

IGEM Grant Report

☐ Progress (due January 1)

☒ Annual (due July 31)

☐ Final (due August 31)

IGEM Grant # IGEM26-006

Principal Investigator: Krishnan S Raja

Name/Full Title of Project: Joining of Non-Oxide Ceramic Components Used in Extreme Environments

Submission Date: July 30, 2026 Primary Institution: University of Idaho

Section 1: Project and its goals

Non-oxide ceramics are used in extreme environments due to their high melting points, high-temperature mechanical strengths, and chemical inertness. Manufacturing of complex shapes requires joining of several sections. Achieving direct bonding without any filler material will be game-changing because the joint is no longer the weakest link. The proposed research will use electric-field-assisted processes to join ceramic materials (SiC or ZrB₂) without an interlayer. The joining process will be further enhanced through modification of the surfaces (one end is metal/metalloid terminated (Si, or Zr), and the other end to be joined is non-metal (boron or carbon) terminated) to promote Zr-B or Si-C reactive bonding.

Section 2: Summary of accomplishments and future plans

Accomplishments: SiC and ZrB₂ disc and cylindrical samples were prepared by sintering and precision-machined to the required dimensions. The flat surfaces of the specimens were polished to a mirror finish, and Raman spectroscopy was performed in the as-polished condition. The polished SiC samples were vacuum-annealed to achieve C-termination on their surfaces. Typical results are shown in Fig. 1.

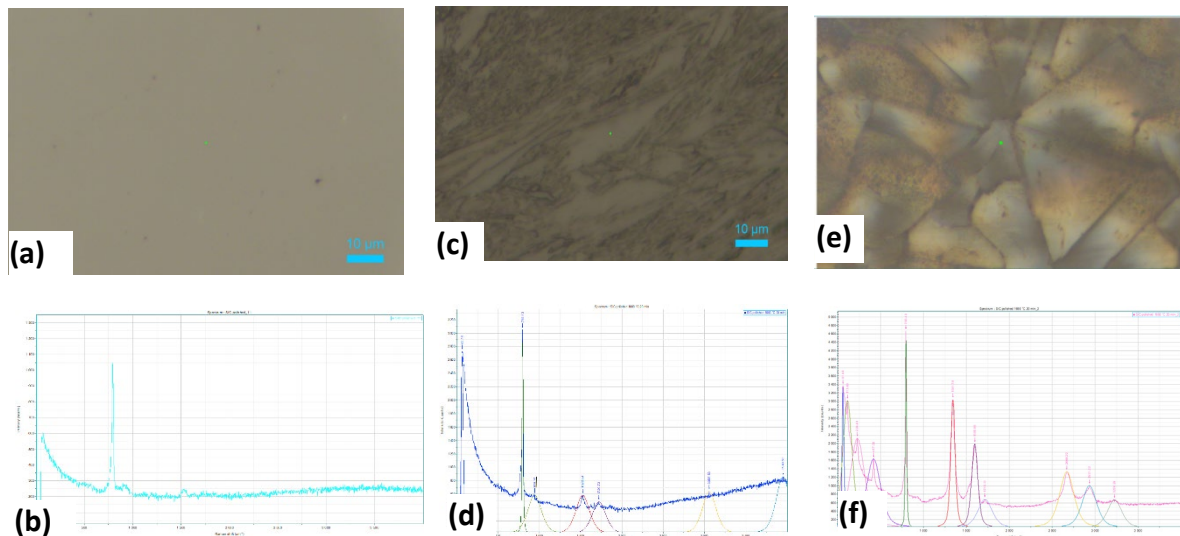


Fig. 1 Microstructures and Raman spectra of SiC sample surfaces in different surface treatment conditions. (a) and (b): as polished, (c) and (d): Treated at 1600 °C, and (e) and (f): treated at 1680 C for 40 minutes, clearly showing the graphitic D and G bands.

spark plasma sintering machine, as shown in Fig. 2. Initial trials were performed using only the C-terminated surfaces with limited success.

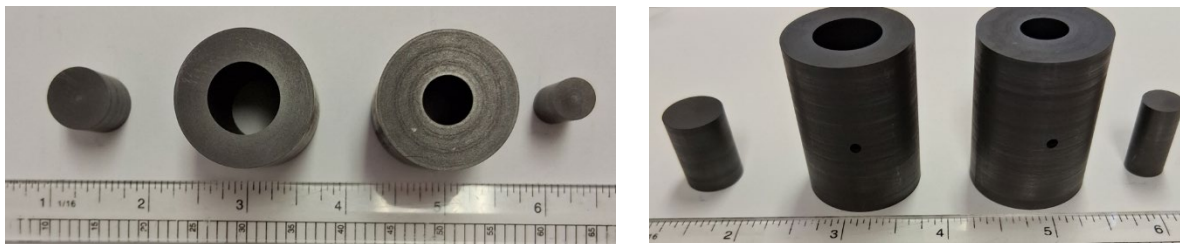


Fig. 2 Graphite punch and die sets for solid-state joining of the ceramic samples of different diameters. Top view (left) and front view (right).

Future Plans: Si-termination experiments are in progress. When both the C-terminated and Si-terminated surfaces are ready, solid-state joining experiments will be performed in September and October of 2026 at INL. The characterization of the welded joints will be performed during 10/26 – 12/26.

Section 3: Summary of budget expenditures

As of 07/10/2026, the total expenditure was \$94,674.19, and the balance was \$62,825.81. The balance includes \$32,000 committed to INL for the use of their spark-plasma sintering machine.

Section 4: Economic development/impact

We are collaborating with Astratomica LLC, a local business, on electric-field-assisted joining of SiC and ZrB₂ and NuCube Energy a nuclear reactor development company. We are writing a research grant proposals on the joining of SiC components for advanced nuclear reactor applications to be submitted to DOE-NEUP and DOE SBIR/STTR calls in collaboration with Astratomica LLC, and NuCube Energy.

Section 5: Participants

Two faculty members and two students work on this project. The students are involved in experimental tasks such as surface modification and the characterization of the surface using XRD and Raman spectroscopy. One student was trained to operate the SPS machine at CAES.

Section 6: Long-term sustainability plan

We will continue our collaboration with the two local companies mentioned in the earlier section and work with other companies, including Aalo Atomics and Studsvik Scandpower, Inc. We submitted a pre-application for a research grant to DOE-NEUP, but unfortunately, we were not invited to submit a full proposal. We believe that the promising results from this project will demonstrate proof of concept and attract additional funding from federal and private sectors. We will submit a research proposal to the NSF CMMI division in fall 2026.

Section 7: Expenditure Report

	Budgeted, \$	Spent, \$	Balance, \$	% Remaining
Salary	63,566.53	51,908.21	11,658.32	18.34
Fringe	10,193.47	9,789.90	403.57	3.96
Materials & Supplies	56,140.00	19332.08	36807.92	65.56
Tuition	27,600.00	13,644.00	13,956.00	50.57
Total	157,500.00	94,674.19	62,825.81	39.89