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Changing the World's Energy Future

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1. Introduction

Quantifying material damage and degradation under reactor conditions enables researchers to make important predictions regarding reactor safety and efficiency. More specifically, thermal property instruments serve as a powerful tool in quantifying the evolution of thermal properties under irradiation, and hence, are necessary in qualifying fuels and materials for reactor use. In addition to providing insight into thermal properties, some instruments may provide a new means of quantifying radiation damage, a challenge in modern nuclear materials research.

2. Current Applications

Thermal properties can be measured with great precision using modern instruments including:

- **Differential Scanning Calorimeter (DSC):** Measures power output of a sample heated at a constant rate as function of temperature. Reveals enthalpic changes in a material stemming from phase transitions, etc.
- **Thermal Conductivity Microscope (TCM):** Uses a thermo-reflectance technique to determine thermal conductivity and thermal diffusivity.
- **Laser Flash Analyzer (LFA):** A high intensity laser pulse is imparted on one side of a material, and thermal radiation is detected on the other side. Measures thermal conductivity, diffusivity, specific heat.

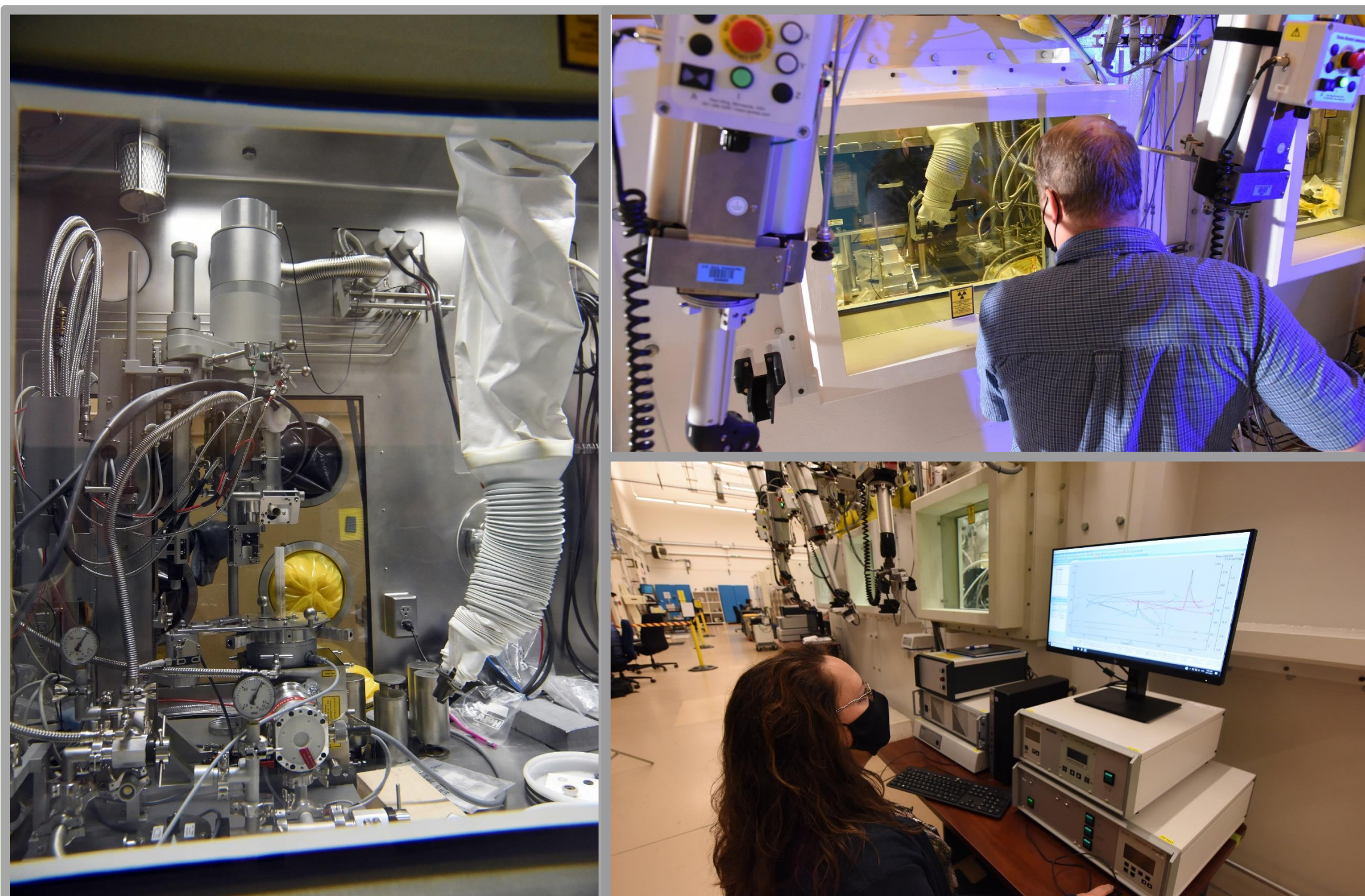


Fig 1. Pictured here are the DSC (left) and TCM (top right) in the Thermal Property Group's TPC located at IMCL. A researcher is seen analyzing DSC data (bottom right).

