PhD Position: Pulsed electrically detected magnetic resonance hyperfine spectroscopy methods development

Electron magnetic resonance (EMR) methods, electron paramagnetic resonance (EPR), electron nuclear double resonance (ENDOR), electron electron double resonance (ELDOR), etc, provide unparalleled information on the nature and local environment of paramagnetic centres. Applications to Materials Physics include the identification of point defects and impurities in semiconductors and insulators of various types, the study polarons, etc. Recently this has, for example, involved the detailed study of doped fullerene molecules for quantum computation and organic solar cell applications, the study of impurity ions in semiconductors, again for quantum computation, the identification of defect centres in wide bandgap materials for novel electronic applications and also for solar cells, etc.

Recent developments are allowing routine time-domain experiments, manipulation of pulse sequences allows certain interactions (Hamiltonian terms) to be directly measured or suppressed. For example electron spin echo envelope modulation (ESEEM) and hyperfine sub-level correlation (HYSCORE) are methods that directly measure hyperfine terms without the additional radiofrequency field used in ENDOR. However, for oriented systems ENDOR remains the best approach, and pulsed ENDOR simplifies and extends the method. It is these hyperfine interactions between the electron spin localised at the centre and any magnetic nuclei in the local environment that often provide the most direct structural information on the detailed arrangement of the centre.
Electrically detected magnetic resonance is an intriguing variant of EMR discovered in 1966,[1] it was found that magnetic resonance could be detected by measuring a change in a transport current through a material or a device, rather than the absorption or emission of electromagnetic energy stimulating the magnetic dipole transition. Progress has been relatively slow, many EPR groups have performed EDMR experiments over the years but it can be notoriously difficult to obtain and to obtain controlled systematic results.[2-7] However, the advantages are dramatic, for example (i) you *know* the paramagnetic centre is electrical active – it has to be - and hence technologically relevant, (ii) the sensitivity gains are huge, the thermodynamic limit of ~10^{11} spins that can be detected by EPR is broken by many orders of magnitude, signals have been obtained from hundreds of spins! (iii) you can measure a 'real' device (OK it may need to be specially fabricated).

Another dramatic breakthrough was made recently when Boheme & Lips were successful in detecting *pulsed* EDMR.[8,9] This was a remarkable achievement because the timescale of the amplifiers needed to detect the signal are orders of magnitude slower than the timescale of the microwave pulses applied – but it works! It is now possible to think of trying to implement some of the powerful pulsed EPR methodologies in pEDMR experiments. People are trying. The intrinsic advantages of EDMR are finally being recognised and there is an increasing number of high impact publications. [10-16]

Very recently, for the first time hyperfine spectroscopy has been performed using electrically detected magnetic resonance (EDMR), both ESEEM and ENDOR experiments have been reported. [17,18] The aim of this project will be to implement ED-ESEEM and ED-ENDOR and to explore the optimisation of these techniques. Further, the project will look to implements these methods at higher microwave frequencies, these first experiments were performed at 9.5 GHz.

References

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