One-step fabrication of nanostructures by femtosecond laser for surface-enhanced Raman scattering

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Femtosecond (fs) laser micromachining has attracted much attention due to the unique properties of minimum thermal damage as the pulse duration is shorter than the thermalization time, and the phenomenon of multiphoton absorption leading to the benefit of machining dielectrics inside the bulk material. Fs laser micromachining in dielectric materials opens a window of opportunity to fabricate functional microdevices directly or indirectly. Recently, periodic micro/nano-structures generated by fs laser irradiations on silicon wafers were demonstrated. Their unique optical property of high absorbability in a wide range of wavelengths (visible light to IR) can be very important for optical detectors to enhance the optical-electric efficiency and the effective wavelength range. Furthermore, the periodic surface morphology, after depositing metal particles on the surface, was used as the surface-enhanced Raman scattering (SERS) substrate. In this work, we develop an efficient approach to fabricate SERS substrates which provide high enhancement factors (EFs). A combined process of material ablation, particle synthesis, and particle deposition were achieved by fs laser micromachining of silicon wafers in aqueous solutions of silver nitrate. A high EF of 109 was obtained for the synthesized silver nanoparticles on the substrate using Rhodamine 6G (R6G) as analyte molecules at the excitation wavelength of 632.8 nm.

Fig. 1. EDS mapping of the sample machined in 0.1 M silver nitrate solutions at a scanning speed of 1 mm/min. (a) SEM image of the mapping area. The scale bar is 500 nm. (b) silver mapping. (c) silicon mapping.
Fig. 2. Surface morphologies of the machined silicon wafer substrates in different concentrations of silver nitrate solutions with a scanning speed of 0.5 mm/min. (a) 1 mM. (b) 10 mM. (c) 0.1 M. (d) 1 M.