3. Opportunities

One thermal property instrument, the DSC, is being considered beyond its traditional usage as a means of quantifying radiation damage.

- The DSC can measure Wigner energy, an energy imparted by neutrons and other colliding particles that takes form through stored defects.
- As the DSC heats up a sample, these stored defects will become mobile and recombine, releasing energy in the process.
- Extracting the energy released from recombination can be a tedious process – crucible effects and characteristic energy releases from the material must be subtracted out.
- Stored energy release however, measured in J/g, can serve as a new measurement of radiation damage in nuclear materials.

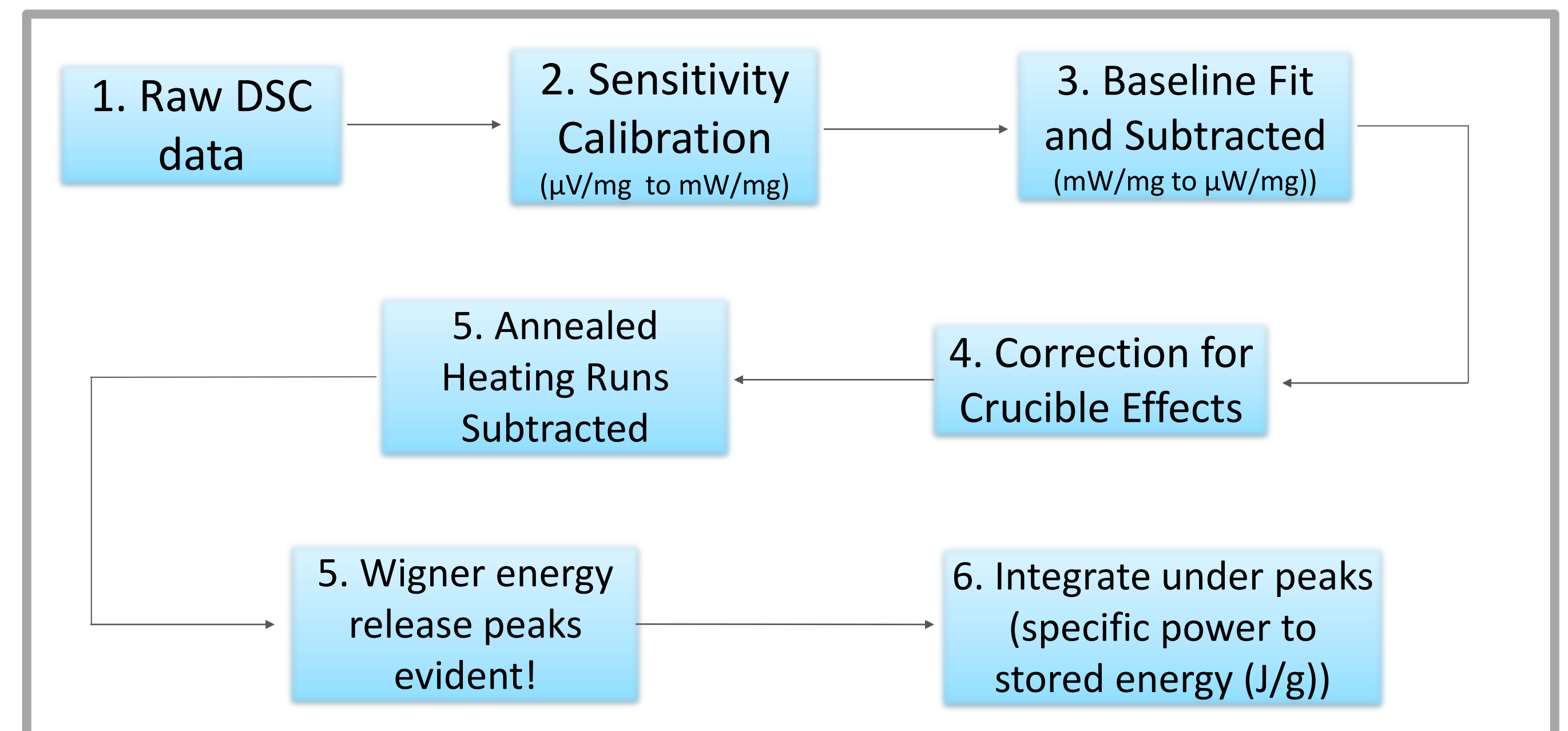


Fig 2. DSC data analysis process for revealing Wigner energy release (Hirst et. al.). Instrument sensitivity, effects of crucible, enthalpic reactions following annealing, and size of exothermic peaks must be accounted for.

