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High-Radiopurity Structural Components Made by Chemical Vapor Deposition

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High-radiopurity structural materials are needed for a variety of high-energy physics experiments, particularly those involved in the search for dark matter or neutrinoless double beta decay in which background radiation from trace impurities can hide the desired signal. The structural material with the highest radiopurity currently available is electroformed copper, but its yield strength is only 12 ksi [1], which limits its utility as a structural material. In this project, using chemical vapor deposition (CVD) Ultramet fabricated articles made of tungsten—a material with very high yield strength and density—with extremely high levels of radiopurity such that the articles can be used for both shielding and structural applications.

Like electroplating, during which the voltage can be adjusted to preferentially deposit one metal instead of another, CVD process parameters can be adjusted such that one metal can be selectively deposited instead of others. CVD is also routinely used to manufacture freestanding structures with wall thicknesses up to several millimeters.

Thermodynamic analyses were performed on mixtures containing tungsten and a variety of undesirable impurities and decay chain progeny (e.g. uranium, thorium, radium, polonium, actinium, radon), and the predicted rejection ratios of the undesirable elements in the solid deposit ranged from roughly three orders of magnitude to over nine orders of magnitude. Similar calculations were performed for tantalum as the matrix rather than tungsten.

In parallel with the thermodynamic analyses, tungsten samples were fabricated by CVD and sent to Pacific Northwest National Laboratory, where an assay technique was developed using inductively coupled plasma mass spectrometry (ICP-MS) to quantify the concentrations of thorium and uranium in a tungsten matrix. Empirically, thorium and uranium levels as low as 80 parts per quadrillion (ppq) and 50 ppq, respectively, were measured.

1. N.R. Overman et al., "Majorana Electroformed Copper Mechanical Analysis,"Pacific Northwest National Laboratory, Richland, WA (April 2012).

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