Femtosecond Laser induced Periodic Surface Nanostructure on Cu-Ag Double Layer inside glass microfluidic channel for Surface Enhanced Raman Scattering

Advanced Laser Processing Research Team, RIKEN Center for Advanced Photonics, RIKEN, 2-1 Hirosawa,Wako, Saitama 351-0198, Japan

(P)Shi Bai, Daniela Serien, Kotaro Obata, Koji Sugioka[1]*

Email: ksugioka@riken.jp

Abstract: Hybrid femtosecond laser processing enabled three-dimensional microfluidic surface enhanced Raman scattering (SERS) chips for highly sensitive sensing of a tiny amount of substances [1]. In this paper, to investigate dependence of laser wavelength on the period of ripple which strongly affects the enhancement factor for SERS, two different wavelengths (525 nm and 1030 nm) of femtosecond laser beams were applied for generating periodic surface nanostructures (nanoripple) on Cu-Ag double metal layers. The metal layers were formed in a closed glass microchannel by selective metallization technique composed of femtosecond laser direct write ablation and successive electroless plating. Femtosecond laser direct writing was able to control the morphology of nanoripple on the metal layers by laser parameters such as laser fluence, laser repletion rate and so on, resulting in formation of high spatial frequency laser induced periodic surface structure (HFSL). In addition, we observed that shorter wavelength (525 nm) decreased the period of nanoripple and the width of groove in nanoripple to 130 nm and to 40 nm, respectively. In contrast, the minimum period obtained by 1030 nm wavelength was approximately 250 nm, which meant the positive correlation between the period of ripple and the laser wavelength. In addition, we also found that the period of ripple was reduced when the repetition rate increased, which was partially ascribed to decrease of the refractive index of metal substrate. Based on our experimental results, we fabricated SERS substrates using homogenous periodic surface structures by two different wavelengths of femtosecond laser on Cu-Ag double layer, which were used for SERS detection of rhodamine6G in glass microfluidic chip. The SERS results presented that with narrower groove width of the nanoripple fabricated by 525 nm femtosecond laser, the SERS intensity was enhanced and the SERS enhancement factor was evaluated to exceed 1×10^8. We used the SERS microfluidic chip for the detection of coumarin (detect limit of coumarin is 10^{-7} M). We also simulated the electric field of enhanced at the nanostructure, which supported the experimental results.

Keywords: nanostructure; microfluidic; SERS.

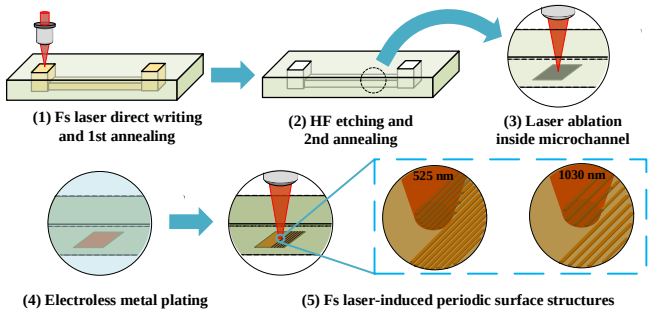

Fig. 1 Schematic of the fabrication procedure of SERS microfluidic chip using all-femtosecond-laser-processing. (1) – (2) Three-dimensional glass microfluidic chip is fabricated by femtosecond laser assisted chemical etching. (3) – (4) Selective metallization in microchannel is realized by laser ablation and subsequent electroless Cu and Ag plating. (5) Periodic surface nanostructures with different periods are created by femtosecond lasers with two different wavelengths.

Reference

[1] Bai, S., Serien, D., Hu, A., Sugioka, K., Adv. Funct. Mater. 2018, 28, 1706262.