Direct Laser Written Periodic Si Ripples Decorated with Au Nanoparticles as a Platform for Surface Enhanced Raman Spectroscopy

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Abstract: High quality ripple-structures on silicon (Si) surface were directly fabricated by femtosecond (fs) laser irradiation in air developing large-area, low-cost substrates for surface-enhanced Raman spectroscopy (SERS). Rippled subwavelength structures exhibit a significant SERS response thanks to both an electromagnetic (EM) field enhancement originating from the narrow gaps between adjacent ripples and a plasmonic coupling among the Au nanoparticles (NPs), where the concentrated hot spots tend to occur. SERS mapping shows a good uniformity, with ±8% deviation over a 15×20 μm^2 area and reveals a large disparity in the signal strength with respect to that displayed by the micron-sized surface structures produced at larger laser fluence, for which a two order of magnitude lower SERS signal is achieved. The SERS rippled substrates are able to detect a Raman analyte at a minimal concentration of 10^{-12} M for RhB and 10^{-11} M for MBA, respectively. Furthermore, a good agreement is attained between the values of the Raman enhancement factors (EFs) obtained experimentally and by simulations through Finite Elements Method calculations. Our findings demonstrate that the proposed approach can provide a feasible and efficient method for the fabrication of SERS substrates with high Raman detection capability of analytes in trace amounts.

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