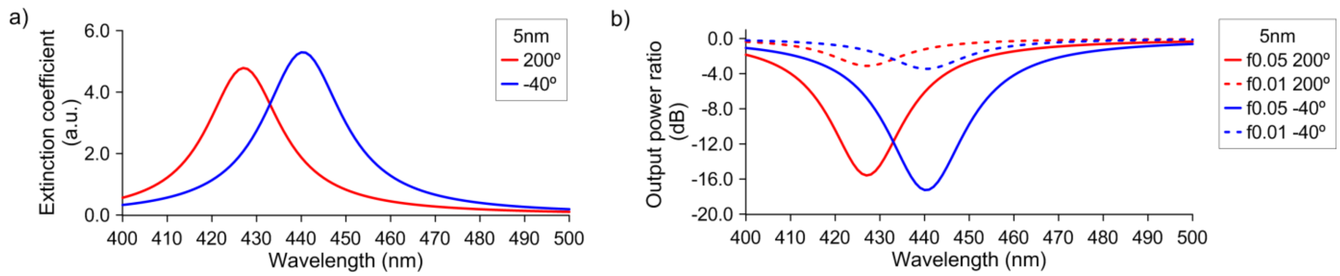

Fig. 1 Thermo-optical properties of composite formed by PDMS and Ag NPs. Particle sizes is R = 5nm. The filling factor is 0.05w% (continuous line) and 0.01 w% (dashed line). a) Extinction efficiency spectra of a spherical Ag NP (R=5 nm) embedded in a PDMS matrix for several temperature values. b) Output power ratio spectrum of a light beam crossing a sample of the compound (10µm of thickness) for two concentrations of NPs, 0.05w% (continuous line) and 0.01 w% (dashed line), and two different external temperatures.

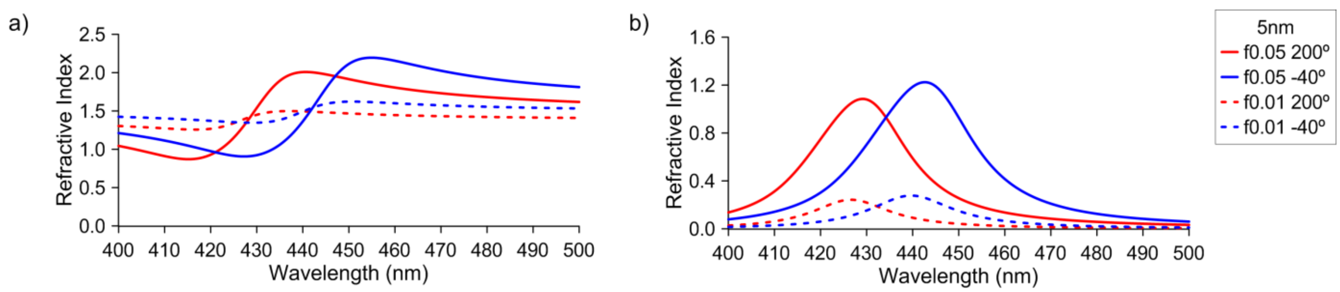

Fig. 2 Effective refractive index of composite formed by PDMS and Ag NPs. The filling factor is 0.05w% (continuous line) and 0.01 w% (blue line). (a) Real part for NPs with 5nm radius. (b) Imaginary part for NPs with 5nm radius.

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