Long-Term Cell Tracking and Nanoscale Temperature Sensing with Fluorescent Nanodiamonds

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Fluorescent nanodiamond (FND) has recently played a central role in fueling new discoveries in interdisciplinary fields spanning biology, chemistry, physics, and materials sciences. The nanoparticle is unique in that it contains a high density ensemble of negatively charged nitrogen-vacancy (NV^-) centers as built-in fluorophores. The center possesses a number of outstanding optical and magnetic properties. First, NV^- has an absorption maximum at ~550 nm and when exposed to green-orange light, it emits bright fluorescence at ~700 nm with a lifetime of longer than 10 ns. These spectroscopic properties are little affected by surface modification but are distinctly different from those of cell autofluorescence and thus enable background-free imaging of FNDs in tissue sections. Such characteristics together with its excellent biocompatibility render FND ideal for long-term cell tracking applications, particularly in stem cell research. Second, the NV^- center in diamond is an atom-like quantum system with a total spin of 1. The ground states of the spins show a crystal field splitting of 2.87 GHz, separating the m_s = 0 and ±1 sublevels. Interestingly, the transitions between the spin sublevels can be optically detected and manipulated by microwave radiation, a technique known as optically detected magnetic resonance (ODMR). In addition, the NV^- spins have an exceptionally long coherence time, making FND useful for ultra-sensitive detection of temperature at the nanoscale. Pump-probe-type nanothermometry with a temporal resolution of better than 10 μs has been achieved with a three-point sampling method. Gold/diamond nanohybrids have also been developed for highly localized hyperthermia applications. This presentation provides a summary of the recent advances in FND-enabled technologies with a special focus on long-term cell tracking and nanoscale temperature sensing. These emerging and multifaceted technologies are in synchronicity with modern imaging modalities.