This paper describes objective technical results and analysis. Any subjective views or opinions that might be expressed in the paper do not necessarily represent the views of the U.S. Department of Energy or the United States Government.

SAND2018-11258C

EFFECT OF RADIATION CONVERTER MATERIAL ON PULSED POWER MACHINE RADIATION OUTPUT

I.J. Owens, C. Grabowski, N. Joseph, G. Gatewood, D. Kirschner and R. Durrer
Sandia National Laboratories
Albuquerque, NM

Abstract

A series of small scale experiments were performed on the SPHINX pulsed power machine at Sandia to determine how the radiation output varies with the material properties of the converter. We examined tantalum converters with differing levels of tungsten alloy mixture and subsequently pure tantalum with variable grain size. A model and simulation of the expected radiation based on the atomic structure of the material as well as the results from laboratory experiments with the alloy mixtures and variable grain size are presented.

Introduction

For many years, the pulsed power machine facilities at Sandia National Laboratories have used tantalum (Ta) converters to produce Bremsstrahlung radiation. Typically, the radiation converter material has been ordered from commercial vendors with differing amounts of tungsten (W) alloy, and variability in the cold working (shaping) and annealing processes. Adding W to the converter helps strengthen the material and adds durability. Cold working both shapes and strengthens the material. Annealing is used to restore the Ta back to its original properties removed during the cold working, but is imperfect and its success or lack thereof greatly influences the underlying micro-structure [1]. The cold working process alters properties such as electrical conductivity. Annealing involves heating the material and changing the grain size. The purpose of this experiment was to examine how both the variability in the Ta W alloy mixture and grain size influence the machine radiation output [2]. The physics of the material interaction is considered by modeling the expected radiation output. However, heavy emphasis is placed on how known changes in the underlying material micro-structure lead to variability in the radiation output. Results from a previous experiment with Ta W alloy as well as information about a planned follow-on experiment with pure Ta of differing grain size is provided.

Modeling and Simulation

To establish a baseline of the expected radiation dose, the radiation output for pure Ta, 2.5% W, 7.5% W and 10% W was simulated using Monte Carlo N-Particle (MCNP) Transport Code software package. The samples were modeled as a homogenous mass and electrons were treated uniformly with respect to the experiment setup geometry. We included 7.5% W in the simulation even though the vendor was unable to provide this sample. The plot in Fig.1 displays the results of the modeling and simulation of the expected radiation dose versus the distance of the of the measurement distance from the centerline of the electron beam on the SPHINX pulsed power machine. From the plot, it is evident there is minimal to virtually no expected variation in the radiation signal output with an increasing level of W added to the Ta converter.

This work was sponsored by

Unlimited Unclassified

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

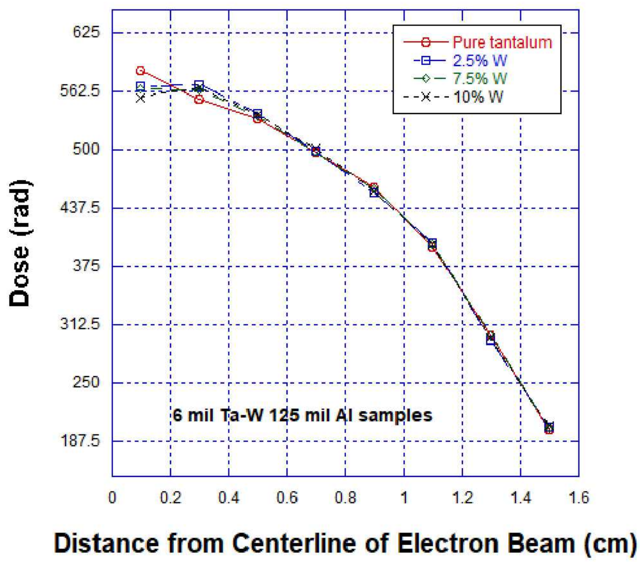

Fig. 1. Radiation dose versus distance from the electron beam centerline to the TLD.