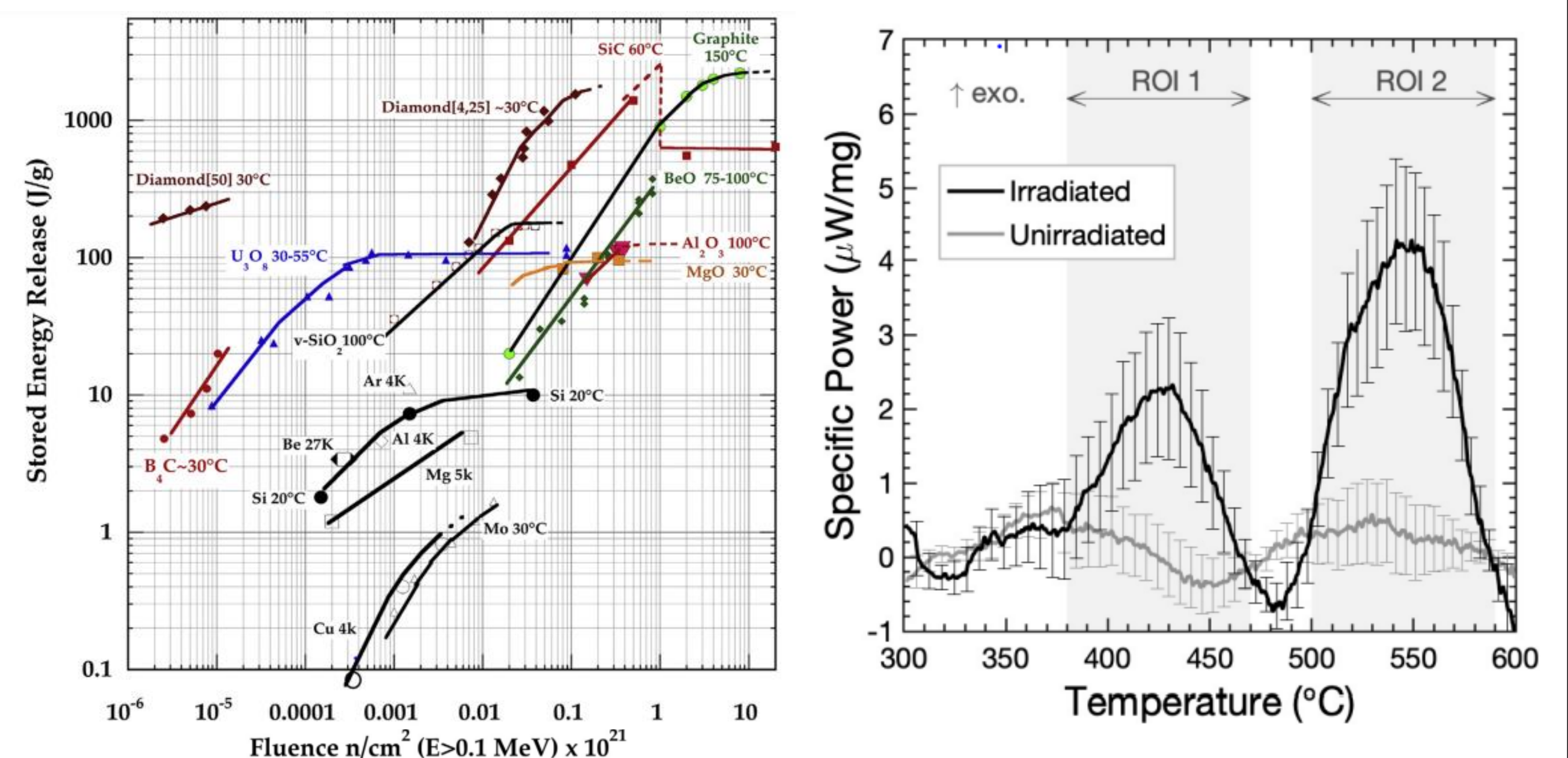


Fig 3. (left) displays stored energy release as a function of fluence for several materials – note that ceramics release much more energy, but at higher temperatures (Snead et. al.).

Fig 4. (right) plots specific power as a function of temperature. The two peaks for the unirradiated data correlate with energy release from defect recombination processes (Hirst et. al.).

4. Why this is Important

- DPA does not always correlate directly with damage since effects such as thermal cascade quenches and cascade morphology are often neglected in cascade simulations (Nordlund et. al.).
- Other methods of measuring radiation damage and defect density, including TEM, STEM, PAS, etc., are often unable to detect the smallest scale of defects or varying types of defects (Hirst et. al.).
- DSC is not limited in its capacity to measure small scale or various defects, since it relies on stored energy release from recombination.

5. Future Work

- Measuring stored energy has mainly been considered for ceramics but could provide great insight into irradiation damage in metals.
- There remains a great potential for the development of differing DSC methods of measuring stored energy.
- Using DSC analysis, a means of harnessing Wigner energy for use can be developed and further researched.

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