Developing a method to quantify radiation damage using stored energy: simulations and experiments

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From the ashes of the 1957 Windscale nuclear disaster, new scientific understanding emerged; the thermally-activated migration and annihilation of irradiation-induced defects resulted in a significant energy release. Fast forward 60 years and this phenomenon may be harnessed to directly measure the radiation damage within a material. It is well known that irradiation changes the microstructure of materials and can greatly impact their performance. Yet the currently accepted 'unit' for radiation damage, the average number of displacements per atom, fails to capture the effects of varying irradiation parameters, and is also fundamentally unable to be measured. This makes comparison between past and present irradiation experiments imprecise and often impractical, a key factor behind the lack of materials innovation in the nuclear industry. We propose to leverage the Windscale findings, to measure defect populations through their characteristic energy release upon annealing. This has been successfully simulated, using molecular dynamics to visualize the defect recovery mechanism and to predict the macroscopic stored energy release. Current experiments are focused on both validating these results and developing differential scanning calorimetry (DSC) as an analytical technique for radiation damage evaluation. Coupling DSC with ion irradiation will allow rapid determination of defect evolution as a function of dose, dose rate, and temperature, and has the potential to greatly accelerate progress in nuclear materials science.