Next Generation Equipment for Muonium Chemistry Research (Joint Research Activity)

Leading beneficiary: EU Researchers

Partners: ISIS, with a University group (to be confirmed)

Estimated budget (in person months, other direct cost) and tentative distribution per partner

PDRA (24 months) and 30kEuros for consumables

Abstract of your innovative activity:

Because of the chemical analogy between the positive muon and the proton, the muon technique offers a valuable method for exploring many mechanisms in chemistry and chemical physics. The scope of the technique is, however, greatly extended by the formation of muonium (a bound muon electron system) during muon implantation, providing a probe species that is chemically very similar to hydrogen. Muon experiments involving these species can provide researchers with valuable information about the chemical environment and reaction kinetics of systems involving hydrogen, while offering a uniquely sensitive method for probing reorientational dynamics of molecular systems. Muon techniques frequently provide results that are complementary to those obtained from both conventional magnet resonance and neutron methods, demonstrating impact across a broad range of science areas.

The complexity of many chemical systems require the application of several muon techniques for a successful study, with the high field spectrometers recently developed by PSI and ISIS enabling novel spin rotation, relaxation and avoided level crossing measurements. Unique information can be obtained from the application of pulsed techniques, such as radio frequency (RF) and laser excitation (currently being developed at ISIS by Alan Drew, funded by the ERC); however, the experimental setup for these measurements, even at a pulsed muon source, is challenging. Ad-hoc systems have been used to date with uncertain reliability; our desire is to provide European facility users with a new, robust and state of the art setup for carrying out these types of experiments, while taking the opportunity to develop novel measurement techniques.

This Joint Research Activity therefore seeks to develop both sample cells and sample environment optimised for variable temperature liquid phase measurements, with an initial focus of the work towards developing a setup suitable for high frequency (RF) measurements. Clean non-metallic cells and a custom designed variable temperature mounting are required for use within large volume RF cavities. Designed as a matched system, the new access geometry should allow large sample volumes with easy access for equipment required for pulsed excitation. A method for in-situ sample loading is required as deoxygenation is needed to avoid rapid spin exchange and loss of muon polarisation, while a method for pumped continuous flow of the sample material

is desirable to allow unstable samples to be measured. Synergy with the magnetic resonance imaging community will provide suitable designs for large volume high frequency RF cavities – we anticipate optimising these to work between 100MHz and 300MHz for muonium spectroscopy. A number of RF techniques will be developed and demonstrated, including methods for measuring muonium (hydrogen) reactions and activation parameters.

While equipment design will initially focus on enabling RF techniques, we anticipate the project will have broad application for chemistry applications and will contribute to the programme of work associated with the current pulsed laser excitation project. Methods developed are likely to be of particular interest to the magnetic resonance community, where there is a similar requirement for non-metallic sample environment. Developments will be publicised through presentations at both technique and science focussed conferences, while facility user meetings and newsletters will be used to keep the community aware of the work and the potential for new types of measurements.