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Subwavelength laser ablation using impulsively excited surface plasmons

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Abstract: We demonstrate the subwavelength thermal-free ablation of nanoscale materials directly by fs oscillator. The plasmonic nanoantennae are used to locally enhance the near-field, which assist the electron-driven electrostatic ablation of small materials at ultralow laser fluence. We also here demonstrate a method to deposit smooth low-density thin nanofilm.

The thermal effects are widely believed as the main mechanism for laser induced ablation of nanoscale materials [1]. However, here we show an electron-driven ablation regime instead of thermal melting when ultrashort laser pulses are employed [2]. Figure 1 shows SEM images indicating the ablation of Au bowtie nanoantenna with (a) and without (b) SiO2 coating by 8-fs oscillator (20 J/m^2). The confirmation of electrostatic ablation and the exclusion of thermal effects are on the basis of the following reasons: First, the ablation of antenna is only observed in the optical hotspot rather than in the thermal hotspot. Second, the dielectric and metallic materials have the similar ablation threshold. Third, the density of this produced nanostructure is very low, we can still clearly see the bowtie tips inside the produced nanostructure.

The plasmon enhanced ablation is universal to different shapes of nanoparticles. We also observe the same effect, i.e. the deposition of a thin gold nanostructure in the optical hotspot, using nanoholes designed for extraordinary optical transmission, as shown in Fig. 1(c). Due to the Gaussian distribution of the laser intensity, the electric field increases along the red arrow. Consequently, the size of the generated nanostructures also gradually increases along the red arrow. The most interesting phenomenon is that at the low incident laser intensity, the gold atoms start to appear in the centre of holes, as shown inside the squared area in Fig. 1 (c). This electron-driven electrostatic ablation process is of interest for thermal-free laser nanomachining and therefore for the deposition of high quality nano thin film.

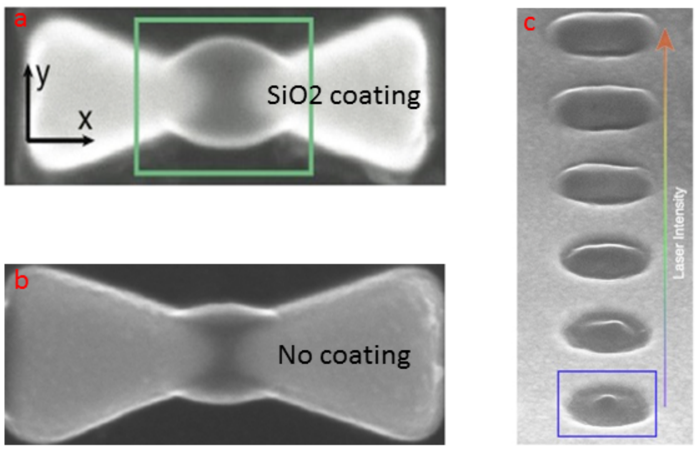

Figure 1. SEM images of nanostructures after laser irradiation. (a) Au bowtie with SiO2 coating, (b) pure Au bowtie, and (c) Au nanoholes.

References

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