Kazan Federal University
METANANO 2020
V International Conference on Metamaterials and Nanophotonics
14 - 18 September, 2020 ONLINE
Laboratory of Nanooptics

Study of the modification of the hydrophobic properties of thin carbon films via Thermo-Assisted Tip-Enhanced Raman scattering method

Saparina S.V, Kharintsev S.S.

Department of Optics and Nanophotonics, Institute of Physics, Kazan Federal University, ul. Kremlin 16, Kazan, Russia.

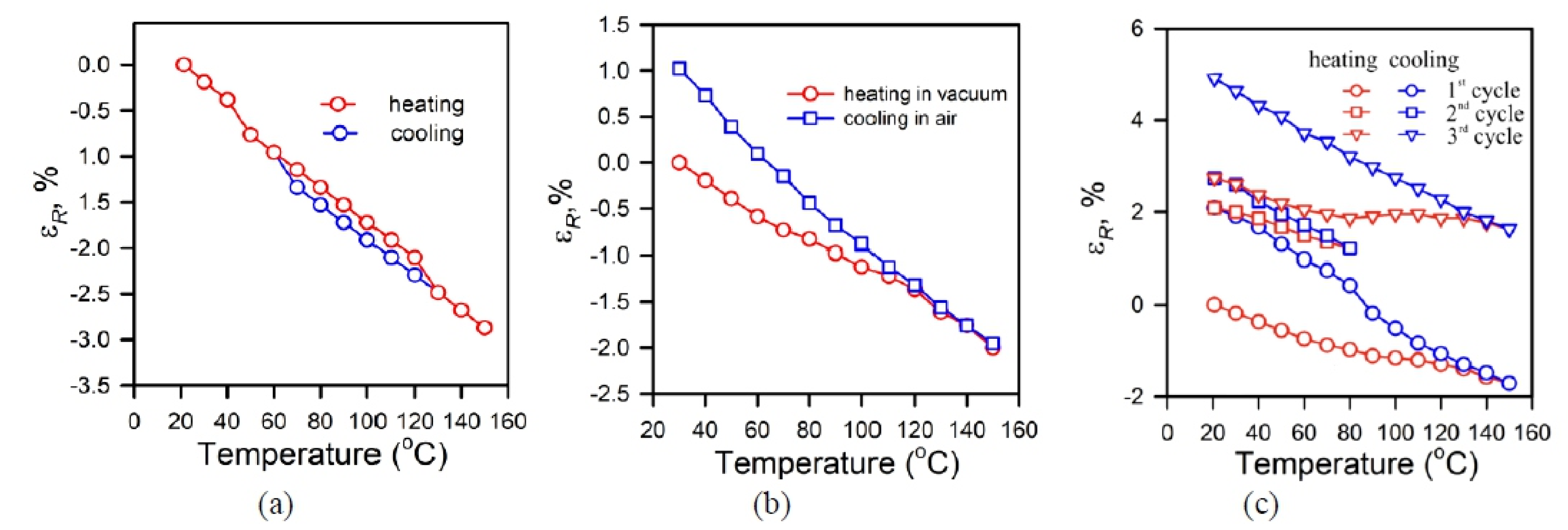
email: sveta.saparina@yandex.ru

Abstract

The chemical composition and optical properties of amorphous carbon films of various thicknesses in the range from 1 to 100 nm on a series of optical fibers were characterized by using far-and near-field Raman spectroscopy. For the first time the presence of a hysteresis of the resistance of a thin carbon film was observed in ambient environment. The Raman spectrum of carbon film in the region of 1000–2000 cm–1 was fitted and well reproduced using seven individual components that were assigned to the oxygen- and hydrogen-containing functional groups defect graphene. Besides that, the thermo-assisted Tip-Enhanced Raman Scattering (TERS) method provided the evidence of the formation of a water molecule in carbon coatings. We propose that during the heat treatment the fraction of functional groups on the initial film structures changes in comparison with room temperature. Such structural modifications of carbon film can lead to a violation of hydrophobic properties of carbon coatings due to temperature change. These findings may provide opportunities for technical design of carbon-based devices.

