SILICON CARBIDE FOR SINGLE-SPIN SENSING AND COMPUTATION

PHYS 522/ECE 695 LECTURE NOTE

APRIL 6, 2014

Introduction

This lecture note is based off a presentation by Abram L. Falk *on engineered defects in wide band-gap semiconductors for single-spin sensing and computation*. Abram started out by talking about wide-gap semiconductors and their uses. After that, he moved on to talk about Nitrogen-Vacancy Center in Diamond and then he switched gears to talk about Silicon carbide which he believed was an alternative to Diamond. He wrapped up his talk by focusing on electron spin control with electric fields and strain.

Wide band-gap semiconductors

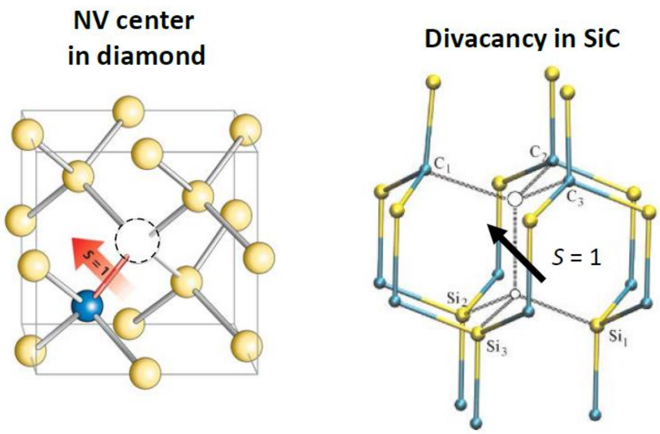
Wide band-gap semiconductors are semiconductors with band-gap around 3 – 5 eV. In the process of trying to get rid of defects in semiconductors, people have studied a lot of wide band-gap semiconductors lately. Their applications include solid-state lighting (Gallium nitride), power electronics (Silicon carbide and Gallium nitride), etc. In fact, a recent article on www.energy.gov mentions that the US government is taking the initiative to make wide band-gap semiconductor-based power electronics cost competitive with silicon chips in 5 years [1].

Diamond Nitrogen-Vacancy (NV) Center

The NV center in diamond consists of a lattice in which one carbon atom is replaced by a nitrogen atom and its neighbor is a vacant space left by another carbon atom [2]. The localized electronic state bound to the NV center has a paramagnetic ground state, hence, it has a potential to be used as a single-spin memory for quantum memory. The spin coherence times at room temperature can go from 10 µs up to 2 ms, which makes it desirable for quantum computing and communication. For more information on NV centers in diamond, please, refer to Lecture S1 notes compiled by Joseph Lukens.

Silicon Carbide

Silicon carbide comes in more than 200 crystal types also known as polymorphs, however, the 3 commonest types are 4H, 6H and 3C. Divacancy in Silicon carbide is comparable to an NV center in diamond as illustrated in the image below:



Some common features between both of them are that they are useful for optical spin polarization and readout and they both have long spin coherence times.

Electron Spin Control with Electric Fields and Strain

Abram Falk and his colleagues observed 2-7 times stronger spin response to electric fields in silicon carbide compared to diamond NV centers [3,4].

REFERENCES

[1] “Wide Bandgap Semiconductors: Essential to Our Technology Future.” Energy.gov (2014)

[2] V. Acosta and P. Hemmer, MRS Bulletin 38, 127 (2013)

[3] A. Falk et al., arXiv: 1311.6832 (2014)

[4] P. Kilmov et al., Phys. Rev. Lett. **112**, 087601 (2014)