IGEM Grant Report

☐ Progress (due January 1) ☐ Annual (due July 31) ☐ X Final

IGEM Grant # IGEM 25-005 Principal Investigator: Krishnan S Raja
Name/Full Title of Project: Self-healing Composites for Aggressive Environments
Submission Date: 06/30/2026 Primary Institution: University of Idaho

Section 1: Project and its goals

Self-healing bulk composite materials were developed via a powder metallurgy route and sintering process, exhibiting self-healing of microcracks and superior resistance to crack initiation, irradiation damage, and corrosion. Self-healing was achieved by distributing metal-core oxide-shell (MCOS) nanocapsules in a nickel alloy matrix and an oxide ceramic matrix. A uniform distribution of these MCOS nanocapsules is expected to improve tolerance to radiation damage. When a dislocation during the damage accumulation stage or a microcrack encounters an MCOS nanocapsule, it shears the oxide shell, exposing the metal core. Because of its nanoscale size, the metal core's melting point is lowered, facilitating material flow and crack filling. In a metal matrix, when oxygen activity is very low, no oxidation occurs. In oxide ceramics, the filler metal oxidizes due to high oxygen activity in the environment. Self-healing occurs in both materials through interactions involving MCOS deformation. In the industry, component repair is typically performed after damage becomes visible. In this project, we demonstrate that self-healing could be initiated during the damage accumulation stage, well before anyone outside the system would even know there is a problem. This self-healing approach enhances reliability, maintains safety, and extends the lifespan of components used in harsh environments, such as nuclear power plants.

Section 2: Summary of accomplishments and future plans

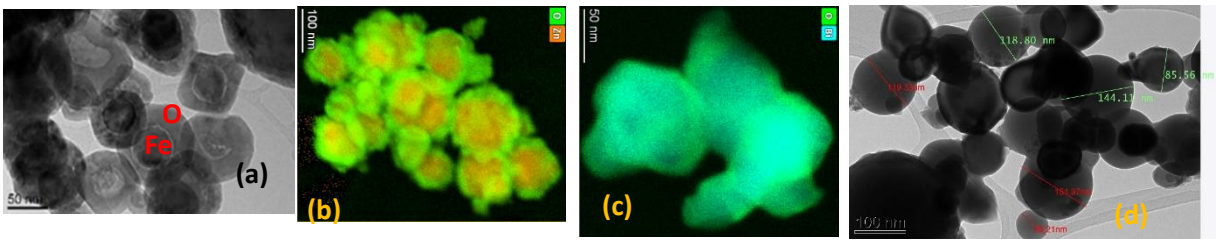

Fig. 1(a) – (c). Transmission electron microscopic (TEM) images of metal core oxide shell (MCOS) nanocapsules. (a) Iron core – iron oxide shell, (b) zinc core – zinc oxide shell, and (c) bismuth core and bismuth oxide shell structures. (d) tin metal core and tin oxide MCOS.

Accomplishment # 1: Four different MCOS nanocapsules were successfully prepared as shown in Fig. 1.

Accomplishment # 2: Self-healing was demonstrated in metal-matrix and ceramic-matrix

composite materials, as illustrated in Fig. 2. 400% increase in fracture time was observed in alumina-MCOS composite.

Accomplishment #3: Two students graduated with M.S. degrees. Three technical presentations were made at national conferences. Three manuscripts are under preparation for submission to high-impact journals.

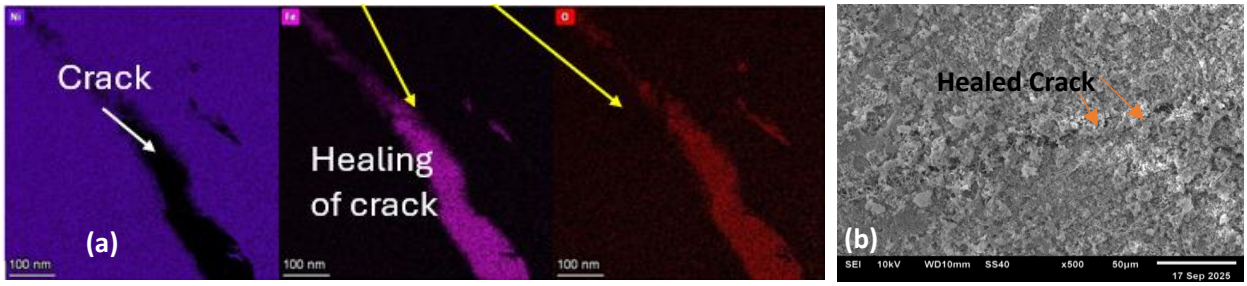

Fig. 2. Demonstration of self-healing. (a) in a metal-matrix composite and (b) a ceramic matrix. The alumina-MCOS composite showed 400% increase in fracture life.

Section 3: Summary of budget expenditures

98.68% of the total budget has been spent.

Section 4: Economic development/impact

Industry Involvement: GenNext Materials and Technologies, LLC, Reno, NV STTR Phase 1 collaboration.
External Funding: $150,000 for nine months, subcontract from GenNext Materials and Technologies through the Department of Energy.
Jobs Created: Two (one engineer and one student intern).

Section 5: Participants

1. Krishnan S Raja, PI, faculty: Overall project direction; 2. Indrajit Charit, co-PI, faculty: Supervision and guidance of research effort; 3. Kavindan Balakrishnan, graduate student (MCOS-Metal matrix composite), and 4. Jonah Hudman, graduate student (MCOS-Ceramic matrix composite).

Section 6: Long-term sustainability plan

We will continue to collaborate with GenNext Materials and Technologies, LLC, Reno, NV, and find additional industrial partners to test the composite materials in specific industrial applications. NuCube Energy is interested in evaluating this concept for its high-temperature gas-cooled reactors. The investigators are writing a 15-page proposal to be submitted to the CMMI division of the NSF by October 2026.

Section 7: Expenditure Report

	Budgeted, $	Spent, $	Balance, $	% Remaining
Salary	109,077.16	106,169.31	2,907.85	3.7
Fringe	9,114.60	9,439.82	-325.22	
Materials & Supplies	40,793.24	40,760.76	32.48	0.08
Tuition	38,615.00	38,615.00	0	
Total	197,600.00	194,984.89	2,615.11	1.32