Enhanced flux pinning in HTS wires through ion-beam induced defects

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Columnar tracks created by heavy-ion irradiation are well known to be of ideal dimensions to contribute to magnetic flux pinning in high-temperature superconductors (HTS), thereby suppressing flux creep and enhancing the critical current (I_c). This enhancement is generally anisotropic relative to the orientation of an external magnetic field, relying on overlap of magnetic flux lines with ion damage tracks. Irradiation studies of HTS materials have historically focused on the ideal-overlap case (magnetic field in the same direction as the ion tracks) which highlights the physics of flux pinning. From an engineering point of view though, this ignores the effects on I_c when the magnetic field is applied in other orientations, as would inevitably arise in practical applications. When flux lines do not overlap ion tracks there is no enhanced pinning, and indeed I_c may be suppressed through the reduced superconducting volume fraction and/or widespread oxygen disorder. Disorder tends to reduce the superconducting transition temperature (T_c), amplifying I_c suppression at temperatures approaching T_c – in particular at 77 K, the most convenient characterisation temperature.

We have investigated the magnetic anisotropy of irradiated HTS wires at temperatures down to 20 K and fields up to 8 T. This provides for analysis of flux pinning anisotropy in different temperature and magnetic field regimes; we see in Fig. 1, for example, that a particular irradiation (185 MeV Au) is largely detrimental to I_c measured at (77 K, 1 T), but is significantly beneficial to I_c measured at (30 K, 3 T), a regime of importance to rotating machines applications [1]. This illustrates that ion energy and fluence should be tailored to the temperature and field intended for operation if the benefit is to be fully realised.

Annealing at 200°C to 500°C can partially restore suppressed I_c by re-ordering oxygen, while higher temperatures produce secondary phases leading to overall reduced I_c. An optimised post-irradiation anneal is therefore an important part of enhancing HTS wires by ion irradiation.

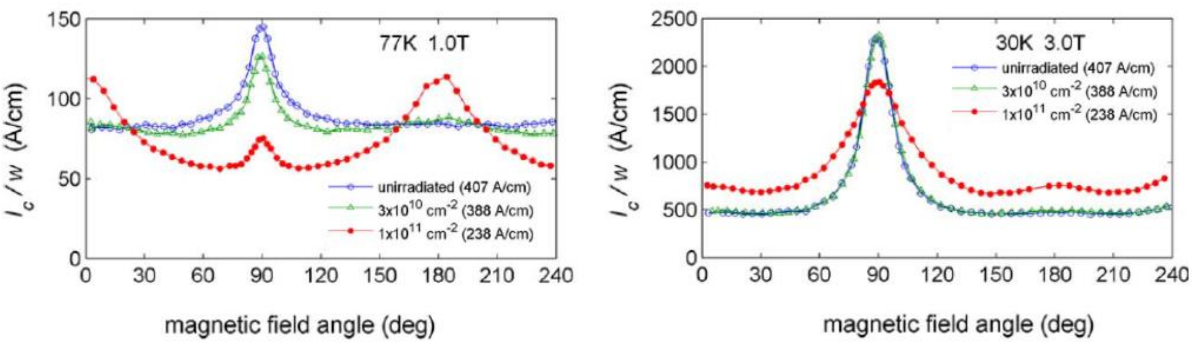

Figure 1. Critical current anisotropy of unirradiated and irradiated HTS wires at 77K, 1T and at 30K, 3T. At 77K, 1T there is a slight enhancement only near θ=0° or 180° (magnetic field aligned with ion tracks) while there is significant suppression of the I_c minimum. At 30K, 3T there is enhancement over a wide range of angles, and the I_c minimum is enhanced.

[1] N.M. Strickland, S.C. Wimbush, J.V. Kennedy, M.C. Ridgway, E.F. Talantsev and N.J. Long, *IEEE Trans. On Appl. Supercond.* **25**, 6600905 (2015).