Visualization of detonation nanodiamonds using coherent anti-Stokes light scattering spectroscopy

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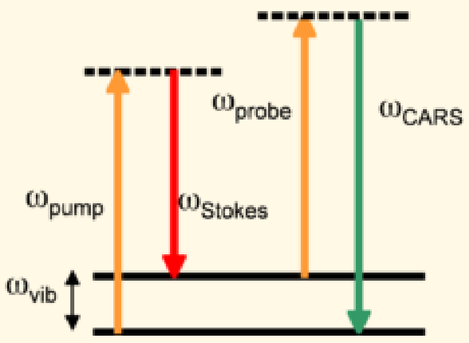
Introduction

Nanotechnology is actively developing in many fields, especially in biomedicine. Nanoparticles are used in the variety of applications – as luminescent markers, for targeted drug delivery, as theranostic agents etc. One of the basic problems of using nanoparticles as markers consists of need in separation of useful signal of nanoparticle from intense autoluminescence background of biological media.

In this study, detonation nanodiamonds in the volume of biological tissue were visualized by the method of coherent anti-Stokes Raman spectroscopy (CARS). To obtain the CARS signal, a system consisting of a pulsed Nd: YAG laser and a parametric light generator was used, which allows the radiation to be tuned in the range of 530-710 nm. CARS signals of carbon nanoparticles (carbon dots and detonation nanodiamonds) were obtained in aqueous suspensions and in the volume of biological tissue (egg white). The analysis of the obtained spectra made it possible to conclude that the fundamental possibility of using CARS spectroscopy for visualizing nanoparticles in the tissue volume.

CARS principals



CARS energy diagram

$$P^{(3)} = \chi^{(3)} E_{pump}^2 E_{Stokes}$$

$$\omega_{CARS} = 2\omega_{pump} - \omega_{Stokes}$$

$$\chi^{(3)} = \underbrace{\frac{A_R}{\omega_{vib} - (\omega_{pump} - \omega_{Stokes}) - i\Gamma_R}}_{\text{vibrationally resonant contribution}} + \chi_{nr}^{(3)}$$

$$I_{as} \approx \left|\chi^{(3)}\right|^2 I_{pump}^2 I_{Stokes} \left[\frac{\sin(\Delta k \cdot L/2)}{\Delta k/2}\right]^{-2}$$

$$|\Delta \boldsymbol{k} \cdot L| = \left|\boldsymbol{k_{as}} - (2\boldsymbol{k_{pump}} - \boldsymbol{k_{Stokes}})\right| \cdot L < \pi$$

