High performance infrared magnetoplasmonics with transparent conductive oxide nanostructures

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Magnetoplasmonics, the combination of magnetic fields and light polarization to actively and remotely modulate the plasmonic response of nanostructures triggered significant improvements in optical nanodevices for telecommunications and refractometric sensing. Two main factors guide the design of high performance magnetoplasmonic platforms: a strong modulation of the plasmonic response and a sharp plasmon resonance. Within this framework, noble metal nanocrystals [1], nickel ferromagnetic nanodisks [2] or hybrid bimetallic nanostructures [3] have been proposed. While noble metals offer relatively sharp resonances, their weak magnetic response limits applicability. On the other hand, hybrid or ferromagnetic magnetoplasmonic nanostructures offer strong field response, at the cost of severely broadened resonances.

To overcome these issues, we propose a paradigm shift in material choice, shifting the attention to a novel class of plasmonic materials: transparent conductive oxides. Here we show that colloidal dispersions of tin-doped indium oxide (ITO) nanoparticles, with a sharp plasmon resonance in the near infrared, afford a 20-fold enhanced magnetic modulation with respect to Au, as detected by magneto-optical spectroscopies. We ascribe the enhanced magneto-optical response to the reduced free electron effective mass (m^*) of free carriers in ITO with respect to most metals, which in turn boosts the magnetic modulation. The latter is given in first approximation by the cyclotron frequency ω_C, which is inversely proportional to m^* and directly proportional to the applied field [1,4]. A further enhancement of the magneto-optical response was achieved in F- and In-co-doped cadmium oxide (FICO) nanoparticles, which display a 2-fold reduced plasmonic line width with respect to ITO and comparable effective mass [5,6].

Finally, using FICO NCs in a proof of concept magnetoplasmonic refractometric sensing experiment we obtained a superior refractive index sensitivity with respect to the most promising magnetoplasmonic systems reported in the literature [1-3] and performance competitive with the current state of the art of plasmonic refractometric sensing employing extinction spectroscopy [7], with the advantage of not requiring complicate curve fitting.

REFERENCES

[1] F. Pineider et al., Nano Letters, 13 (2013) 4785.
[2] N. Maccaferri et al., Nature Communications, 2015, 6, 6150.
[3] J. B. Gonzàlez-Diàz et al., Small, 2008, 4, 202.
[4] K.H. Hartstein et al., Journal of Physical Chemistry Letters, 2017, 8, 1831.
[5] X. Ye et al., Journal of the American Chemical Society, 2014, 136, 11680.
[6] A. Gabbani et al., arXiv:2104.07772 [physics.optics].
[7] M. Svedendahl et al., Nano Letters, 2009, 9, 4428.

FIGURES

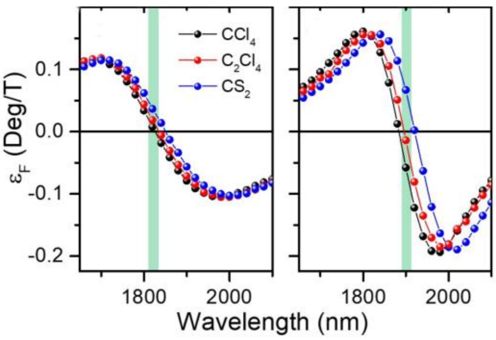

Figure 1: Proof of concept of a magnetoplasmonic refractometric sensing experiment. Change in magneto-optical ellipticity of ITO (left) and FICO (right) nanoparticles in media with different refractive indexes.