Research Highlight #1501

Bharat Gwalani, Ph.D.

Assistant Professor, Department of Materials Science and Engineering,
North Carolina State University

Professor Bharat Gwalani is passionate about connecting materials processing methods to resulting microstructures and mechanical properties. Gwalani has had a diverse set of experiences that he now leverages in his research as an Assistant Professor of Materials Science and Engineering at NC State University. One of his current research interests is investigating nanoscale mechanical properties of solid-phase-processed materials using the Hysitron PI 89 SEM PicoIndenter.

Foundational background in processing and microstructure

Professor Gwalani has a unique background that includes a combination of experience working in the steel manufacturing sector, a DOE national lab, and now academia. After receiving his Bachelor of Engineering degree from the National Institute of Technology in Jaipur, India in 2010, he worked in the steel industry (stainless steels then carbon-based steels) for three years. Based on his strong interest in fundamentals and first-principles knowledge, he moved to research and development was given a recommendation by management to lean further into research.

> "Both the firms I worked for, I was moved to research and development soon after joining—that was giving me a hint that I should probably go for a higher degree to learn the materials better, because I just loved that part…. I used to predict certain things from thermodynamic calculations and then go melt my own alloy, cold roll, heat treat them, and create a variety of microstructures that I liked to study. It was like cooking, just the temperatures were a little higher. And then the microscopy group during my PhD helped me to hone my skills in characterization."

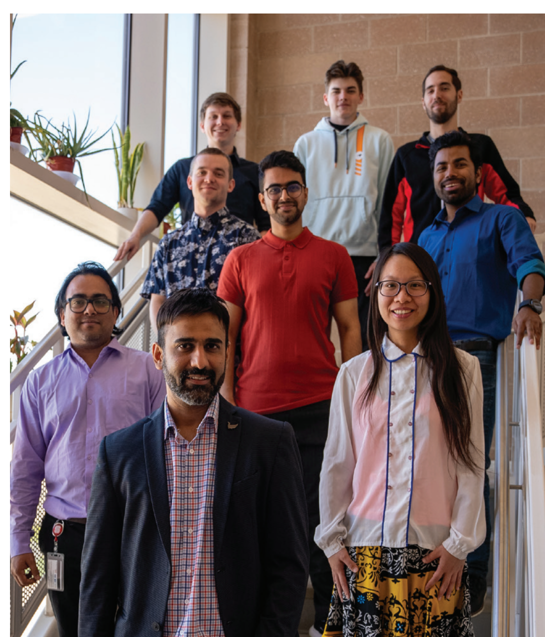
Gwalani went on to earn his PhD from the University of North Texas in 2017 with a dissertation topic on developing precipitation-strengthened high-entropy alloys. He focused on the microstructure and mechanical properties of these materials at the nanoscale. For his postdoctoral studies, Gwalani joined Pacific Northwest National Laboratory (PNNL), where his projects combined microstructural investigation with energy-conserving processing routes, namely solid phase processing along with developing in-situ characterization techniques to probe materials under extreme conditions.

ABOUT THE RESEARCH

Bharat Gwalani is an Assistant Professor of Materials Science and Engineering at North Carolina State University (NC State).

- PhD, Materials Science and Engineering, University of North Texas
- BE, Materials Science and Engineering, National Institute of Technology

Website: https://www.mse.ncsu.edu/gwalani/



Members of Gwalani's research group.

Diversity of experiences prompts innovative research plan

Gwalani's nonlinear career path brings a unique perspective to his current position as Assistant Professor. Having been on both sides of the divide, he can now effectively bridge the gap between materials processing and microstructural characterization.

> "I think all that experience helps to think in a direction that is not just processing-oriented, and not just microstructure characterization-oriented. It's bringing these two fields together, trying to understand what happens during processing that influences your properties, and bridging the gap and creating those kinds of processing environments that could be beneficial for your microstructure and property eventually."

