FABRICATION OF SUB-MICRON 3D HELICAL ANTENNAS BY FIB INDUCED DEPOSITION AND GLAD FOR SUBWAVELENGTH POLARIZATION OPTICS

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A wide variety of optical applications and techniques demand control of light polarization. Manipulation of light polarization has recently experienced extraordinary advances with the emergence of plasmonics, leading to the concepts of polarization meta-optics [1]. However, all the structures developed so far rely on collective optical effects on arrays of nanostructures. They are therefore restricted to areas much larger than the wavelength of light, which limits design strategies in polarization control. Tailoring light with individual sub-λ devices would overcome limits but it remains a challenge [2].

Based on spin-orbit interaction of light [3], we have designed a Helical Travelling-wave Nanoantenna (HTN) to produce directional light beam of tunable polarization through a twisted plasmonic effect. The fabrication method of the HTN is based on Ion Beam Induced Deposition [4]. To improve the plasmonic properties of the HTN developed in [4], we propose a carbon-gold core-shell structure of much better plasmonic properties.

The HTN is engineered onto a 100-nm thick gold layer deposited onto a glass cover slip. A dual beam FEI Helios Nanolab 600i is used to realize and control the growth of a helical carbon skeleton. The naphthalene precursor is injected close to the area of interest thanks to a dedicated Gas Injection System (GIS) and the carbon deposition occurs upon exposure to the ion beam. The voltage and the ion beam current are optimized to increase the deposition rate. A fine-tuning of the dwell time and of the pixel size leads to a 3D deposition. Metal coating is then realized using GLAD, i.e., by sputtering with a tilted target and a rotational substrate holder. The resulting nanostructure consists of a 105-nm diameter carbon helical wire covered by a thin gold layer. Finally, a rectangle nano-aperture is milled right at the helix pedestal (Fig 1a). To evaluate the quality of the fabricated HTN, 3D reconstruction has been conducted in the dual beam. It consists in a slice and view process. One slice is shown in Fig 1b and the full reconstruction is shown in Fig 1c.

With this new fabrication process, we demonstrated polarization conversion at the scale of an individual subwavelength nano-antenna [5,6]. Using this approach, we evidenced new degrees of freedom in the control of light polarization. We demonstrated a new phase-plate like structure whose properties are forbidden with usual polarization optics [5] and the conversion between longitudinal fields and circularly polarized waves [7]. Finally, we also showed the possibility to engineer a HTN at the apex of a sharp fiber tip (Fig 1d), thus opening the route for moveable chiroptical probes.

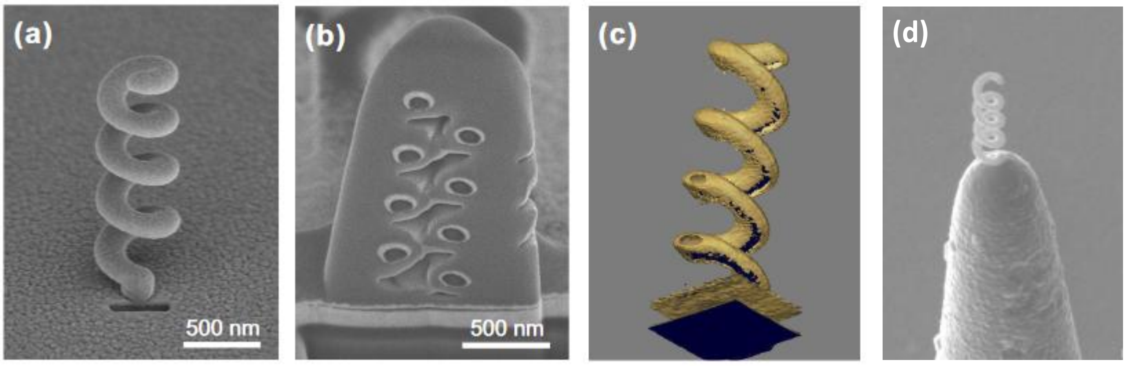

Figure 1. (a) SEM image of a HTN, (b) SEM image of a cross section of the HTN embedded in platinum, (c) Reconstructed 3D image of the fabricated gold coated HTN (yellow = gold, black = carbon), (d) HTN at the apex of a tip.

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