THE PROPERTIES OF NITROGEN-VACANCY CENTRES IN NANODIAMOND

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To my Family, my dad Stanislav, my mum Laura and my sister Kristina

To Melanie

To all my Friends

Abstract

Diamond is unique. Whether mechanical, thermal, electrical or optical, its properties are within the most extreme compared to those of any other material. This, together with the fact that in the last fifty years the synthesis of artificial diamond has become a reality, makes it very attractive for engineering and technological purposes. The range of diamond-based applications is very diverse and, among the others, includes its use in mechanical machining, high-power high-frequency electronics and high transmissivity optics.

Diamond is also host to a wide variety of crystallographic defects. Appropriately controlled, they can be used to tune the characteristics of the material, but even more interestingly they often possess attractive optical properties on their own. In particular, nitrogen-vacancy (NV) centres in diamond have been the subject of extensive study in the last few years. They possess unique room-temperature optical and spin properties which make them promising systems for solid-state qubits in quantum information technologies and for emerging applications in biotechnology, nanomedicine and high resolution magnetometry, such as drug delivery, fluorescent biomarking and spin imaging.

This thesis is focused on NV centres in diamond. I first present an extensive review on diamond as a material, describing in detail its physical properties, the methods that have been developed to synthesise it and some of its possible applications. I then move the attention specifically to NV centres in nanodiamonds (NDs), i.e. diamond crystals in the

nanometre size range (0-100 nm). They are a potential candidate for emerging technologies including high-resolution magnetometry and biomedical imaging. For these applications, specific material requirements, such as the small size of the diamond nanocrystals and the optical stability of the hosted NV centres, are crucial. The NV stability with respect to the nanodiamond size and surface is the central theme of this thesis. I analyse the optical behaviour of NV centres in nanodiamond while varying a number of key parameters such as size, surface termination and diamond origin. Based on the measurements, I conclude whether the nanodiamond size and the NV surface proximity are factors that must be taken into consideration in order to control the material and realise nanotechnologies based on NV centres in nanodiamonds.

Declaration

I certify that the work in this thesis has not been submitted for a degree nor has it been submitted as part of requirement for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the presentation of the thesis itself has been acknowledged.

I certify that all information sources and literature used are indicated in the thesis.

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Carlo Bradac

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