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Muon characterization of dielectric insulation in an electric field

How we are going to spend the next 10 minutes....

- VERY short intro to RAL / ISIS
- Background / reasons for work – PhD arose to study the reasons behind the failure of the ISIS bending magnets
- Breakdown of problem –
 - 1) Introduction to magnet system
 - 2) Breakdown phenomena
- Muons....

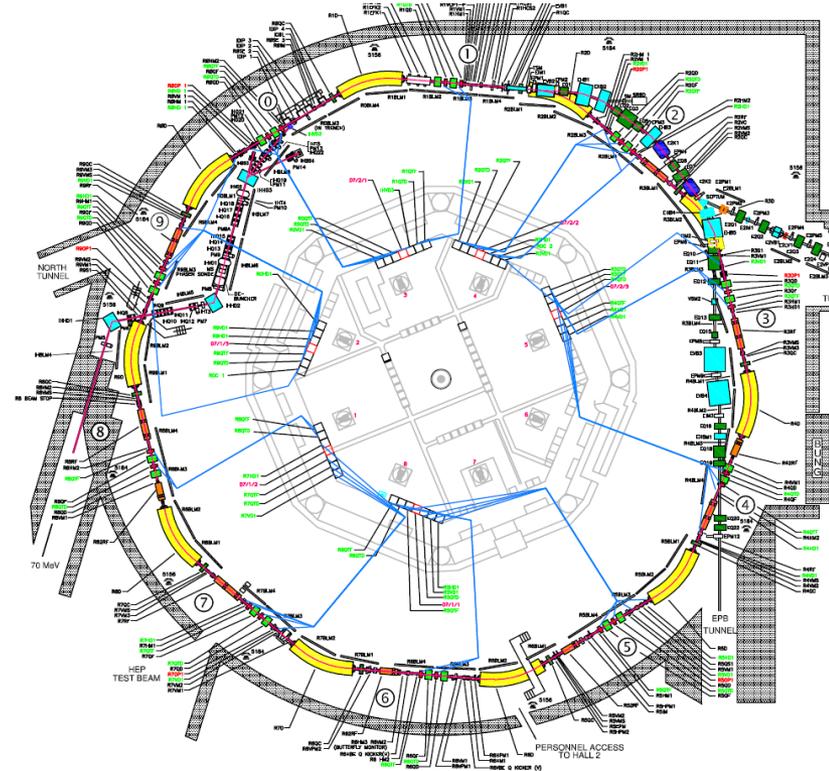


Credit: STFC

- The ISIS spallation neutron source is located at the Rutherford Appleton Laboratory in Harwell, Oxfordshire.
- It provides a source of high energy neutrons and muons which provide unique insights into materials on an atomic scale....



- The synchrotron is a quasi-circular accelerator
- Acceleration occurs in the straight sections.
- At the end of each straight is a large **dipole bending magnet**.
- Magnets approximately 4m long
- Peak field of around 0.7 T. voltage of **11kV_{peak}** and a current of 1kA.





Dipole bending magnet

- Reason for study:
 - The dipoles have experienced a number of catastrophic failures
 - Breakdowns are costly and cause disruption to users experiments

Which leads us on to the subject of breakdown....



Dipole bending magnet after failure

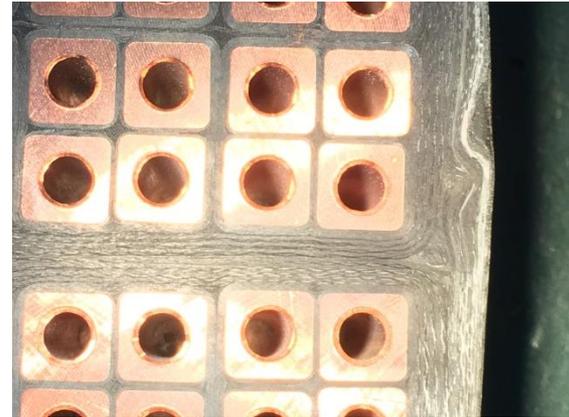
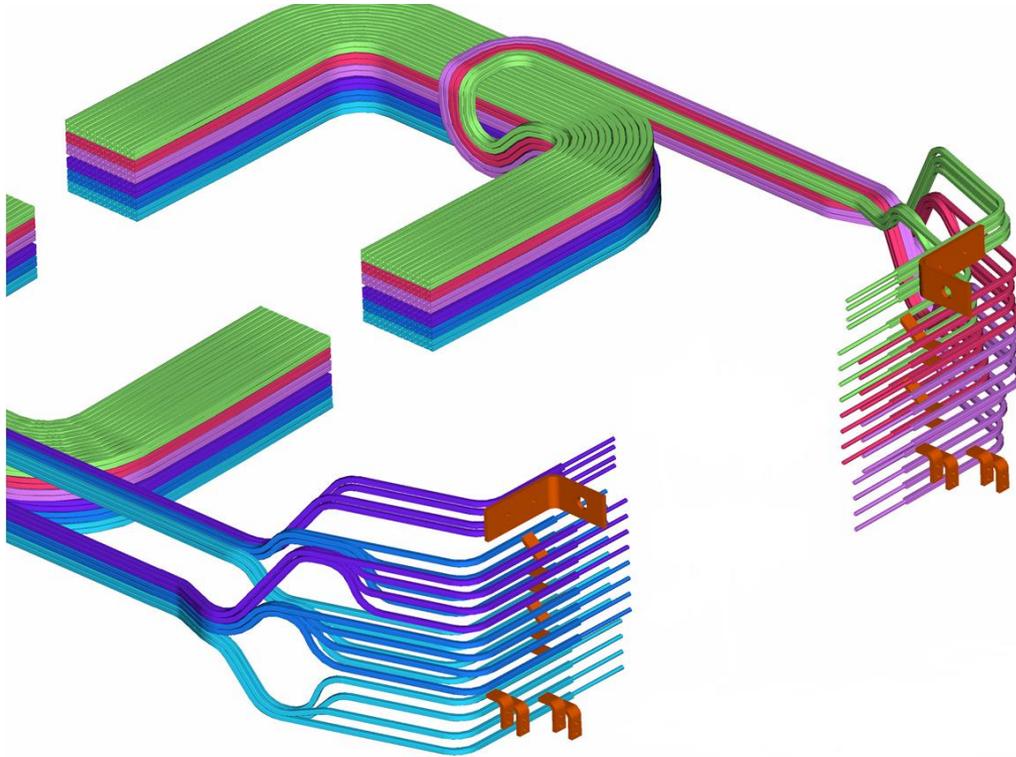
Breakdown

