UV-SERS Assisted by Nano-Focusing in Plasmonic Gratings with Tapered Slits

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Abstract: The potential for UV-SERS is demonstrated using subwavelength Al gratings grown on sapphire substrate. The role played by the slit geometry and analyte coverage is explored, demonstrating that enhancement factors greater than 100,000 are possible.

OCIS codes (240.6695) Surface-enhanced Raman scattering; (240.6680) Surface plasmons; (310.6628) Subwavelength structures, nanostructures; (260.7190) Ultraviolet.

Surface-enhanced Raman scattering (SERS) has been widely studied both theoretically and experimentally due to a large variety of potential applications in chemical and biological sensing. In a recent publication [1] we have theoretically shown that, although in the ultra-violet (UV) SERS is limited by the metallic dampening, yet enhancements as large as 10^5 can be achieved when the pump is tuned at the plasmonic band edge of an Al metallic grating grown on a sapphire (Al_2O_3) substrate. In this work we extend these findings to include the role played by the slit's geometry. In a different, but related, context, it has been experimentally demonstrated [2] that plasmonic gratings with tapered slits, i.e. slits with sloped instead of parallel walls, can boost the extraordinary optical transmission (EOT) in the visible by nanofocusing of radiation. Here we investigate the possibility of consistent enhancement of UV-SERS when the operation at the plasmonic band edge of the structure as in [1] is combined with the nanofocusing effect as in [2]. In Fig.1(a) we show one of the typical geometries that we have theoretically analyzed. In Fig.1(b) the absorption of the structure vs. the incident wavelength is reported. It is noted that in this case the structure admits two resonances in the UV, one at λ=255nm and the second at λ=310nm. Finally in Fig.1(c) and 1(d) the field localization at the two resonances is calculated.

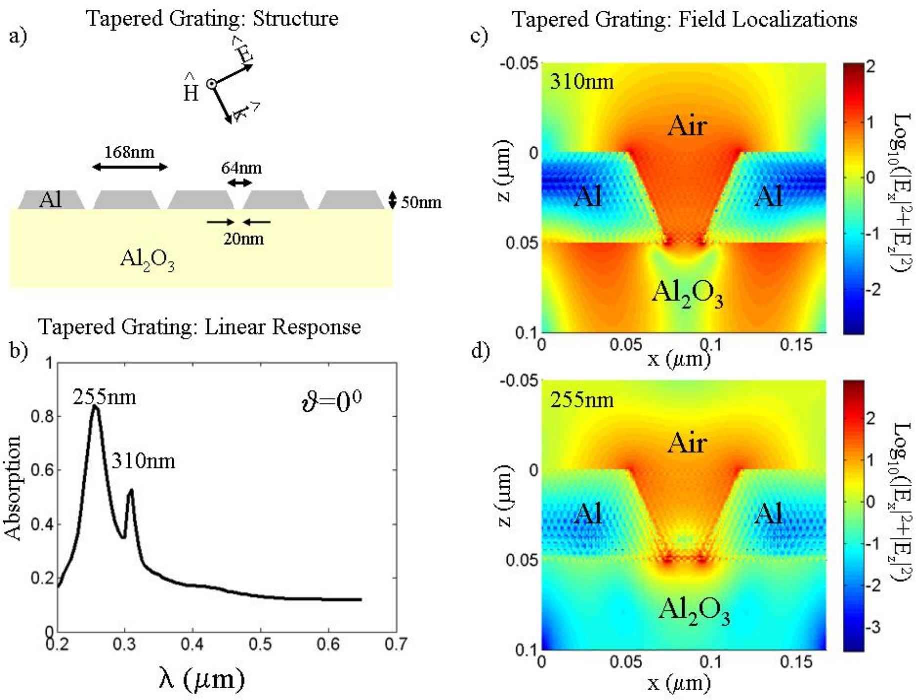

Figure 1: (a) Schematic drawing of the geometry and excitation conditions. A TM-polarized, plane, electromagnetic wave is incident on an Al grating grown on a sapphire substrate with typical dimensions shown in the figure. In this case the tapering angle of the grating is approximately 20^0. (b) Absorption vs. incident wavelength at normal incidence. (c) Field localization at λ=310nm. (d) Field localization at λ=255nm.

In preparation for an experimental proof of principle of the concept, we fabricated several Al grating arrays with several periodicities. 50 nm thick Al films were deposited on sapphire substrate using e-beam evaporation technique. We used Focused Ion Beam (FIB) milling method to fabricate grating arrays. SEM images of a 175 nm periodicity Al gratings are shown in Fig. 2. The width of the grooves was optimized by varying the current and the number of passes of the ion beam. We obtained 20 nm wide grooves at the metal-sapphire interface (see Fig. 1a) with a side wall angle of 20^{0}.

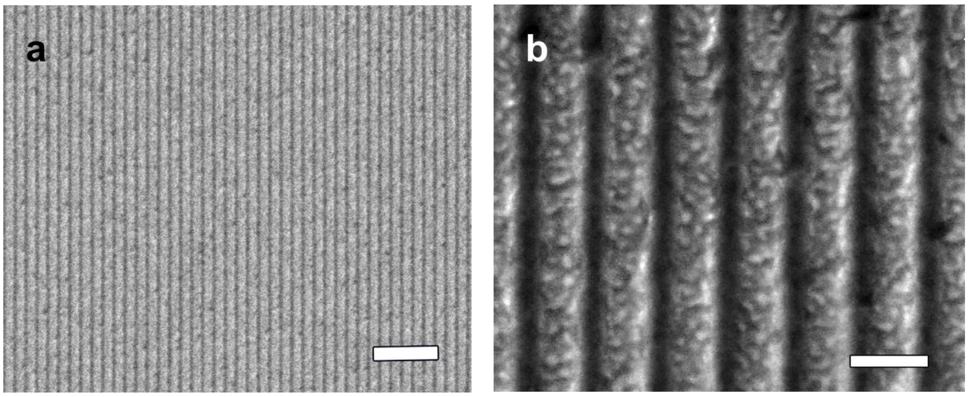

Figure 2: Example SEM images of the fabricated Al gratings with a periodicity of 175 nm at magnifications of (a) 12K and (b) 80K. (The scale bars are 1 µm and 200 nm for (a) and (b), respectively.)

Experimental verification of our theoretical predictions for Raman enhancement will have been undertaken using a spectrometer constructed especially for UV Raman spectroscopy [3]. Enhancement factors will have been calculated by comparing the strength of the Raman signal from the grating region with the strength of the Raman signal from adjacent regions without a grating. The dependence of the enhancement factor on laser wavelength and grating pitch will have been explored, and the enhancement factors obtained will have been compared with theoretical estimates.

References

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