8th High Power Targetry Workshop
November 6-10, 2023

Contribution ID: **87** Type: **Contributed Oral**

# Multiphysics analysis of LBE windowless target design under high-power electron beam

*Tuesday, 7 November 2023 14:45 (15 minutes)*

Los Alamos National Laboratory (LANL) supported Niowave Inc. as a part of the National Nuclear Security Administration (NNSA)'s Molybdenum-99 (Mo-99) program [1], where USA establishes a reliable domestic supply of Mo-99 production through cooperative agreements between industries and national labs. The decay product of Mo-99, technetium-99m, is essentially used in various medical procedures. LANL helped Niowave develop, design, and evaluate a lead-bismuth-eutectic (LBE) windowless target used to produce neutrons (so-called neutron converter) by electron irradiation at a beam power of 200 kW with a beam energy of 40 MeV. Two superconducting electron accelerators are used to irradiate two neutron source converters embedded in an uranium target assembly where Mo-99 is produced by fission reactions. The neutron converter is designed such that there is a thin stainless steel (SS) housing surrounding LBE flow in vacuum. The LBE layer falls, driven by gravity, and forms free-surface in vacuum. The heat deposited on the irradiated LBE target and SS housing is removed through forced convection by LBE flow. At high incident electron beam power, high-fidelity simulation is essential to ensure the target in-beam survival and the integrity of the target system.

21-GPM LBE enters the converter at 200℃. The design of the converter was optimized by 2D/3D computational fluid dynamics (CFD) hydraulic analysis using ANSYS Fluent [2] volume-of-fluid model to obtain uniform and stable LBE layer formed with the maximum velocity of 1.96 m/s with a favorable pressure gradient avoiding wall separation. LBE velocity is under velocity limitation of 2 m/s to prevent LBE-SS interface erosion issues. Positive pressure over the LBE volume assures no cavitation in LBE flow near ultra-high vacuum conditions.

Attila4MC software [3] was used to import a customized SolidWorks [4] geometry of the discrete LBE, vacuum, SS volume and to generate unstructured meshing for Monte Carlo N-Particle (MCNP) 6.2 code [5]. Volumetric heat deposition by an electron beam on the LBE and SS was obtained by MCNP radiation transport calculations. The direct mapping of data from MCNP to CFD enables high-resolution 3D multiphysics analysis.

Conjugate heat transfer analysis was performed to obtain the 3D temperature profile for the LBE and SS. The LBE maximum temperature reaches 363 ℃, below the LBE evaporation initiative temperature, 450 ℃. The LBE-SS interface temperature reaches up to 346 ℃, which has low risk of severe SS corrosion problems.

**Acknowledgment**
This research is supported by Department of Energy NNSA.

**References**

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## Themes for the contribution

4 Target design, analysis, and validation of concepts:

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**Session Classification:** Topic4-1