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Optical detection of single defects in silicon

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The boom of silicon in semiconductor technologies was closely tied to the ability to control its density of lattice defects. After being regarded as detrimental to the crystal quality in the first half of the 20th century, point defects have become an essential tool to tune the electrical properties of this semiconductor, leading to the development of a flourishing silicon industry. At the turn of the 21st century, progress in Si-fabrication and implantation processes has triggered a radical change by enabling the control of these defects at the single level. This paradigm shift has brought silicon into the quantum age, where individual dopants are nowadays used as robust quantum bits to encode and process quantum information. These individual qubits can be efficiently controlled and detected by all-electrical means, but do not feature an optical interface adapted to long-distance propagation in optical fibers. In order to develop applications for quantum communications, we have started investigating defects in silicon that are optically-active in the near-infrared telecom bands.

Recently, we have demonstrated that this semiconductor hosts a large variety of point defects that can be detected at single scale by using optical confocal microscopy operating at 10K [1,2]. These fluorescent individual defects are either carbon-related complexes, such as the so-called G-center, or radiation damage centers made of interstials. Besides opening new perspectives for Si-based quantum technologies, these results could also benefit to other research fields. The optical characterization of Si-based devices at single-defect scale could enable early-stage detection of their degradation in environments with strong radiations such as particle-physics detectors.

[1] W. Redjem et al., Nature Electronics 3, 738 (2020).
[2] A. Durand et al., Physical Review Letters 126, 083602 (2021).

Author: Dr DREAU, Anaïs (Laboratoire Charles Coulomb, CNRS & University of Montpellier)

Presenter: Dr DREAU, Anaïs (Laboratoire Charles Coulomb, CNRS & University of Montpellier)

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