Radiation Resistance

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Inspired by discussions with
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and many other people

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High Luminosity LHC U.S. LARP

Going on…

Several programs are going on:

- EuCARD is testing radiation damage on several properties of some materials (CE, epoxy, mix, …)
- LARP is testing electrical and mechanical properties of Matrimid and Epoxy/CE mix and developing coil potting process
- CERN is testing radiation damage of Nb_3Sn and is doing a thorough review of literature with interesting results
- And I'm sure I am missing something …

Something is missing …

We need to understand and set requirements for the MQXF

- Now we can and do it should start ASAP
- So far we have electrical requirements for the insulation
  - But other properties give up at lower dose…

An Example: structural properties

- We know that shear is the structural property most sensitive to radiation damage

- But different measurement techniques give significantly different degradation vs. dose:

TE-MSC-MDT

EFFECTS OF RADIATION ON EPOXY RESIN MATERIALS

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DATA AT ROOM AND CRYOGENIC TEMPERATURE

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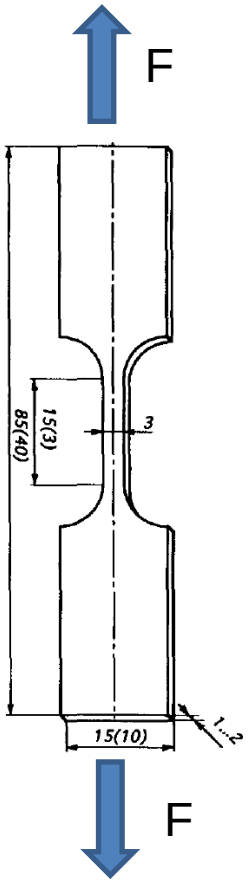
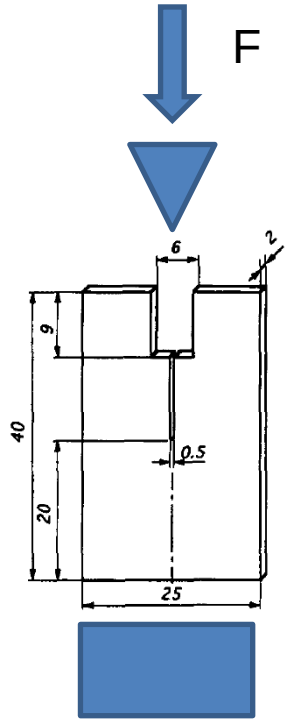
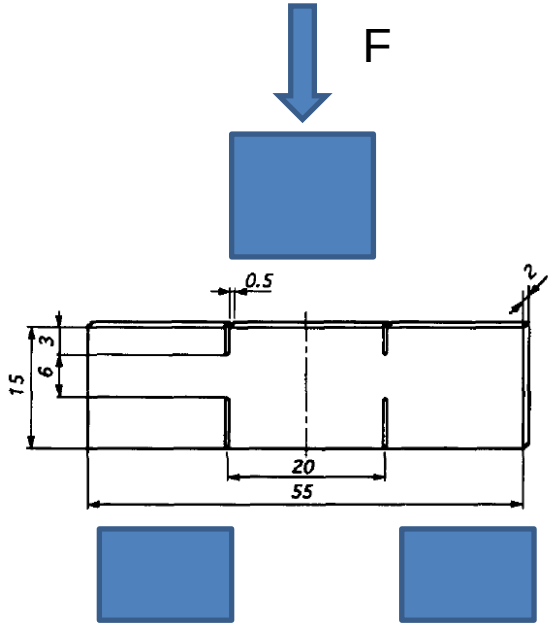
SFM: Test procedures



UTS



Mode I:
intralaminar crack opening



Mode II:
intralaminar shear mode

SFM: Fracture in mode I and mode II at RT

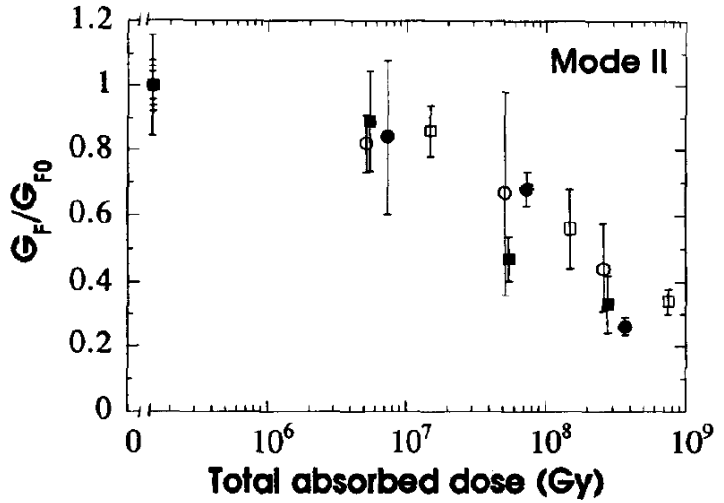
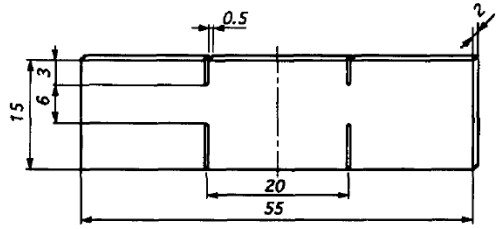