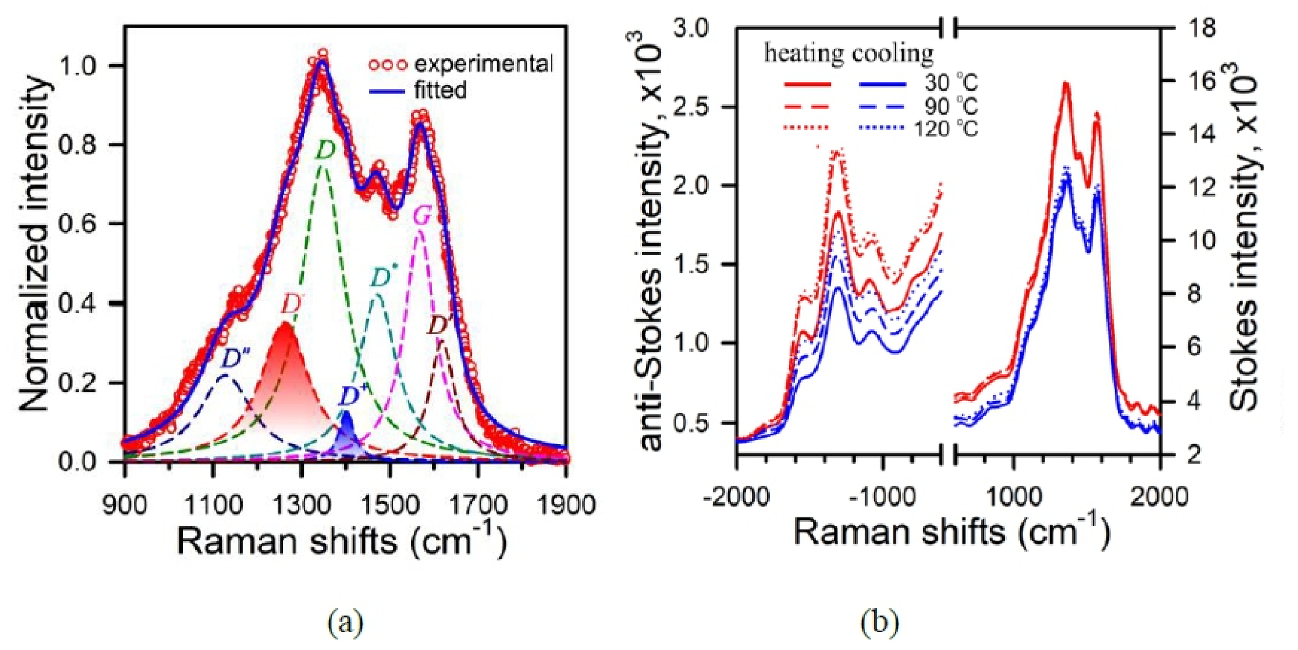
Electrical measurements

Figure 1(a) shows the dependence of the relative change in resistance of the 31 nm thick carbon film on the temperature during experiments in vacuum. The relative change in resistance was calculated: $\varepsilon_R = \frac{R - R_0}{R_0} \times 100\%$, where R_0 is the resistance at 25 °C.



