Surface optimization of nanodiamonds using non-thermal plasma

Michal Gulka[1,*], Priyadharshini Balasubramanian[2], Ekaterina Shagieva[3], Jakub Copak[1,4], Josef Khun[5], Vladimir Scholtz[5], Fedor Jelezko[2], Stepan Stehlik[3], Petr Cigler[1]

[1]Institute of Organic Chemistry and Biochemistry, of the CAS, Flemingovo nam. 2, Prague, Czechia
[2]Institute of Quantum Optics, Ulm University, Ulm 89081, Germany
[3]Institute of Physics of the Czech Academy of Sciences, Cukrovarnická 10, 162 00 Prague 6, Czechia
[4]Department of Physical and Macromolecular Chemistry, Faculty of Science, Charles University in Prague, Czechia
[5]Department of Physics and Measurements, University of Chemistry and Technology in Prague, Czechia
[*]gulka.michal@gmail.com

Possibility of local sensitive monitoring of intracellular processes using quantum sensing with nitrogen-vacancy (NV) centers in nanodiamonds (NDs), would greatly advance cell biology and would enable numerous medical applications. Although such probes have been studied extensively [1], they are still limited in sensitivity. Whereas the NV center in bulk diamond holds record room-temperature electron spin coherence time among solid-state qubits, NVs in NDs exhibit much poorer relaxation times. As suggested in [2], prolongation of the NVs relaxation time should be possible by ND surface optimization creating mixed H/O termination.

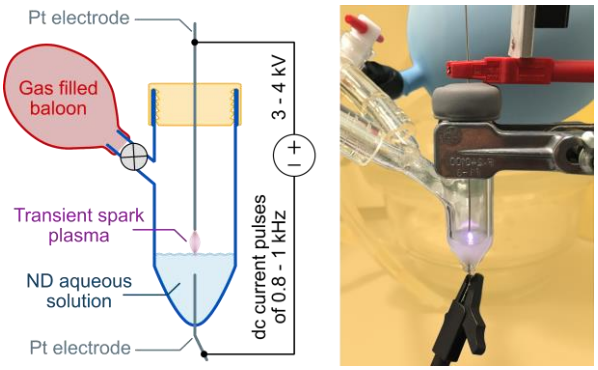

Fig. 1. Non-thermal plasma system for ND modifications

Here we employ a non-thermal plasma (NTP) [3], with the aim of prolongation of the NV electron spin relaxation times (Figure 1). We have used various nanodiamond samples (HPHT/detonation, H-/O-terminated surface) and ambient gases (air, O_2, He, and H_2). The NTP modification induces changes in C=O bonds, restructuration of C-H bonds, and differences in OH termination. Using hydrogen as the ambient gas results in the biggest changes in FTIR spectra. For oxidized HPHT NDs the zeta potential dropped from an initial ~ -40 mV to ~ -50 mV. Both T_1 and T_2 NV electron relaxation times improved significantly after the modification.

Acknowledgement
This project has received funding from the European Union's Horizon 2020 research and innovation program. The work was further supported by the Czech Science Foundation project No. 23-04876S, the Ministry of Education, Youth, and Sports of the Czech Republic (project No. CZ.02.01.01/00/22_008/0004558, co-funded by the European Union), the European Union project C-QuENS (Grant No. 101135359), the Czech Academy of Sciences – Strategy AV21 – Research program VP29 (to P.C.), TACR project Nr. TH90010001 (QuantERA – ERA-NET Cofund, project EXTRASENS), and Horizon project No 101086142 (FLORIN).

References
[1] T. Zhang et al., ACS Sens. **6**, 2077–2107 (2021).
[2] M. Kaviani et al., Nano Lett. **14**, 4772–4777 (2014).
[3] J. Khun et al., Plasma Sources Sci. Technol. **27**, 065002 (2018).