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Which perspectives for hybrid metallic nanostructures and magnetoplasmonics?

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Abstract. The present paper aims at introducing preliminary results about the magnetoplasmonic properties of bimetallic nanorods. Our study seems confirming that the Localized Surface Plasmon Resonance (LSPR) wavelength of such structures could be tuned by applying an external magnetic field, which could open new perspectives of applications.

1. Introduction

Smart technologies have deeply changed our way-of-life for the past two decades. However, technology has now to face a major challenge lying in the energy-consumption reduction of electronic devices. Indeed, if 1bit energetically costs about 1pJ, the drastic increase of operations induced by the use of smart systems will in the next decades consume more than the world energy production may produce. With the current technologies, computing will not be sustained around 2040's as predicted by the Semiconductor Industry Association and the Semiconductor Research Corporation [1]. One global objective is thus to develop full-optical technologies, explaining why plasmonics- due to the possibility of manipulating light at the nanoscale- has emerged in the past two decades as a promising way to design full-optical components (optical isolators...). However, in order to achieve such ambitious technological target, the development of active plasmonics- that is to say the possibility to tune plasmonic properties with external actions- has become a necessity which lies at the root of the rising of mechanoplasmonics [2,3], thermoplasmonics [4] or magnetoplasmonics [5].

Among these emerging fields, the strongest potential probably lies in magnetoplasmonics and the possibility to tune plasmonic properties of nanostructures taking advantage of external magnetic fields. Recently, more attention was indeed paid to nanostructures combining optical and magnetic properties. Few pioneering groups even started investigating the possibility to use pure nickel for plasmonics [5-7]. In particular, it has been evidenced that pure Ni nanostructures exhibit Localized Surface Plasmon Resonances (LSPR) in the UV-visible range [5,8]. Nevertheless, due to strong plasmon damping in pure ferromagnetic nanostructures, many studies focused on hybrid nanostructures made of a noble metal layer and a ferromagnetic one. Such hybrid structures have also shown enhanced magneto-optical activity [9-11]. Another interesting feature which has been experimentally demonstrated by Wei et al. Lies in the possibility to tune the Localized Surface Plasmon Resonance (LSPR) of Au nanoparticles embedded in a Co thin film by applying an external magnetic field [12]. The authors of this study explained the observed spectral blue-shift by the modification of the Co film dielectric constant when



applying an external magnetic field. Such a result could open promising perspectives for active plasmonic devices.

In this paper, we focus on bimetallic metallic nanorods in order to experimentally assess the influence of external magnetic field on the plasmonic properties of such hybrid nanoparticles.

2. Nanoparticles synthesis and characterization

Bilayered Au/Ni nanorods with various lengths have been synthesized by electron beam lithography. Using electron beam deposition, a 3nm Cr adhesion layer was evaporated on a glass substrate followed by the evaporation of 25nm Au layer and 25nm Ni layer. The diameter of all the nanorods was set to 50nm while the length was tuned from 80nm to 180nm. The distance between nanorods was set to 250nm. The geometry and dimensions of all Au NPs were confirmed by scanning electron microscopy (see Figure 1).

Similar monometallic Ni and Au nanoparticles have been made following the same procedure with a thickness of 50nm in order to evidence the role of the interface between Au and Ni by comparison of the properties of monometallic and bimetallic nanorods.

The extinction spectra of the systems have been measured with a transmission optical microscope coupled to a micro-spectrometer using a multimode optical fiber as confocal filtering. The setup has been upgraded to allow applying an external magnetic field in the sample plane as well as out of the sample plane.

3. Results and discussion

In this section, we intend to discuss preliminary results obtained on such hybrid bimetallic nanostructures.