Figure 11 Specific fracture energy for crack initiation G_F in mode II of ZI-005 (○), ZI-003 (●), CTD-101 (□) and ISOVAL-10/S (■) as a function of total absorbed dose following room temperature reactor irradiation and fracture at 77 K. G_{F0} is the fracture energy for crack initiation in mode II prior to irradiation. G_{F0} (in N mm^{-1}) in mode II is 49 (ZI-005), 42 (ZI-003), 51 (CTD-101) and 46 (ISOVAL-10/S)

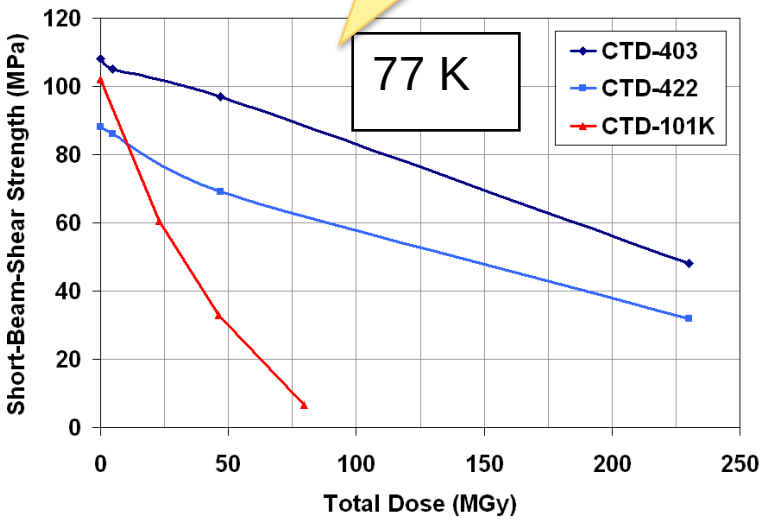


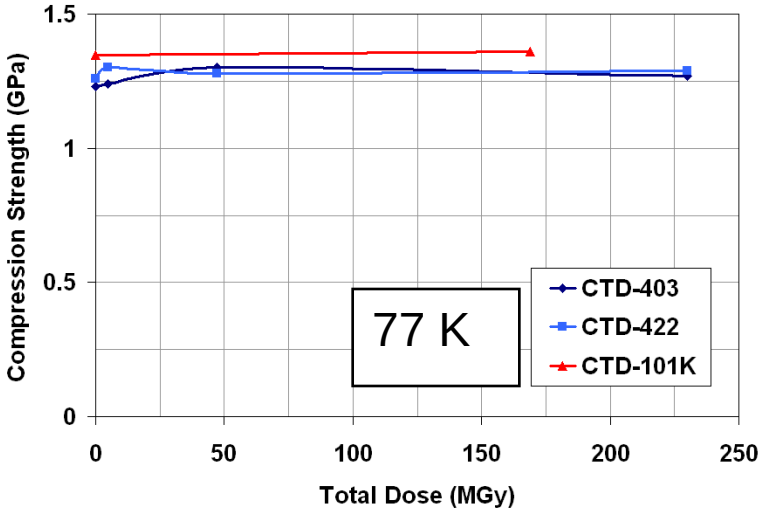
- Irradiation at RT in TRIGA Mark II reactor and tested at 77 K
- The data do not show any significant difference in the dose dependence of the specific fracture energy for all the materials investigated.
- In comparison to UTS, a considerably stronger degradation is observed and the decrease of the specific fracture energy amounts to ~70% at a dose level <1000 MGy

