Multi-functional diamond particles for various applications

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Summary

In this dissertation, some different applications of diamonds are discussed. All of the chapters are based on the Nitrogen-Vacancy center (NV center) in diamond, it applied to quantum measurements. More specifically, the NV center in diamond can be used to measure relaxation rates (T1). These reflect how long an NV^- center can remain in a prepared state before returning to equilibrium in nano diamond or bulk diamond. Besides that, different kinds of modification methods on diamond surfaces provide more functions which can be used in different applications.

In **Chapter 1**, a general introduction to the field and the topics of this thesis is given. First, the macroscopic properties of diamond are introduced. Then the mechanism of sensing with NV centers is discussed briefly. This chapter includes how the NV centers are formed, species of NV centers, and the differences between NV^0 and NV^-. After that, I discuss the medical applications of FNDs, including their use as drug delivery platform, fluorescent marker, and free radical sensor. Besides that, the bulk diamond applications are introduced.

In **Chapter 2**, we present the function of modified FNDs. After modification with a diazoxide derivative, more FNDs enter HeLa cells and are able to deliver this drug into the cells. Compared to the free diazoxide, we observed a sustained drug release over 72 hours than 12 hours for the free diazoxide. Apart from drug delivery, the FNDs can detect free radical generation directly by diamond magnetometry. This has the advantage that the response is measured locally, where the drug is released.

Chapter 3 focuses on bulk diamond modification and the relaxation rate (T1) performance. In this chapter, diamond plates with a shallow ensemble of NV centers were treated by air plasma, and a gradient is formed on the surface of the bulk diamonds using a mask. Thanks to the chemical gradient, we can investigate hundreds of different local points on the surface of a single diamond, and the gradient oxygen containing groups. To achieve the goal, the gradient was formed by air plasma treatment after masking with a right-angled triangular prism mask. As a result, the surface contained gradually more oxygen towards the open end of the mask. We then performed wide-field relaxometry to determine the effect of surface chemistry on the sensing performance. As expected relaxation times and thus sensing performance indeed varies along the gradient.

In **Chapter 4**, we detect free radicals in clinical samples by diamond relaxometry. To be more specific, synovial fluids from arthritis patients were investigated. There are two kinds of arthritis samples: osteoarthritis and rheumatoid arthritis.

We can clearly differentiate between osteoarthritis and rheumatoid arthritis by synovial fluid from patients and cells derived from it. Besides that, after adding piroxicam, a common non-steroidal anti-inflammatory drug (NSAID), we observed different responses to the synovial fluid and cells from it. Compare to stable free radical load in samples from rheumatoid arthritis, the samples from osteoarthritis showed a dramatic decrease. This offers a possible explanation why Piroxicam is more beneficial for patients with osteoarthritis than rheumatoid arthritis.

Finally, in Chapter 5, we discuss future applications of NV centers in diamond and the prospect of diamond surface modification to broaden its applicability to new applications.