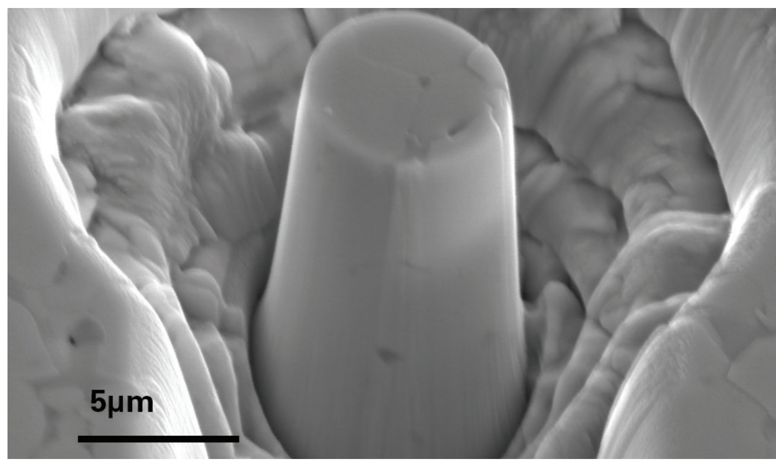
Gwalani's research group at NC State now has two main research areas: developing alloys with multifunctional properties for extreme conditions and cost-effective multi-stimuli manufacturing routes for material processing from ore to component.

Gwalani's students working with Bruker's in-situ SEM PicoIndenter.

Multifunctional structural components

Multifunctional materials are often sensitive to melting and can lose their functional properties when heated to the liquid phase or other harsh processing conditions. Gwalani is using solid-phase processing to avoid melting these materials when embedding them into structural components. For example, he can use site-specific alloying to add magnetic particles or carbon nanotubes into a load-bearing part to improve its local magnetic or conductive properties, respectively.

> "Because a lot of magnets require structural properties. Now they can be functionally strong and structurally strong."

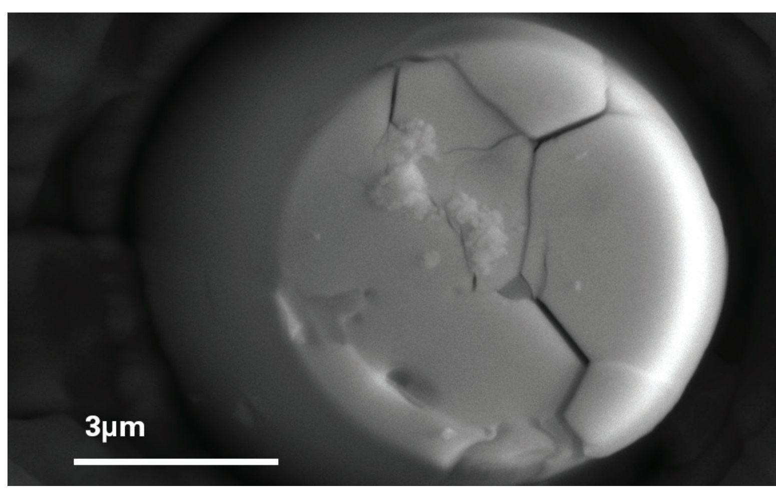


Micropillar for compression testing of high-entropy carbide materials.

High-temperature, high-strength alloys

Typical alloy development uses conventional equilibrium processing, melting together the desired components and precipitating out phases as the system goes toward equilibrium. To decrease the energy input, Gwalani and his group are using non-equilibrium processing (friction stir processing) to embed desired materials, such as oxide dispersion particles, in aluminum or steels.

> "And so, that allows us to create high temperature properties in conventionally softer and lower temperature alloys."



Top-down SEM micrograph of micropillar after compression.

Multi-stimuli integration in alloy design

Typically, in alloy design and manufacturing, thermal activation, mechanical, and chemical stresses are applied separately to extract material in purer states and modify the microstructures, often resulting in states that may be an inefficient utilization of precious metallic ingredients. Gwalani's research aims to integrate multiple-stimuli approaches to create composite materials and alloys targeting sustainable and frugal manufacturing routes.