Radiation Resistance

2009 data

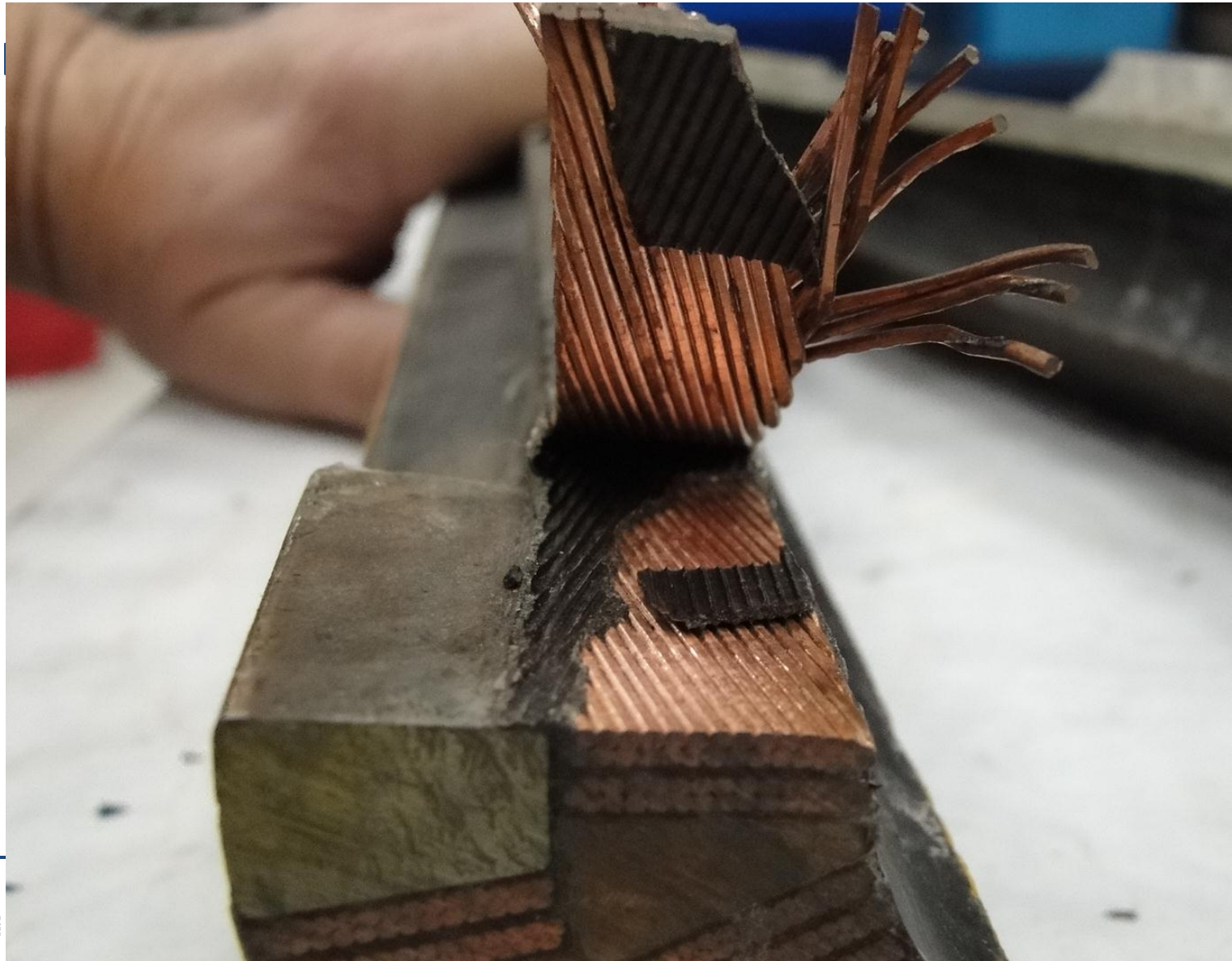
- Insulation irradiations at Atomic Institute of Austrian Universities (ATI)
  - CTD-403 (CE)
  - CTD-422 (CE/epoxy blend)
  - CTD-101K (epoxy)
- CTD-403 shows best radiation resistance
- CTD-422 is improved over epoxy, but lower than pure CE
- Irradiation conditions
  - TRIGA reactor at ATI (Vienna)
  - 80% gamma, 20% neutron
  - 340 K irradiation temperature





Which is the weak link in the chain?

- If you t
  impreg



An Example: structural properties

- We know that shear is the structural property most sensitive to radiation damage

- But different measurement techniques give significantly different degradation vs. dose:

- Different measurement techniques test different combination of structural properties:

➔What measurement is appropriate for MQXF?

➔What is the MQXF requirement for this?

Other requirements needed:

- Thermal conductivity of the insulation and at the interface with conductor
  - Impact on heat extraction
- Minimum RRR (keeps degrading with dose and does NOT fully anneal at RT)
  - Impact on quench protection and stability
- Maximum acceptable swelling
  - Thermal cycle will be needed to reset it (fully?)
  - Impact on coil stress

Next

- Goal of this talk is to start the discussion about MQXF requirements
- Other property/requirement we should address?
- We are going to have a dedicated mtg(s) to set these requirements or to make plan(s) to arrive there.

- Stay tuned …

Thanks