EDMR via Spin Dependent Variable Range Hopping

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Introduction

Electrically detected magnetic resonance (EDMR) is of great interest for quantum computation and electronic materials physics. EDMR involves detection of electron paramagnetic resonance through changes in the current or voltage measured in a device. The EDMR technique called dependent recombination (SDR) is extensively utilized; its underlying physical mechanisms are understood in terms of models which evolved from a seminal paper by Kaplan, Solomon and Mott (KSM) [1]. KSM explained the SDR/EDMR response in terms of the behavior of a pair of spins involved in recombination, now understood to be associated with a deep level and a charge carrier. A remarkable aspect of the KSM model is its prediction that the SDR response is, to first order, independent of the field and frequency of measurement. KSM explained that this field and frequency independence arises because spin dependent capture is not an instantaneous collision-like process, but involves the coupling of two spins for finite time. A second EDMR detection scheme with considerable promise is spin dependent trap-assisted tunneling (SDTT). Like SDR/EDMR, SDTT/EDMR has potential for quantum computation and electronic materials physics. However, the very limited SDTT/EDMR literature provides little direct evidence of the physical mechanisms involved. One might envision two types of SDTT/EDMR: one in which a pair of spins is involved in a tunneling process which takes a finite time or an instantaneous collision like process analogous to the early SDR/EDMR model developed by Lepine [2]. If the SDTT/EDMR process involves an essentially instantaneous collision like process, such as that envisioned by Lepine for SDR/EDMR, the magnitude of the effect would scale with the square of the electronic polarization [2] and thus the square of the field of resonance; whereas a coupled spin-pair like model would yield, as KSM proposed and other have demonstrated, a near field independent response [1].

Experimental

We conducted EDMR measurements on thin films of amorphous hydrogenated SiC (a-SiC) at magnetic fields of approximately, 0.013 and 8.7 Tesla, magnetic fields which differ by a factor of over six hundred. If the EDMR process is Lepine-like, a difference in the high and low field response would be more than a factor of three hundred thousand. If the EDMR process is KSM like, the response at room temperature would be roughly comparable. The low (0.013 T) magnetic field EDMR measurements were made at Penn State using a home built instrument. The 8.7 Tesla measurements were made at the NHMFL using the 12.5 T magnet-based heterodyne spectrometer.

Results and Discussion

In Fig. 1, we illustrate a key result. In the illustrated room temperature measurements, the RF/microwave frequency magnetic field amplitudes were roughly equal. The amplitudes of the responses at 0.013 and 8.7 Tesla are the same order of magnitude, with the low field amplitude about 2 times larger. The results of Fig. 1 thus strongly support an SDTT/EDMR model involving a coupling between pairs of spins for a finite time. In this case, the spins would correspond to two paramagnetic sites involved in a tunneling event, likely a variable range hopping process.

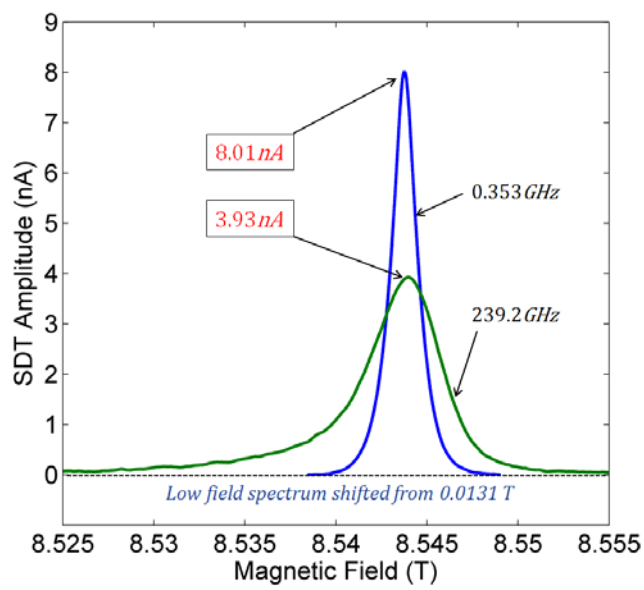

Figure 1. Very low and very high field EDMR via trap assisted tunneling in amorphous SiC.

Acknowledgements

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References

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[2] Lepine, D.J., Phys. Rev. B, **6**, 436 (1972).