New-Type SERS-Active Substrates Formed with Ag Ion Implantation of Si

A Rogov[1,2], V V Vorobev[1,2], Y N Osin[2], V I Nuzhdin[1], V F Valeev[1], and A L Stepanov[1]

[1] *Kazan Physical-Technical Institute, Kazan, Russia*
[2] *Kazan Federal University, Kazan, Russia*
Contact Email: alexeyrogov111@gmail.com

It is a well-known effect that nanoparticles of noble metals could enhance Raman signal from organic molecules [1]. There are several methods for fabrication of SERS-active substrates mostly based on chemical reactions. In this work we show that low-energy high-dose ion implantation (being a physically clean method in opposite to chemical ones) could be used to create porous silicon layers with silver nanoparticles (Ag:PSi) which could act as a SERS-active substrate [2].

The wafer of crystalline silicon (100) was implanted by Ag+ ions with the energy of 30 keV, dose of $1.5{\times}10^{17}$ ion/cm^2 and ion current density of 8 μA/cm^2 using the ion accelerator ILU-3. Surface morphology of Ag:PSi substrate is characterized by scanning electron microscope (SEM) Merlin (Carl Zeiss) which was equipped with Aztec X-Max energy-dispersion spectrometer (Oxford Instruments) for energy-dispersive X-Ray spectroscopy (EDX) analysis and by scanning probe microscope Dimension Fastscan (Bruker). Raman spectra are measured using optical confocal DXR Raman Microscope (Thermo Scientific). Second harmonic of solid state Nd:YAG laser with the wavelength of 532 nm and the maximum power of 10 mW is used for Raman excitation. The 0.01 M solution in bidistilled water of Methyl Orange dye as testing analyte (MO) is used to study SERS on the Ag:PSi substrate.

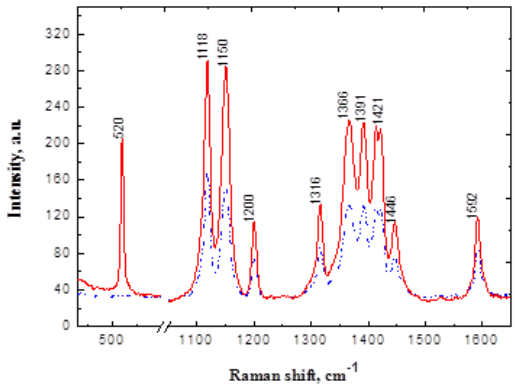

Figure 1: Raman spectra of MO solution (dashed) and MO drop on the Ag:PSi substrate (solid)

Fig. 1 shows the Raman spectra of MO solution and MO drop on the Ag:PSi substrate. The Raman bands plased at 1118, 1150, 1200, 1316, 1366, 1392, 1421, 1446 and 1592 cm^{-1} correspond to the vibration frequencies of MO molecules [3]. The intensity of these bands is approximately two times higher for MO layer on the Ag:PSi surface. The band at 520 cm^{-1} corresponds to silicon wafer. Enhancement factor (EF) can be estimated as [4]:

$$EF = I_{SERS} * C_{SRS}/I_{SRS} * C_{SERS},$$

where I_{SERS} and I_{SRS} are Raman intensities for SERS on the Ag:PSi substrate and for spontaneous Raman scattering in solution respectively; C_{SERS} and C_{SRS} are corresponding molar concentrations of MO. Enhancement factor is 1.9 and 1.7 for frequences 1150 and 1366 cm^{-1}, respectively.

The main result of the work is experimental demonstration of SERS-activity of the new substrate with silver nanoparticles, which created by a novel approach based on low-energy high-dose ion implantation. These results demonstrate a perspective for using of a new SERS-substrate on Ag:PSi as chemical and biological sensors.

Acknowledgements: This work was supported by the Russian Scientific Foundation No. 17-12-01176.

References

[1] M V Chursanova, L P Germash, V O Yukhymchuk, V M Dzhagan, I A Khodasevich and D. Cojoc, Appl. Surf. Sci. **256**, 3369 (2010)

[2] A L Stepanov, V I Nuzhdin, V F Valeev, V V Vorobev, T S Kavetskyy and Y N Osin, Rev. Adv. Mater. Sci. **40**, 155 (2015)

[3] A Zhang and Y Fang, J. Colloid Interface Sci. **305**, 270 (2007)

[4] X Sun,N Wang and H Li, Appl. Surf. Sci. **284**, 549 (2013)