Master thesis proposal

Synthesis and functionalization of high-quality nanodiamond particles for the development of a new generation of quantum nanotechnologies.

This internship is part of the NanoG4V project, funded by the French National Research Agency (ANR), and which includes funding for a PhD position. This research work aims to produce a new generation of high-quality **quantum-grade nanodiamonds** for a wide range of applications, such as extreme-conditions sensing, nanoscale thermometry and live-cell dual-color imaging. **This work will enable the student to acquire multidisciplinary skills in materials and plasma science, high-pressure physics, with a special focus on the development of quantum diamond nanotechnologies.** The student will join the CQSD group of the MPOE team at the IRCP institute and will work closely with internationally renowned researchers from the LSPM and LuMIn laboratories.

Keywords: quantum technologies, nanodiamonds, SiV color centers, CVD synthesis, matter, optics.

Scientific description: Diamond is an extremely interesting material due to its various technological applications. Its compact and regular crystalline structure allows it to be used in diverse scientific fields, such as particle sensors and power electronics devices [1]. More recently, with the advancement of diamond synthesis techniques, new opportunities have arisen for quantum applications on the micro- and nanometric scales, such as in high-pressure and biomedical physics. This internship focuses on the synthesis of diamond nanoparticles via chemical vapor deposition (CVD), incorporating SiV color centers. The SiV center is a point defect in the diamond lattice, consisting of an interstitial silicon atom (Si) and two adjacent vacancies (V) [2]. This defect introduces energy levels into diamond's bandgap, which behave similarly to the energy levels of an isolated atom. When subjected to external perturbations (pressure, temperature, etc.), these energy levels shift. By detecting this shift, it is possible to measure the perturbation causing it. Thus, the SiV center can act as a sensor at a nanometric spatial scale. The crystalline quality of the diamond nanoparticles will be crucial for fully exploiting the quantum properties of the SiV center. Nanodiamonds will be produced using high-power, microwave-assisted plasma CVD with an H_2/CH_4 gas mixture, Fig. 1 [3, 4].

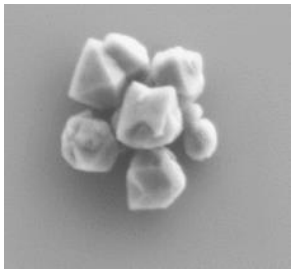

Figure 1. SEM image of CVD nanodiamonds (diameter ≈ 200 nm).

During the internship, the CVD technique will be used to enable the homogeneous nucleation of particles in the gas phase and their doping by Si. Introducing a silicon wafer into the plasma chamber will bring solid-source Si impurities, forming SiV centers in the particles. The optical properties of SiV centers in nanodiamonds will be characterized by photoluminescence measurements and enhanced through novel post-synthesis treatments developed with the intern (such as specialized high-temperature and high-pressure annealing, plasma oxygen surface treatments, etc.). This new generation of high-quality quantum particles will be tested as high-pressure nanosensors and nanoscale thermometers, surpassing current results [5].

The intern will mainly work in the CQSD group, which offers an international environment alongside other PhD students, post-doctoral and permanent researchers.

Techniques/methods in use: CVD diamond synthesis, optical characterization (Raman and PL spectroscopy at room and low temperatures), surface characterization (SEM, among others), and plasma simulations.

Applicant skills: The intern should demonstrate aptitude for experimental work and a strong interest in material physics and chemistry. Skills in simulations and calculations are appreciated. Dynamism and determination are essential qualities for this research activity.

Industrial partnership: No.

Internship supervisor(s):

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Internship location: Institut de recherche de Chimie Paris (Paris 75005) and Laboratoire des Sciences des Procédés et des Matériaux (Villetaneuse 93430).

Internship duration: 6 months, expected start in March 2025 (to be defined with the student).

Possibility for a doctoral thesis: Yes. This internship can be followed by a PhD thesis (36-month long) depending on the candidate work. The PhD thesis is already funded by the ANR (NanoG4V project).

References

[1] M. De Feudis, PhD Thesis, University of Salento (Italy) and University of Sorbonne Paris Nord (France), 2018.
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[3] M. De Feudis, et al., Advanced Materials Interfaces 7 (2) 2019, 1901408.
[4] A. Tallaire, et al., ACS Appl. Nano Mater. 2 (9) 2019, p. 5952-5962.
[5] B. Vindolet, et al., Physical Review B 106 (21) 2022, p. 214109.