New Microscopes to Resolve the Science Enabling Sustainable Manufacturing

Leora E. Dresselhaus-Marais, PhD
Department of Materials Science and Engineering,
Mechanical Engineering (Courtesy), Photon Science (Term, SLAC)
Stanford University

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Abstract: Modern metals manufacturing relies on centuries-old techniques that must be revisited for environmental and resource sustainability. To reinvent metals refinement, processing, and shaping of metals at scale requires new insights to systematically connect fundamental science to process design. My group develops a “modern toolbox” of characterization and computer-vision methods to connect fundamental science to sustainable metals manufacturing. My talk will first describe our work developing time-resolved dark-field X-ray microscopy (DFXM) to directly “watch” the motion and interactions of dislocations deep inside metals over ms-fs timescales. I will show how we now use DFXM to directly measure the microscopic origins of plasticity, failure, and annealing – all essential to metals’ performance in technology. Shifting gears, I will then describe our applied work focusing on science to enable decarbonization in steelmaking. While steel is ubiquitous in modern society, its refinement currently contributes 8% of the global CO2 footprint annually; 64% of this emission originates from the coal-based reduction of iron ores in the first step (“ironmaking”). Using X-ray and electron microscopy and scattering, we reveal how kinetics and multiscale structural dynamics for H2-based direct iron reduction give rise to unprecedented phase transformations and sticking in the previously unexplored nanoscale particles that have always been present inside modern ironmaking reactors. Our findings open a new direction for the ironmaking community showing the importance of establishing multiscale models to optimize new reactor design and performance. Our science and new approaches to studying dislocations, metals separations, and processing offer key opportunities to redesign and advance sustainable manufacturing approaches required across industry.

Bio: Leora is an Assistant Professor in the Department of Materials Science & Engineering, with a courtesy appointment in Mechanical Engineering, and a term appointment in Photon Science at the SLAC National Accelerator Lab. Leora studies how modern methods can enable new opportunities to update “old-school” materials processing and manufacturing for sustainability. This includes designing new microscopes with computer-vision methods to quantify them, and using these new tools to get a deeper view into the extraction, forming, and functional properties of metallic materials. Leora’s group works on thrusts in sustainable steelmaking (specifically ironmaking), metal 3D printing, and studies of the fundamental mechanisms underlying properties in materials. For her work, Leora has been recognized as a Precourt Center Fellow, a Gabilan Fellow, and was selected for a Young Investigator Research Program Award from the Air Force Office of Scientific Research in 2023. Before joining Stanford, Leora was a Lawrence Fellow in the Physics Division of Lawrence Livermore National Labs, studying shock waves and high-temperature metallurgy. Leora did her PhD in Physical Chemistry with Prof. Keith Nelson at the Massachusetts Institute of Technology and got her Bachelor of Arts and Master’s of Science both in Chemistry at the University of Pennsylvania.