High aspect-ratio doped Si nanostructures for plasmonics induced light funneling applications

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Plasmonic nanostructures at subwavelength scales are becoming widely known for their ability to uniquely manipulate light, giving rise to a variety of new applications in bio-sensors, solar technology, and a wide range of nano-photonic devices. The properties of high aspect-ratio nanoslits were investigated in recent work on so-called "funneling" of infrared light into slits etched into a Au film, demonstrating that light is effectively coupled into Fabry-Perot resonance modes, even with a single slit (Fig. 1(a)) [1].

The difficulty with these structures is that fabrication of μm deep, nano-scale slits is typically performed using electron or focused ion beam lithography, limiting their use outside of the experimental arena. However, recent work has shown that nanoimprint lithography can be used to generate these features over large areas and extremely high aspect ratio nanoslits can be etched into Si using a modified Bosch process [2]. Previous work has already demonstrated that plasmonic responses in the mid-infrared can be achieved [3,4]. This work aims to investigate if the light funneling effect can be observed in high aspect-ratio sub-wavelength slits etched into heavily doped Si.

Utilizing a 700 nm period, wide linewidth mask created using nanoimprint lithography, nanoslits of approximately 3 μm depth (~30:1 aspect ratio) were etched into a heavily doped ($>10^{20}$ /cm^3 concentration, p-type) Si sample (Fig. 1(b)). Results from Fourier Transform Infrared Spectroscopy (FT-IR) reflection measurements are shown in Fig. 2. To verify if the dips in reflection are related to the funneling effect, the structure was simulated in COMSOL using the Drude model with a plasma frequency (ω_p) modified to account for increased doping, as demonstrated in Ref. [4]. The simulated peaks and dips for transverse magnetic (TM) polarized light match very well with measured values, mirroring results from previous works that reveal the plasmonic induced funneling phenomena [1,5]. Future work will focus on further control of mask and etch profiles and higher doping to achieve stronger dips in the reflectance.

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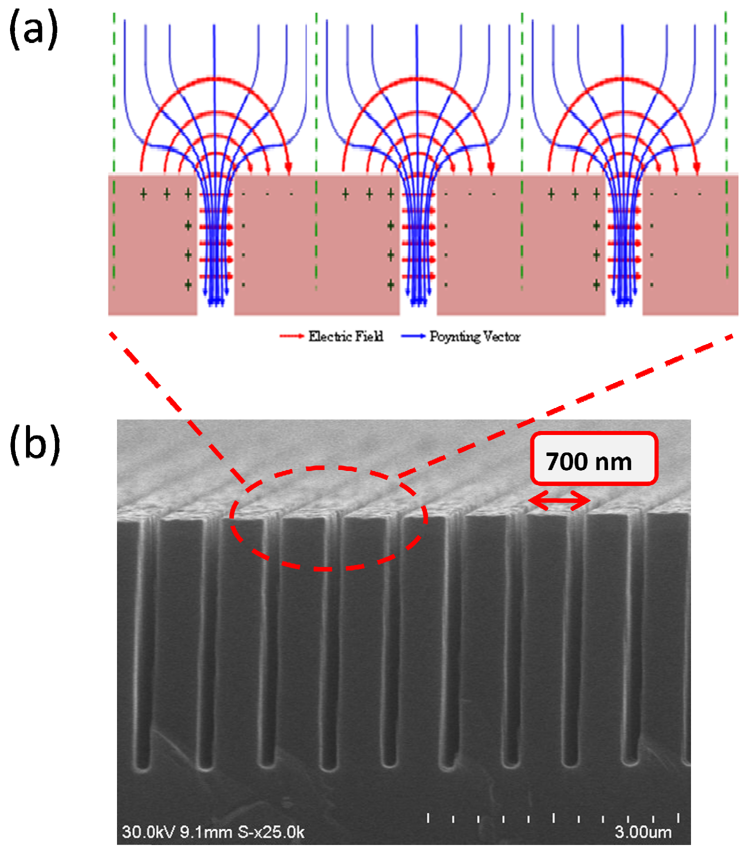

Figure 1: (a) Model demonstrating “light funneling” into nanoslits [1]. Red arrows represent electric field lines while blue shows power flow (b) SEM image of etched nanoslits in doped Si.

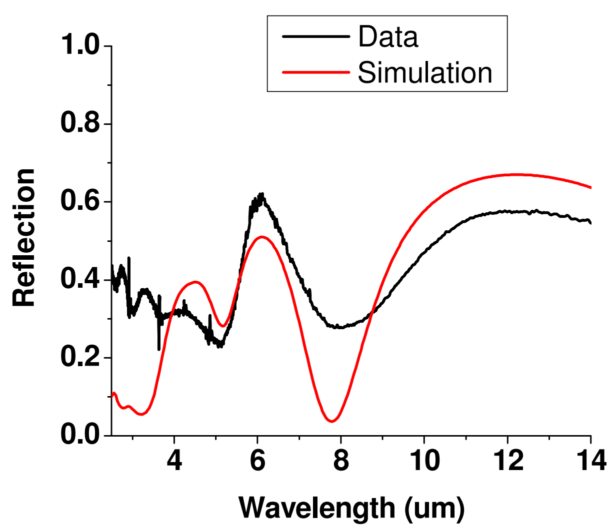

Figure 2: Comparison of simulation and FT-IR measured data for TM polarized light.