Beta-detected Nuclear Magnetic Resonance (β-NMR): Towards depth resolved NMR

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Nuclear magnetic resonance (NMR) spectroscopy is a powerful technique in chemistry and condensed matter physics. It is non-destructive, non-perturbative, and can analyze a large variety of samples. However it requires large sample sizes (~1 g), it is a bulk technique, and there is an intrinsically small signal-to-noise ratio. Beta-detected NMR is a twist on conventional NMR, in which the signal is measured by the beta decay of a polarized, radioactive ion. In β-NMR a low energy ion beam (0.1-30 keV) is implanted into the sample of interest, and the asymmetry in the beta decay of the ion is measured. The most common isotope used is ^{8}Li, which has a half-life of 848 ms, and spin $I=2$ [1].

Our group uses the β-NMR facility at TRIUMF in Vancouver. At TRIUMF, the ISAC facility produces beams of short-lived radioisotopes for research in nuclear physics and materials science. For Li, a surface ionization source can routinely produce high quality beams of intensity ~10^7/s with typical transport energy of 20 keV. The ion beam can be electrostatically decelerated at the spectrometer end station, allowing depth-resolved NMR measurements in the range 2 to 200 nm. Using this technique our group has investigated a variety of samples; which include thin films, heterostructures, and crystals [2,3,4,5,6,7].

Although we have been successful in doing depth resolved β-NMR measurements for certain samples, the technique is inherently limited, at the lowest implantation energies (< 2 keV), by a background signal due to backscattered ions. Knowledge of the implantation profile is a key input for a quantitative interpretation of depth dependent phenomena. Typically the profiles are calculated using TRIM [8]. This is reasonable in many cases, but in some cases it is not sufficient, for example, when channeling is important.

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