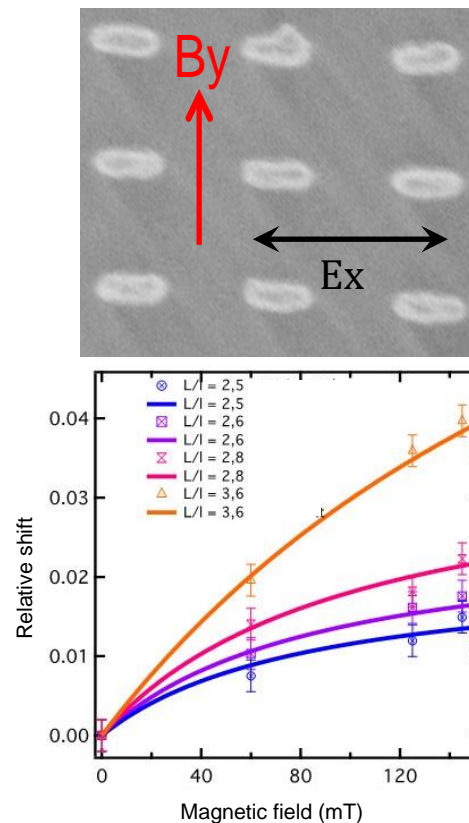


Figure 1: (top) SEM image of bimetallic nanorods. The X direction is set along the long axis of the rods and the Y direction along the transverse axis. (bottom) optical extinction spectra obtained for nanorods with various aspect ratios as a function of the applied magnetic field.

For all the samples, the external magnetic field has been applied along the the directions X, Y (in-plane) and Z (out-of-plane). It appears (not shown here) that no difference is observed when the external magnetic is applied along the X direction. However, when the external magnetic field is applied along the Y direction, a redshift of the LSPR may be observed by increasing the magnetic field value for the Ex polarization while no shift is observed for the Ex direction.

When the magnetic field is increasingly applied along Bz, in this case a red-shift may be also observed but for both incident polarizations of the incident light, Ex and Ey. These results are consistent for all the values of the anorod lengths. It thus appears that a shift of the LSPR is noticeable only when the incident light polarization is transverse to the applied magnetic filed direction. The evolution of the shift value depending on the applied magnetic field values is displayed for all the NRs geometries on Figure 1.

4. Conclusion

In this paper, preliminary results on bimetallic nanorods and the dependency of their plamsonic properties as a function of the applied external magnetic field have been exposed. Such results need to be confirmed, however their potential could open new perspectives, especially for the development of integrated optical modulators.

References

- [1] Semiconductor Industry Association and Semiconductor Research Corporation, Rebooting the IT Revolution: A Call toAction (2016).
- [2] T. Maurer, J. Marae-Djouda, U. Cataldi, A. Gontier, G. Montay, Y. Madi, B. Panicaud, D. Macias, P.M. Adam, G. L  v  que, T. B  rgi, and R. Caputo, *Front. Mater. Sci.* **9**, 170 (2015).
- [3] J. Marae-Djouda, A. Gontier, R. Caputo, G. L  v  que, N. Bercu, Y. Madi, G. Montay, P.M. Adam, M. Molinari, S. Stagon, and T. Maurer, *ACS Applied Nano Materials* **1**, 5, 2347 (2018)
- [4] A. P. Bell, J. A. Fairfield, E. K. McCarthy, S. Mills, J. J. Boland, G. Baffou, D. McCloskey, *ACS Nano* **9**, 5551-5558 (2015)
- [5] S Schuermans, T Maurer, J Martin, JB Moussy, J Plain, *Opt. Mater. Express* **7**, 6, 1787 (2017)
- [6] V. Bonanni, S. Bonetti, T. Pakizeh, Z. Pirzadeh, J. Chen, J. Nogu  s, P. Vavassori, R. Hillenbrand, J.   kerman, A. Dmitriev, *Nano Lett.* **11**, 5333, (2011).
- [7] J. B. Gonz  lez-D  az, A. Garc  a-Mart  n, G. Amelles, D. Navas, M. V  zquez, K. Nielsch, R. B. Wehrspohn, U. G  sele, *Adv. Mater.* **19**, 2643 (2007)
- [8] J. Chen, P. Albella, Z. Pirzadeh, P. Alonso-Gonz  lez, F. Huth, S. Bonetti, V. Bonanni, J.   kerman, J. Nogu  s, P. Vavassori, *Small* **7**, 2341 (2011)
- [9] J. C. Banth  , D. Meneses-Rodr  guez, F. Garc  a, M. Gonz  lez, A. Garc  a-Mart  n, A. Cebollada, G. Armelles, *Adv. Mater.*, 24 (2012)
- [10] J. B. Gonz  lez-D  az, A. Garc  a-Mart  n, J. M. Garc  a-Mart  n, A. Cebollada, G. Armelies, B. Sep  lveda, Y. Alaverdyan, M. K  ll, *Small* **4**, 202 (2008).
- [11] H. Wang, D. W. Brandl, F. Le, P. Nordlander, N. J. Halas, *N. J. Nano Lett.* **6**, 827-832 (2006)
- [12] C.-M. Wei et al., *Optics Letters* **36**, 514 (2011)

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