Beam heating from a fourth-generation synchrotron source

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Fourth-generation synchrotron X-ray sources bring increasing levels of flux and coherence, allowing unprecedented levels of resolution for a wide range of techniques, but with increasing risk of radiation damage. The high flux achievable at synchrotrons has been well known to cause damage in biological samples at around 5-20 keV, however, with increasing flux we have found that radiation effects become significant even for metal samples and high-energy X-rays through beam heating.

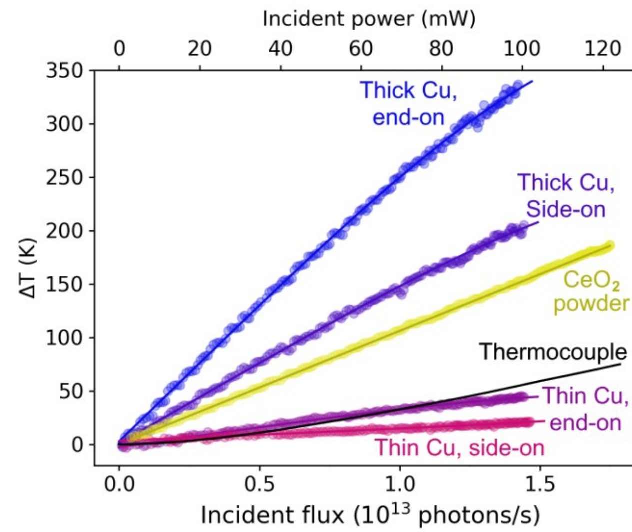

Figure 1. Change in temperature of samples as a function of incident flux at 43.44 keV, with 0.19 mm thick and 0.025 mm thin Cu wire measured align end-on and side-on to the beam, a 0.5 mm capillary of CeO2, and a type K thermocouple.

Beam heating effects were investigated at the ID11 beamline at the newly upgraded European Synchrotron Radiation Facility-Extremely Brilliant Source, using thermal lattice expansion to perform in-situ measurements. Results showed significant increases in temperature for metal and ceria samples in a focussed 43.44 keV beam, as displayed in Fig. 1. These temperature increases may affect sample properties and drive significant chemical or physical changes, such as the rapid recrystallisation of copper wire shown here.

Aluminium and Copper wire samples were investigated and compared to a lumped thermodynamic model. By designing samples to maximise effects and simplify the thermodynamics of the system, we facilitate quantitative comparison to the modelled beam heating, helping to understand the severity of the problem. With these results we show that radiation beam heating is a potential issue for all samples, not only soft matter, and provide information needed to consider, predict, and mitigate its effects.

Keywords: Beam heating; radiation damage