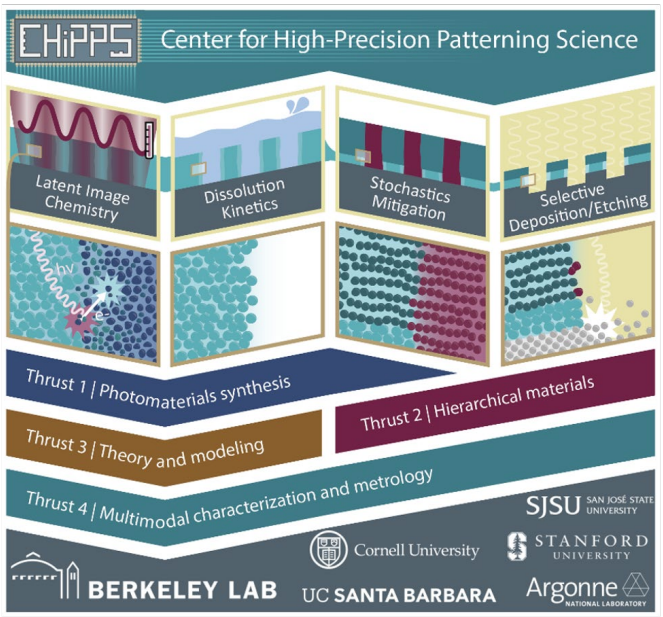
Center for High Precision Patterning Science (CHiPPS)
EFRC Director: Ricardo Ruiz
Lead Institution: Lawrence Berkeley National Laboratory
Class: 2022 – 2026

Mission Statement*: To create new fundamental understanding and control of patterning materials and processes for energy-efficient, large-area patterning with atomic precision, thereby enabling at-scale advanced manufacturing of future generation microelectronics such as quantum and spin-based memory, storage, and logic devices.*

Microelectronics is arguably the single, most critical example of advanced manufacturing, representing a $526B/year economic engine that today drives every sector in the global economy, making it essential to the U.S. economy, and its physical and energy security. Continued scaling of at-scale advanced microelectronics manufacturing to the realm of atomic scale precision is critical to realizing the potential of future generation microelectronics such as quantum and spin-based memory, storage, and logic devices that will in turn enable transformative compute capabilities, while minimizing compute center carbon footprints.



It is evident that continued progress in microelectronics, as well as maintaining U.S. advanced manufacturing leadership, is predicated on future advancements in patterning methods and materials. Even new future technologies that are less dependent on two-dimensional scaling, such as quantum computing and spin-based systems, are also patterning constrained because achieving their promise requires patterning precision well beyond the limitations of current methods and materials.

CHiPPS pursues its holistic approach to patterning science by studying the fundamentals of relevant interactions of light and matter and proposing co-designed materials for precision patterning from monodisperse or sequence defined resists to molecular-level control of solvation steps to bottom-up hierarchical and functionalized materials for low-impact stochastics to molecularly precise and selective pattern transfer. Our research comprises four highly integrated thrusts to meet the Mission CHiPPS:

1. **Thrust 1. Patterning Materials.**
   This thrust is focused on the design and synthesis of top-down radiation sensitive materials with precise architectures to control reaction fronts and stochastic variation in chemical patterning at sub-nm length scales.
2. **Thrust 2. Bottom-up hierarchical materials and processes.**
   Thrust 2 further integrates bottom-up hierarchical materials and processes with Thrust 1 materials to *heal* the adverse stochastic effects on the photoresists and to enable pattern transfer methods with atomic or molecular precision. Thrusts 1 and 2 are tightly integrated and

coordinated within CHiPPS, enabling co-design of top-down and bottom-up materials and processes.

3. **Thrust 3. Theory and Modeling.**
   Thrust 3 develops fundamental understanding of the chemical reactions involved in pattern formation. It informs Thrust 1 by implementing quantitative theory and modeling for rational design of patterning materials and performs experimental validation with Thrust 4.
4. **Thrust 4. Multimodal Characterization.**
   The cross-cutting Thrust 4 develops unique operando characterization, providing critical feedback and validation of design rules for Thrusts 1 and 2 as well as validating Thrust 3 theory. Thrust 4 will include at-scale advanced manufacturing relevant characterization by leveraging the world's most advanced EUV patterning facility built at the Advanced Light Source.

Center for High Precision Patterning Science (CHiPPS)	
Lawrence Berkeley National Laboratory	Samuel Blau, Weilun Chao, Brett Helms, Frances Houle, Oleg Kostko, Ricardo Ruiz (Director), Bruno La Fontaine (Deputy Director), Cheng Wang
Argonne National Laboratory	Paul Nealey
Cornell University	Christopher Ober
San Jose State University	Dahyun Oh
Stanford University	Stacey Bent
University of California, Santa Barbara	Rachel Segalman

Contact: Ricardo Ruiz, Director, ricardo.ruiz@lbl.gov
510.495.2893, https://chipps.lbl.gov