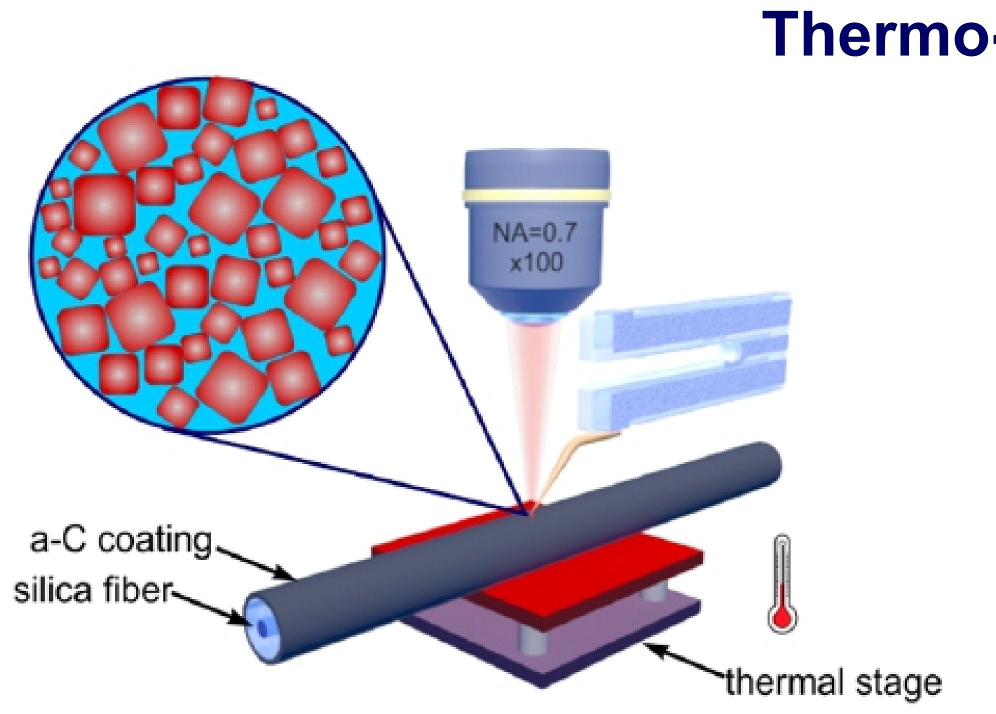
The dependence of the relative change in resistance of the 31 thick nm carbon film with temperature during heating and cooling processes in low vacuum with the pressure 15 mbar (a); The dependence of the relative change in resistance of the 107 nm thick carbon film with temperature during heating in vacuum (b) and under the ambient air (c) and cooling under the ambient air (b), (c)

Stokes and Anti-Stokes Raman spectroscopy

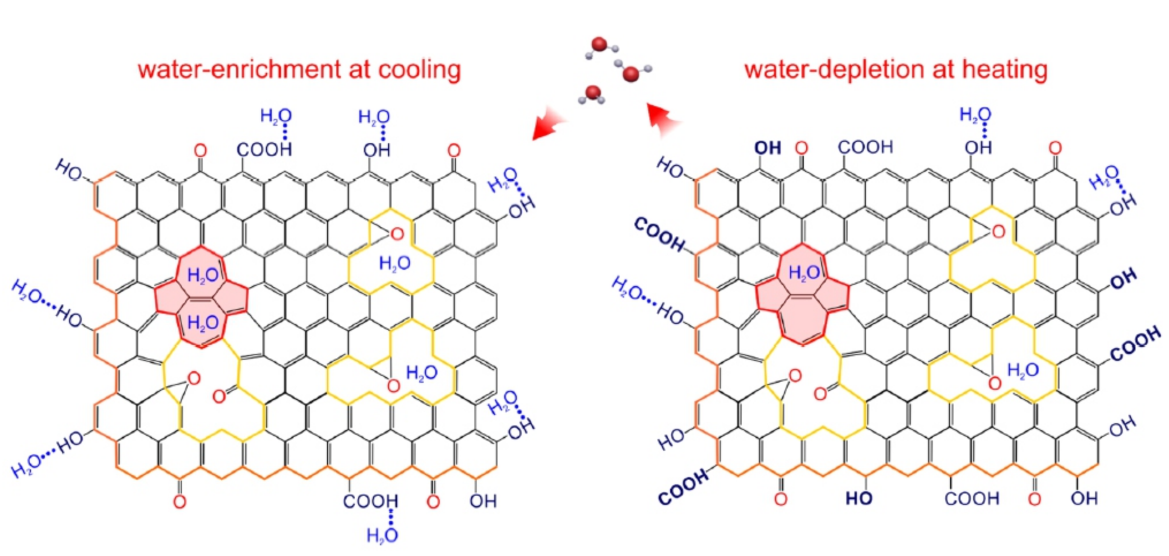


(a) Raman spectrum from the 31 nm thick carbon layer with the 632.8 nm excitation wavelength (red dots) and a sum of seven Lorentzian-shaped profiles (D'', D$^+$, D, D$^-$, D*, G, D$'$; blue line); (b) The temperature-dependent Raman spectrum from the 31 nm thick carbon layer during the heating and cooling in air;

