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Acoustic detection of nanoparticle structural stability in physiological media after their laser irradiation

I.V. Zelepukin^{1,2*}, A.A. Popov¹, A.V. Kabashin^{1,3}, S.M. Deyev^{1,2}, A.V. Zvyagin^{1,4,5}

¹ National Research Nuclear University MEPhI, Russia

² Shemyakin-Ovchinnikov Institute of Bioorganic Chemistry RAS, Russia

³ Aix Marseille Univ, CNRS, LP3, Campus de Luminy, France

⁴ I.M. Sechenov First Moscow State Medical University, Russia

⁵ ARC Centre of Excellence for Nanoscale BioPhotonics, Macquarie University, Australia

*Presenting author e-mail address: zelepukin@phystech.edu

Abstract — Here we present a method of photoacoustic detection of nanoparticle degradation. To validate the method, we used biodegradable silicon nanoparticles, which can absorb light in the Uv-Vis region and generate acoustic waves in response. The photoacoustic method allows measuring kinetic of their degradation in real-time with high limit of detection up to a hundred ng of particles.

Keywords — nanoparticles; photoacoustics; laser ablation; degradation.

I. INTRODUCTION

Novel methods for non-invasive imaging and quantifying of various biological processes are under development nowadays [1-5]. Although a lot of optical techniques were designed for investigation of nanoparticle pharmacokinetics and distribution, they usually have limitations for measuring long-term processes. For example, biodegradation and excretion of luminescent nanomaterials can't be precisely quantified due to the sharp decrease of their brightness during nanocrystal deformation.

Contrary, photoacoustic detection [1] can be a promising platform for imaging of long-term fate of luminescent contrast agents, as well as any absorbing light nanomaterials. That approach detects acoustics waves, which generates in the response to nanomaterials heating after their irradiation with a pulsed laser. The method can almost in real-time, quantitatively detect small amounts of "black" (by their spectra) nanomaterials *in vivo*, and spectrally distinguishes the signal from nanoagents from background noise.

Here we applied the photoacoustic method to measure complex kinetics of silicon nanoparticle degradation in various buffer solutions.

II. RESULTS AND DISCUSSION

Photoacoustic detection of structural changes in nanoparticles can be possible due to high decrease in the absorbance spectra or volume of nanomaterials during the process of their degradation, which significantly lower acoustic waves generation.

To validate optoacoustic technique for that aim we used pure silicon nanoparticles, a material with a known ability to biodegradation *in vivo* [6]. These nanoparticles can be

dissolved due to nanocrystal water hydrolysis and ion exchange with the release of silane acids.

Silicon particles were prepared by the femtosecond laser ablation method and show high absorbance at the Uv-Vis region after the synthesis. Structure, composition and colloid-chemical properties of the nanocarriers were investigated by scanning electron microscopy, Fourier transform infrared spectroscopy and dynamic light scattering technique.

Laser irradiation of silicon nanoparticles at 532 nm led to a strong photoacoustic signal from them. It allowed us to measure the kinetics of their degradation at different pH, particle composition and concentrations in solutions. We found that pH in media is the most important parameter and its tuning allows accelerate nanoparticle full degradation time from several weeks to 1 day.

III. CONCLUSION

Our results demonstrate applicability of photoacoustic for quantitative detection of structural stability of silicon nanoparticles. Potentially, photoacoustic technology can be translated for *in vivo* study of the long-term fate of a wide range of light absorbing nanoagents.

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