Resistivity recovery of Fe after high dose proton irradiation

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A variety of applications involve bombardment of materials with intense fluxes of energetic particles, producing significant changes in microstructure. These applications include high-energy accelerators, advanced fission or future fusion reactors, high-energy ion beam processing of materials, decomissioning of radioactive waste, and surface modification of materials by ion beams. Low dose exposure produces isolated atomic defects due to the displacement of lattice atoms by the energetic particles. Such defects typically recover to a large extend after thermal annealing. However, recent experiments and simulations show that high-dose irradiation can produce extended damage microstructures which exhibit high thermal stability. A still outstanding question is how these high-dose microstructures can recover as a result of thermally activated processes[1]. This question becomes crucial for applications when it comes to Fe, since it forms the basis of ferritic steels employed as structural materials in advanced nuclear energy systems.

In this contribution we investigate experimentally the recovery of radiation damage in Fe irradiated with high energy protons at two significantly different damage levels, 10^{-6} and 10^{-4} displacements per atom (dpa), respectively. Irradiations were performed at low temperature (100 K) in the IR^2 facility of the NCSR "Demokritos" TANDEM accelerator. Recovery of radiation damage was observed by means of electrical resistivity measurements during post-irradiation isochronal annealing. We found substantial differences in the recovery as a function of temperature between the high and low dose irradiations. However, our analysis shows that the observed differences can still be attributed to isolated radiation defects. There is no clear evidence for the formation at this damage level (10^{-4} dpa) of a stable extended high-dose microstructure.

References

[1] Derlet, P. M., and Dudarev, S. L. "Microscopic structure of a heavily irradiated material," *Physical Review Materials*, V. 4, No. 2, 2020.