Metallic tips for efficient plasmon nanofocusing and advanced optical nano-imaging

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1. Introduction

Plasmon nanofocusing, energy compression of propagating plasmons on a tapered metallic tip, is a promising tool for near-field scanning optical microscopy due to its unique properties such as background suppression and broadband property[1]. Although applications of plasmon nanofocusing has been still limited so far, it would make the plasmon-nanofocusing-based techniques more reliable and practical if an efficient fabrication method of metallic tips is established.

In this work, we introduce a tip fabrication for efficient plasmon nanofocusing, in which we achieved 100% reproducibility of plasmon nanofocusing in more than 20 fabricated tips through precise optimizations of fabrication processes[2]. The metallic tip was fabricated through silver thin film deposition by thermal evaporation and grating fabrication by focused ion beam (FIB) lithography, as shown in Fig. 1(a). The structure was precisely optimized through simulations and experiments. Such an efficient plasmon nanofocusing easily led us to perform optical nano-imaging and even a brand-new nano-imaging technique, scattering spectral nano-imaging via broadband plasmon nanofocusing.

2. Results and Discussion

We used a commercially-available silicon cantilever tip which had pyramidal shape. We first oxidized it in an electric furnace, which turned silicon to oxidized silicon with much less optical absorption. We then deposited a silver thin film on one surface of the pyramidal structure. By controlling evaporation angle and rate, we obtained extremely smooth film with 0.5 nm surface roughness. We fabricated grating structure by FIB lithography. Here, the thickness of silver film was 40 nm, and the grating period was 780 nm, which were optimized through finite-deference time-domain (FDTD) method for 642 nm wavelength of excitation laser. The fabricated tip is shown in Fig. 1(b).

To confirm if the fabricated tip induces plasmon nanofocusing, we illuminated the grating with the laser as shown in Fig. 1(c). A bright spot was observed at the tip apex through plasmon nanofocusing from the grating to the apex, which was further confirmed through polarization dependence. More importantly, because of optimized structure and highly smooth silver film, we have observed plasmon nanofocusing with 100% reproducibility in more than 20 fabricated tips.

Such efficient metallic tips for plasmon nanofocusing easily leads to optical nano-imaging. We performed optical nano-imaging of carbon nanotubes with 20 nm spatial resolution, far beyond diffraction limit of light. Furthermore, by taking the advantage of broadband feature of plasmon nanofocusing, we demonstrated scattering spectral imaging with nanoscale spatial resolution. By optimizing the tip structure for white light illumination, we again fabricated metallic tips through the same procedure. By illuminating a plasmon coupler on the tip, we obtained scattering spectral images of carbon nanotubes, which revealed energy band structures at nanoscale.

References

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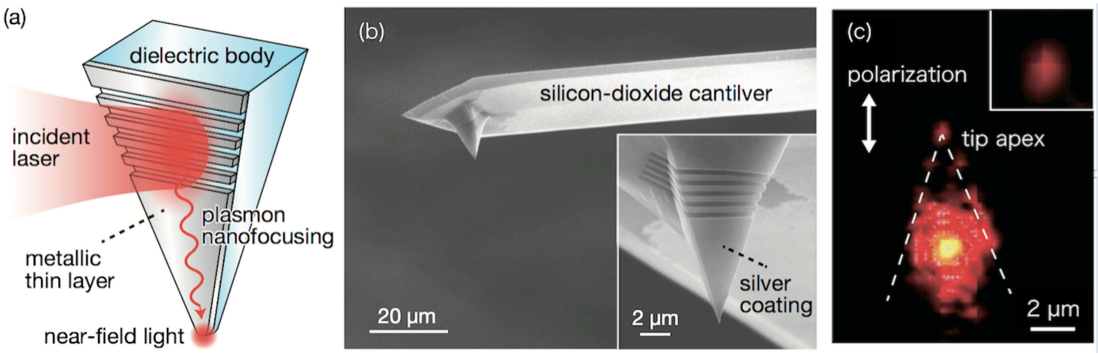

Figure 1. (a) Schematic of a metallic tip designed for plasmon nanofocusing. (b) SEM images of a metallic tip fabricated on a silicon cantilever. (c) Optical image of the tip with incident laser at the grating. In-set shows the enlarged image of light spot induced through plasmon nanofocusing at the tip apex.