# Development of Nitrogen - vacancy - center based quantum sensors for biomolecular sensing

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**Specific problem being addressed**: Atomic-scale quantum sensors, utilizing Nitrogen-Vacancy (NV) centers in diamonds, demonstrate exceptional stability and performance at room temperature, unlike other quantum systems prone to issues like photobleaching. These NV centers, present in nanodiamonds, offer optical detection of various parameters, such as magnetic and electric fields, and temperature. Binding nanodiamonds with antibodies creates quantum sensors capable of specifically identifying biomarkers. In this study, we use NV centers in nanodiamonds tagged with antibodies to monitor the replicative senescence of human mesenchymal stem cells (hMSCs). While our focus is on specific proteins and cell types, the technology's broader applications extend to diverse cell systems, including cancer cells.

**Project Summary:** Cutting-edge biosensors for diagnostic systems in the next generation aim to detect and identify specific biomolecules at extremely low concentrations, even at the single or a few molecule level. This is particularly crucial for early diagnosis and treatment of diseases like cancer, heart conditions, and neurological disorders. Reactive oxygen species (ROS) play a dual role in the human body. On one hand, they contribute to aging by triggering cell cycle stoppage, known as replicative senescence. This mechanism can prevent damaged cells from proliferating, acting as a form of cancer prevention. However, in the cancer microenvironment, ROS can act as signals for cell proliferation. ROS also influence cellular metabolism, making it vital to closely monitor cellular senescence for overall health. To comprehend the intricate activities of ROS both in laboratory settings and within living organisms, accurate measurement of ROS levels in the extracellular matrix and living cells is essential. The ideal probe should be capable of detecting low ROS levels, be non-toxic, and traverse cells without disrupting normal cellular processes related to the cell cycle. Achieving this requires atomic-scale components aligned with the principles of quantum mechanics. Nitrogen-vacancy (NV) centers in diamonds, belonging to a class of solid-state quantum systems, serve as promising candidates for developing atomic-sized quantum sensors. These sensors can be investigated using simple, readily available equipment, offering a valuable tool for cancer and aging research. [References: Annual Review of Physical Chemistry (2014), 65:1, 83-105, ACS Sens. (2021), 6, 2077−2107]

**Impact of this innovation:** Confocal microscope manufacturers and other companies that develop medical diagnostic imaging tools can obtain licenses for the proposed technology. Quantum-assisted biosensing techniques have not received much attention in India up to this point. A few teams at IISER Bhopal, IISER Pune, and IIT Madras have begun to create room temperature setups to study color defects in diamonds. One of the first investigations into biomolecular interactions in human cells at extremely low concentrations will be this one.