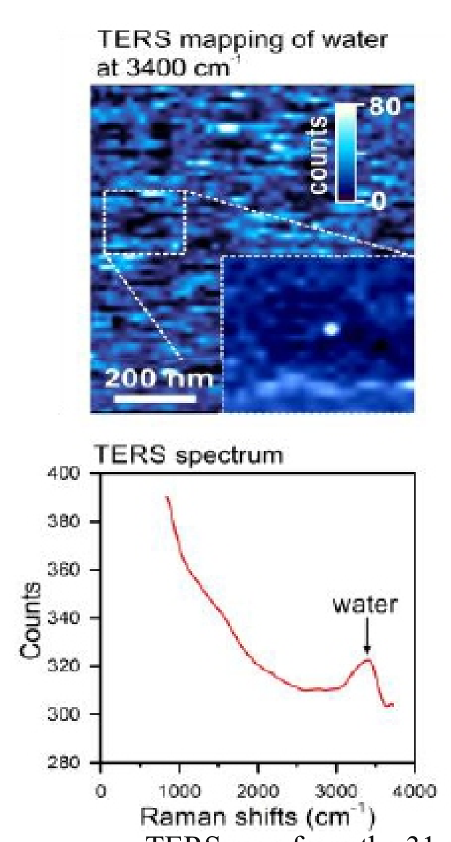
Thermo-Assisted Tip-Enhanced Raman scattering

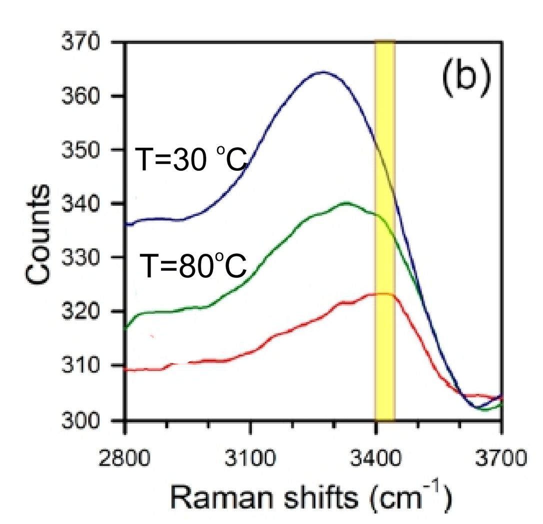


Schematic of experimental setups for thermal-assisted Raman spectroscopy and nanoscopy



sp^2 carbon sheets enriched and depleted with water directly interacting with structural defects and functional groups.





TERS map from the 31 nm thick carbon layer and TERS at 3420 cm-1

Conclusion

In this work amorphous carbon thin films fabricated at similar conditions using a chemical vapor deposition method were investigated by using far- and near-field Raman spectroscopy. In the region of 1000–2000 cm^{-1} of Raman spectrum the presence of at least seven peaks is confirmed by the band fitting of Raman spectrum via the regularized least squares method. It was found that carbon layer consists of oxygen- and hydrogen-containing functional groups on the basal plane and at the edges of graphene sheet. By using the TERS method the presence of water molecules in the composition of carbon film was also found. Under the heat treatment these functional groups experience phase transformations that was confirmed by the changes in the behavior of the electrical resistance of carbon film. These results open up the opportunities in technical design of carbon-based devices that operate above room temperature.

This work was supported from the Russian Scientific Fund (19-12-00066)