The PicoIndenter's role

For Gwalani’s work, the Hysitron PI 89 SEM PicoIndenter with cryogenic- and high-temperature capabilities, enables material testing from -130 °C to 1000 °C, has two primary benefits: enabling in-situ mechanical behavior studies, and adding an element of temperature variation. Small-scale evaluation is valuable for multifunctional structure components because the site-specific alloying only affects small volumes, not the bulk. For high-temperature, high-strength alloys, small amounts of each alloy to be tested can be manufactured and evaluated at high temperatures using the PI 89 heating stage.

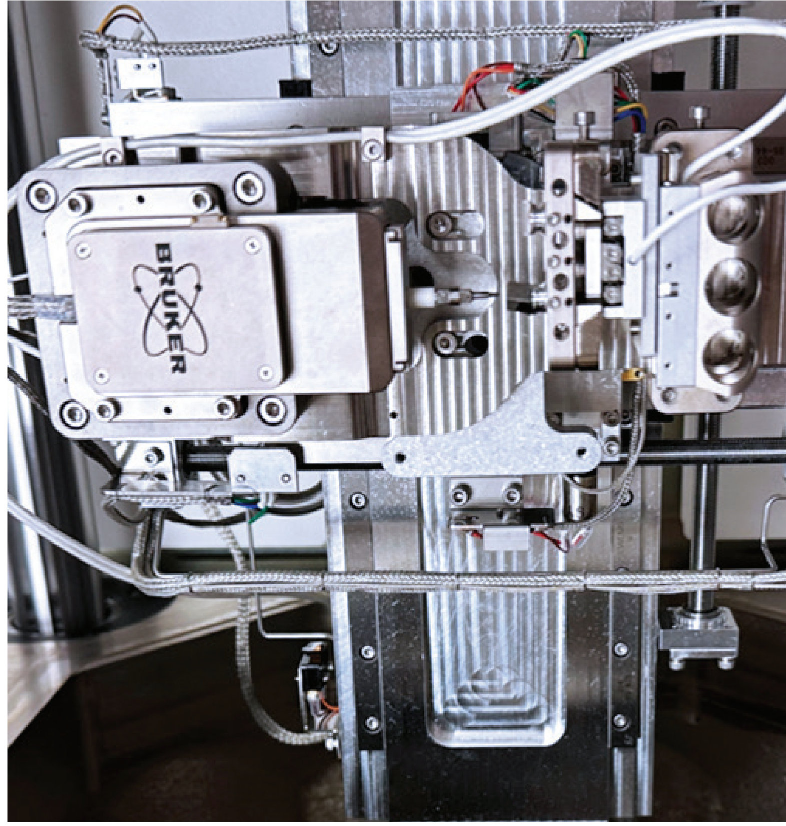
Spotlight on collaboration

In support of and beyond his current research, Gwalani has a passion for collaboration. His varied background has given him insight into different research institutions and industries, which helps him to see the path toward broader collaboration.

> “I can reach out to the right person, and I know how their environment works. My personal experience helps a lot in at least initiating the conversation with industry about research.”

He encourages other early career professionals to look beyond their own labs and imagine what could be possible through shared research efforts. Particularly related to nanomechanical testing and PI 89, he challenges researchers from a broad range of fields—from geology and semiconductors to solid-state batteries and textiles—to ask: “What can mechanical testing at the micro- to nanoscale do for me?” and to seek out knowledgeable collaborators that can help find answers.

> “What are different directions that nanomechanical testing capabilities can be used and are less utilized?”



Top-down view of Gwalani's PI 89 instrument installed in the SEM.

A look ahead

Professor Bharat Gwalani is building a lab at NC State to conduct collaboration-fueled research bridging the gap between solid-state materials processing and microstructural characterization. He looks forward to using Bruker’s Hysitron PI 89 SEM PicoIndenter to advance this research by providing insight into the local structure of multifunctional structural components and high-temperature, high-strength alloys developed by his group.

Bruker Nano Surfaces and Metrology

Minneapolis, MN • USA
Phone +1.952.835.6366

productinfo@bruker.com

www.bruker.com/PicoIndenters