Abstract

Several disease processes taking place in the cells are characterized by an increase of the concentration of nucleic acids, in particular micro RNAs (miRNAs). A detection system that could selectively detect the increased presence of the miRNAs directly in the living cells in real time with nanoresolution is therefore highly desired. Fluorescent nanodiamond particles are considered promising candidates thanks to their biocompatibility, small size, allowing them to penetrate the cell membrane, and stable fluorescent defects in the crystal lattice, namely nitrogen-vacancy (NV) centres. The NV centres are the most studied colour centres of nanodiamonds due to their unique room-temperature optical properties, allowing for highly sensitive detection of changes in the magnetic field (magnetic noise) with quantum sensing techniques. For instance, the length of the T_1 relaxation time NV electronic spin is greatly influenced by the presence of paramagnetic species, which causes a shortening of the T_1 relaxation time depending on the proximity to the NV centres. However, for selective quantum sensing with nanodiamonds, the use of molecular transducers is necessary to bind targeted molecules with high specificity and allow their detection via the change of the NV spin properties. In this work, miRNAs-selective probes are developed based on the fluorescent nanodiamonds with covalently attached molecular beacons on their surface as a transducer. The sensing mechanism is based on gadolinium paramagnetic ions (Gd^{3+}), which are attached to the end of the molecular beacons and generate significant magnetic noise (thus shortening the T_1 relaxation time). After binding the target miRNA molecule, molecular beacons open up and the Gd^{3+} ions are moved further from the fluorescent nanodiamonds. Successful detection of the miRNA molecules is monitored optically by a prolongation of the T_1 relaxation time of the NV centres. This work represents a first step for localized and selective detection of miRNA, which would enable to identify disease processes inside living cells at an early stage.

Keywords: nanodiamonds, NV centres, molecular beacons, T_1 relaxation time, gadolinium, quantum sensing, fluorescence