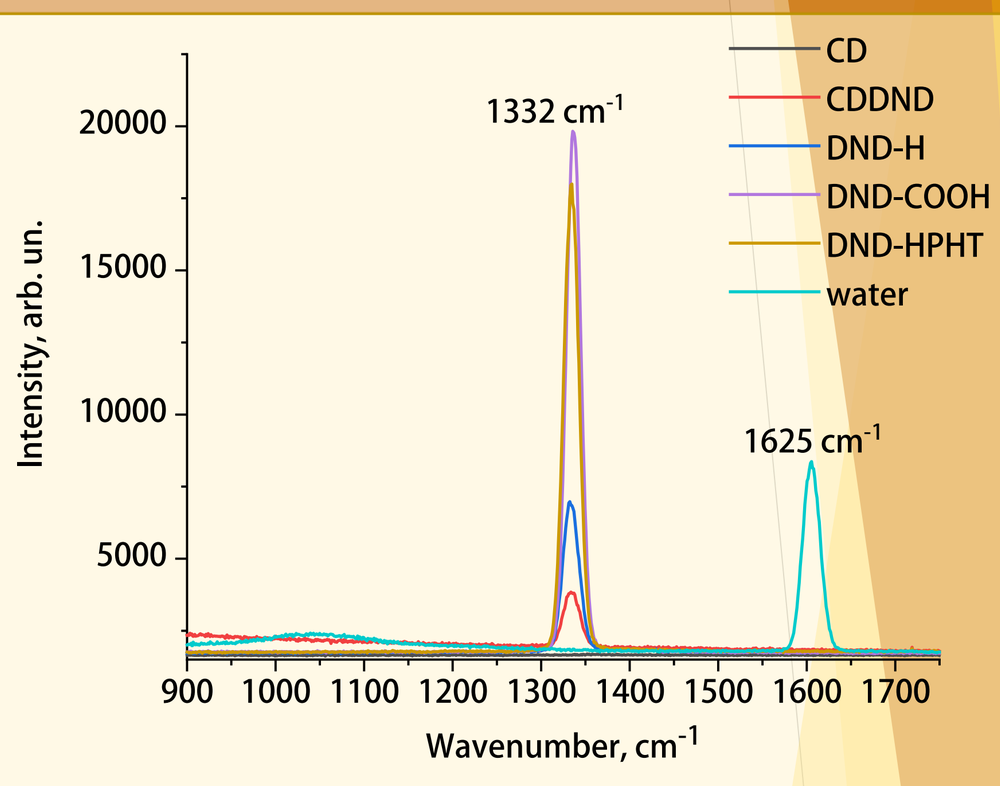
Objects of research

Samples of detonation nanodiamonds (DND) with the different surface functionalizations were used as objects of research:

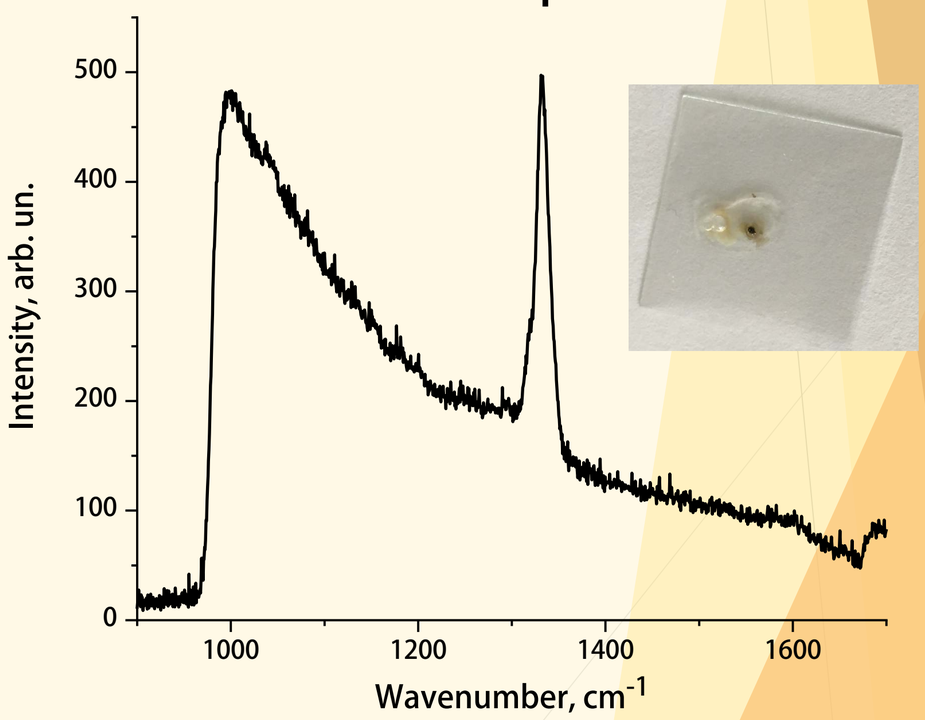
- Carbon dots (CD),
- DND-COOH,
- DND-H,
- DND, covered with carbon dots (CDDND)
- DND-HTHP

synthesized by Adamas Nanotechnologies (USA).

Nanocarbon visualization with CARS



CARS spectra of aqueous suspensions of carbon nanoparticles



CARS spectrum of CDDND in the biological tissue

Conclusions

CARS signals of carbon nanoparticles (carbon dots and detonation nanodiamonds) were obtained in aqueous suspensions and in the volume of biological tissue (egg white). The analysis of the obtained spectra made it possible to conclude the fundamental possibility of using CARS spectroscopy for visualizing nanoparticles in the tissue volume.

This study has been performed at the expense of the grant of Russian Science Foundation (project №. 20-72-00144)