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Nanocomposite Absorbers, Energy Conversion, and Nuclear Decay Energy Spectroscopy in Microcalorimeters

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Microcalorimeters with embedded radioisotopes are an emerging category of sensor with a wide range of potential applications ranging from basic science (e.g. neutrino mass, metrology) to nuclear safeguards (e.g. determining the age of radioactive materials). For each nuclear decay, the energy of all decay products captured by the absorber (alpha particles, gamma rays, X-rays, electrons, daughter nuclei, etc.) is measured in one pulse. For alpha-decaying isotopes, this gives a measurement of the total nuclear reaction energy (Q value) and the spectra consist of well-separated, narrow peaks. For beta-decaying isotopes, the spectra show a continuum ending at the Q value due to the escape of the antineutrino. A central challenge for these detectors is encapsulation of the radioactive material inside the absorbing component in a way that ensures complete capture of the relevant decay radiation and is free of spectral artifacts. We now have experimental evidence that the key to optimized energy thermalization and spectral performance is control of the absorber structure at the nanoscale. We have demonstrated a simple mechanical alloying process to create a nanocomposite absorber structure consisting of a gold matrix with sub-50 nm inclusions of a radioactive sample. By distributing the radioactive sample in domains that are small compared to the relevant decay radiation path lengths, we achieve an optimized Q spectrum for alpha-decaying isotopes (1.0 keV FWHM at 5.3 MeV with minimal tailing). We will present

ongoing work to create and characterize absorbers by several methods including mechanical alloying and constrained crystal growth in a nanoporous matrix (e.g. gold nanofoam). The sensitivity of these detectors to absorber structure gives us a new tool to understand radiation interaction and energy conversion processes in materials for many potential applications.