- Is defined as (IEC BS 60505:2011):

“...when a dielectric between two electrodes, subject to a constant or increasing voltage, loses all its insulation properties and becomes conductive, resulting in a short circuit between the electrodes....”

- Essentially there is a physical and chemical change in the structure of the dielectric
- Lots of types of breakdown but here we are interested in electrical breakdown
- There are lots of methods of looking into electrical breakdown, but none of them can really tell us what actually happening at an atomic or electronic level in a material whilst the process of breakdown is occurring

Structure



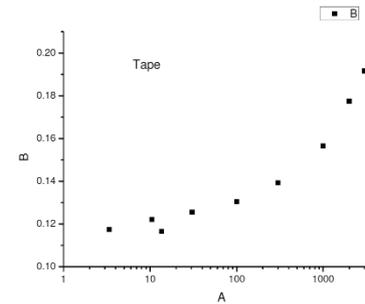
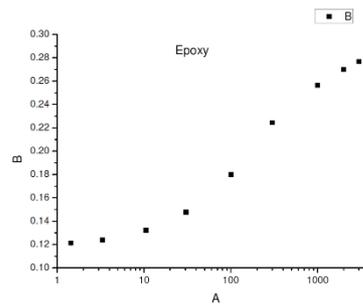
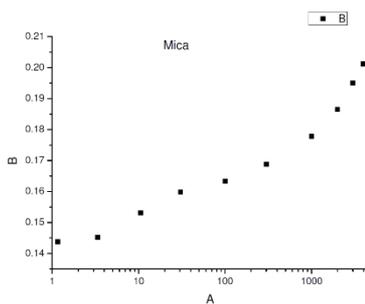
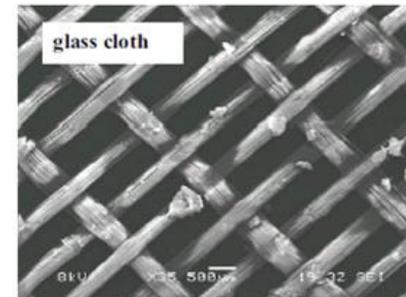
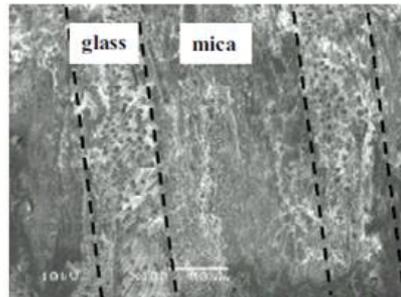
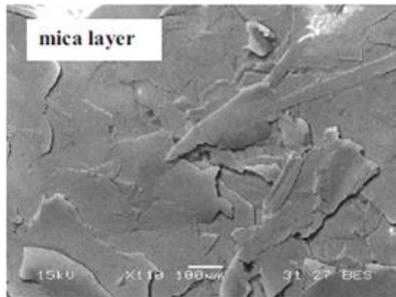
The dielectric is composed of several elements

Aim: Muons How

- By observing the space charge accumulation, the location of the build - up of charge can be determined. Consequently the site of initiation and the evolution in the material can be identified. The aim of the study is to measure the charge distribution in the dielectric under the application of an electric field – both in the run up to and during a break down event – by studying the interactions between the muons and any free charge that constitutes the space charge build up.

Work done

We have analysed the muon response of the individual components to see if we can differentiate between them.



What's next....

- Now we want to investigate the effects of an applied electrical field on the accumulated space charge in the individual materials:
 - We want to measure the diamagnetic and paramagnetic fraction versus applied electric field
 - We will want to characterise the paramagnetic centres in epoxy using ALC
 - Look to see if there are any changes in these centres as we apply an electric field
- Then finally to use this understanding to analyse the whole material

Why it's unique

Ultimately muons could allow us to establish how the electric field evolves on a molecular level, providing a unique view of the processes and dynamics that contribute to, and eventually cause electrical breakdown.

Summary

Ultimately we want to be able to use muons to investigate the composite material...

- We will be able to see in which components the charge is building as the field is applied - as we know the response of each component
- We will also be able to observe the evolution of the charge in the run up to, and throughout catastrophic failure
- This will contribute to our understanding of the composite dielectric and may provide a new method of analysing the capability of dielectrics and determining suitability of materials...



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Thank you all for listening