Ta W Alloy Experiment

To scale the radiation output variability observed on the larger pulsed power machines such as Saturn and HERMES III, we decided to conduct the experiment on SPHINX due to accessibility and relative ease of operation. SPHINX is a comparatively small accelerator, but versatile in that it can be fired every five minutes. It operates at up to 2.5 MeV with 50 kA, and has a .35 ns continuously variable pulse width. The maximum dose rate is 4.0E11 rad(CaF2)/s on the face plate. The experiment was divided up into three tests including pure Ta, 2.5% W Ta, and 10%W Ta alloy mixtures. For all three tests, the radiation converter samples were affixed to the end-point of the machine with an array of nine TLDs. Each of the individual TLDs were placed 1 cm from the centerline of the electron beam. Fig.2 shows a plot of the average TLD dose versus the TLD ID number used in the experiment. For each individual TLD, the data points shown in the plot were averaged over ten shots. Each individual TLD varied by approximately 10% in radiation signal value, and it was important to use the average value of their signals for comparison of the full array of TLDs. From the plot, it is clear there is a trend for higher radiation level with less W added to the Ta. The pure Ta sample showed the highest average radiation level, and 10% W had the lowest average. This result appears to be inconsistent with the simulation. The simulation showed virtually no variation in the radiation level for the different samples. This discrepancy between the simulation and experiment results has motivated a follow-on experiment to determine if differences in the material micro-structure could account for the inconsistency in the radiation levels.

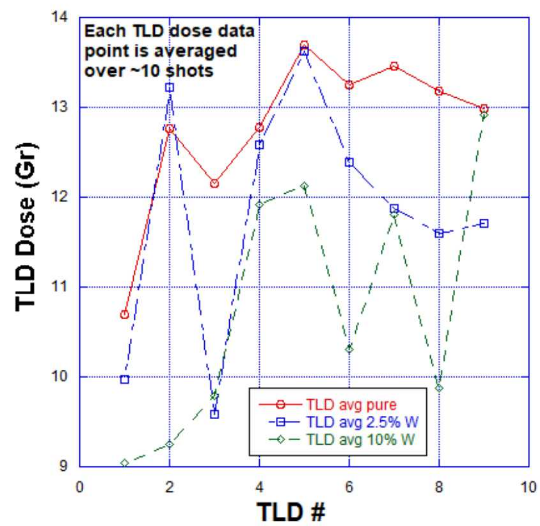

Fig. 2. Average TLD radiation dose versus TLD identification number.

Pure Ta with Variable Grain Size Experiment

The upcoming experiment (slated for 10/2018) is to determine if the micro-structure in pure Ta is affecting the radiation output level. Three types of pure Ta samples have been selected with grain sizes ranging from approximately 30-60 microns. As with the variable W experiment, a series of ten shots with each sample will be performed. The data will be analyzed and trends in the radiation output will be treated alongside material properties.

Conclusion

In summary, the effects of Ta material properties on the radiation output of pulsed power machines has been treated. Even though modeling and simulation showed slight variation in the expected radiation dose, the subsequent experiment demonstrated a trend for increasing radiation level with decreasing T alloy. The planned experiment using pure T with variable grain size will help to shed light on the effects of the underlying micro-structure.

Acknowledgment

The authors would like to thank the Accelerators Operations Group at Sandia for running the SPHINX pulsed power machine as well as Eagle Alloy INC. for providing the Ta samples used in the experiment.

Sandia National Laboratories is a multi-mission laboratory and operated by National Technology Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy National Nuclear Security Administration under contract DE-NA000352.

References

[1] Fan, Haiyang & Liu, Shifeng & Chao, Deng & Wu, Xiaodong & Cao, Lingfei & Liu, Qing, “Quantitative Analysis: How Annealing Temperature Influences Recrystallization Texture and Grain Shape in Tantalum”, International Journal of Refractory Metals and Hard Materials, p. 72, 2017.

[2] Kim, S. & Jung, Y., “Effects of Grain Size on the Bremsstrahlung Spectrum of Electron-Dust Grain Collisions in Dusty Plasmas”, Zeitschrift für Naturforschung A, 64(3-4), pp. 229-232, 2018.