



**UNITED STATES
NUCLEAR REGULATORY COMMISSION**
WASHINGTON, D.C. 20555-0001

Grant # 31310021M0004

Grantee: University of Nevada - Reno

Title of Grant: A Self-Powered Platform to Measure and Report Spent Nuclear Fuel Package Temperatures during Transport without Containment Boundary Penetrations

Period of Performance: 11/30/2020-11/29/2023 (FY2020 Notice of Funding Opportunity NOFO)

Executive Summary

Nuclear power stations throughout the United States will likely ship their spent nuclear fuel (SNF) to Consolidated Interim Storage Facilities once those facilities become operational. The SNF will be primarily shipped by rail in large thick-wall packages. Federal Regulations (10CFR71) require that, after Normal Conditions of Transport (NCT), SNF remain in its original configuration, to allow it to be retrieved and processed. This requires analysts to determine the vibrations, accelerations, and temperatures to which SNF will be subjected during NCT and assure that those conditions will not affect SNF integrity. It has been difficult to measure SNF temperatures during transport because it is contained within a thick metal boundary, and it is not possible to physically penetrate that boundary to provide power to measurement devices, or to receive their data. The objective of the proposed research is to develop a self-powered and wireless proof-of-concept monitoring platform that can be installed inside SNF transport packages to measure temperatures of fuel cladding, package seals, and other components that protect fuel integrity. Molecular dynamics simulations and experimentation will be used to develop advanced thermoelectric (TE) modules to power the platform. Geometrically accurate computational fluid dynamics simulations will be used to choose transport package interior locations where the TE modules will harvest the most energy. Electromagnetic simulations will be employed to design and optimize a low-power magnetic-resonance signal to transmit data wirelessly through the metal containment boundary. A power management system will be developed that will initiate measurement/transmission events after sufficient electrical power is accumulated. TN Americas LLC will guide the university researchers to conduct tests of the data transmission system and ensure the measurement platform's safe integration into the radioactive transport package environment.

Principal Investigator: Miles Greiner, greiner@unr.edu

Presentations and Publications

The list of publications was submitted with the final report after grant expiration.

1. Journal Paper: Maranets, T., Nasiri, M., & Wang, Y. (2024). Influence of Spatial Coherence on Phonon Transmission across Aperiodically Arranged Interfaces. arXiv preprint arXiv:2403.01321. (Under review at Physics Letters A)
2. Conference Presentation and Poster: Theodore Maranets and Yan Wang, "Thermal Transport in Embedded Nanoparticle Composites: A Molecular Dynamics Study of the Optimal Size Distribution," International Mechanical Engineering Congress and Exposition (IMECE) 2023, October 30 - November 2, 2023, New Orleans, LA
3. Conference Presentations (Abstract Accepted): Theodore Maranets and Yan Wang, "Direct atomistic wave-packet simulation of coherent phonon transport in superlattice structures," 22nd Symposium on Thermophysical Properties & 18th International Conference on the Properties of Water and Steam, June 23–28, 2024, Boulder, CO
4. Conference Presentation Theodore Maranets and Yan Wang, "Lattice Thermal Conductivity of Embedded Nanoparticle Composites: The Role of Particle Size Distribution," 22nd Symposium on Thermophysical Properties & 18th International Conference on the Properties of Water and Steam, June 23–28, 2024, Boulder, CO
5. Conference Presentation and Paper (submitted): B. Hager and M. Hadj-Nacer, 2024. "Thermoelectric Devices to Power a Monitoring Platform of SNF Cask Internal Conditions." 2024 Waste Management Conference, Phoenix, AZ.
6. Journal: Maranets, T., and Wang, Y., "Ballistic phonon lensing by the non-planar interfaces of embedded nanoparticles," 2023 *New J. Phys.*, 25 103038
7. Journal: Maranets, T., Cui, H., and Wang, Y., "Lattice thermal conductivity of embedded nanoparticle composites: the role of particle size distribution," *Nanotechnology*, 35(5), 055701 (2023).
8. Journal: Panneerselvam, I.R., Kim, M.H., Baldo, C., III, Wang, Y., and Sahasranaman, M., "Strain engineering of polar optical phonon scattering mechanism—an effective way to optimize the power-factor and lattice thermal conductivity of ScN," *Physical Chemistry Chemical Physics* 23, no. 40 (2021): 23288-23302.
9. Conference Presentation and Poster: Maranets, T., and Wang, Y., "Molecular Dynamics Analysis of Mode-Resolved Phonon Scattering by Embedded Nanoparticles" - Poster and Technical Presentation, International Mechanical Engineering Congress and Exposition (IMECE) 2022, October 29 – November 3, 2022, Columbus, OH.
10. Conference Poster: Maranets, T., and Wang, Y., "Atomistic investigation of phonon transport through nanoparticles" - Poster and Technical Presentation, APS March Meeting 2023 - Las Vegas, NV, March 9, 2023.
11. Conference Presentation: Hager, B., and Hadj-Nacer, M., (2023), "Thermo-Electric Devices for Powering Sensing Platforms of Internal Conditions of Spent Nuclear Fuel Canisters," ASME Pressure Vessels & Piping Conference, July 16-21, 2023, Atlanta, Georgia.

12. Conference Poster: Hager, B., Hadj-Nacer, M., and Greiner, M., 2023, "Optimization of Thermo-Electric Devices for Powering Monitoring Platforms of Internal Conditions of Spent Nuclear Fuel Casks WM Symposium, Phoenix, AZ.
13. Conference Poster: Maranets, T., Wang, Y., Hadj-Nacer, M., Greiner, M., "Analyzing the effect of nanoparticles on thermal transport for improved thermoelectric performance," NV NASA Programs Virtual Poster Competition, 2022.

Patents

N/A