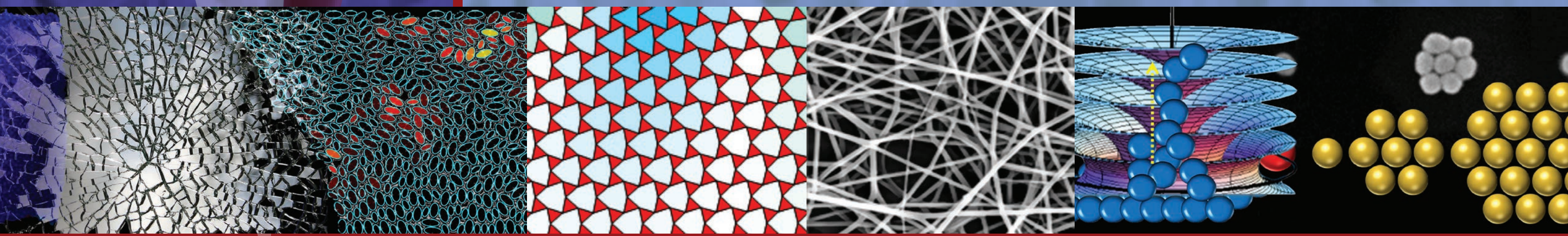
THE LABORATORY FOR RESEARCH ON THE STRUCTURE OF MATTER

University of Pennsylvania

Rearrangements & Softness in Disordered Solids
Structural Chemo-Mechanics of Fibrous Networks
Pluperfect Nanocrystal Architectures

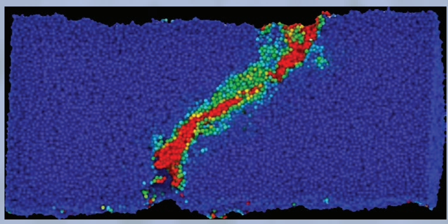


LRSM

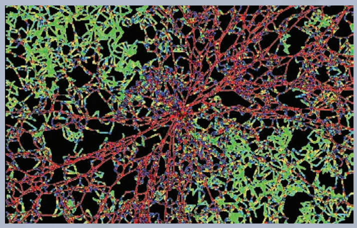
The Laboratory for Research on the Structure of Matter (LRSM) at the University of Pennsylvania (Penn) is host to the NSF Materials Research Science & Engineering Center (MRSEC).

The LRSM MRSEC research program centers on three Interdisciplinary Research Groups (IRGs) that employ a multi-disciplinary approach integrating design, synthesis, characterization, theory, and modeling of materials to solve fundamental problems likely to underlie applications of future technologies, and thus substantially impact the research, educational, and economic needs of society. The research is comprehensive, encompassing soft matter, hard matter, and biomaterials, and exploring systems that span from atomic glasses and nanocrystals, to liquid crystals and colloids, to polymer and biomaterial networks. Recurrent themes are networks, interfaces, assembly, design rules, local and collective interactions, controlled response, and the goal to create and understand advanced materials with unique properties and applications.

IRG1 **Rearrangements & Softness in Disordered Solids** aims to develop fundamental understanding of the organization and proliferation of localized particle-scale rearrangements in disordered solids deformed just beyond the onset of yield, and thereby identify strategies for controlling nonlinear mechanical response and enhancing toughness. The materials studied by the team span a wide range of length scales from amorphous carbon and atomic/molecular glasses, to nanoparticles and colloids, to macroscopic bubbles and grains. When pushed beyond yield, some materials crack or shatter due to rearrangements that collect along planes, whereas others flow smoothly because rearrangement events remain separated. New theoretical concepts, some based on machine learning, will be developed to understand this dramatic difference, and these theories will be tested by atomistic simulations and experiments on systems for which it is possible to measure microstructure versus time during a large imposed deformation. Ultimately, these factors will be optimized to widen the window between yield and failure and hence to improve toughness.



IRG2 **Structural Chemo-Mechanics of Fibrous Networks** aims to develop a new field of network chemo-mechanics by understanding and harnessing the structural, chemical, and mechanical complexity inherent in fibrous networks. Fibrous networks are ubiquitous in biology but are underexplored in materials science. The team will create and characterize new fibrous materials with structural chemo-mechanical properties, and it will develop theory and models to enhance understanding of them. Specifically, we aim to synthesize materials in which spatially localized chemical reactions are controlled through management of local fibrous network structure. This local chemical control can occur by focusing applied macroscopic stress to targeted regions in the material; this phenomena enables us to concentrate or align chemical species with specific reactant and catalyst sites, and thereby alter their reaction kinetics. The group will thus lay foundations for materials with stress-reinforcing and self-renewal capabilities and materials with an expanded range of non-linear elastic responses to large multiaxial strains. The new concepts are useful for advanced fibers, adhesives, elastomers, textiles, and scaffolds for tissue repair and regeneration.



DIRECTOR: Arjun G. Yodh

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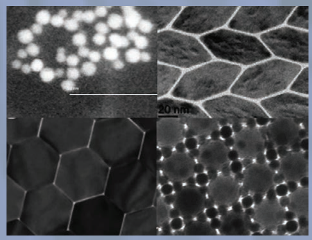
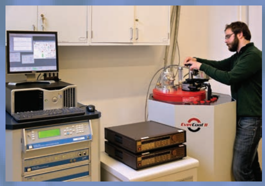
AT THE UNIVERSITY OF PENNSYLVANIA www.lrsm.upenn.edu

IRG3 **Pluperfect Nanocrystal Architectures** aims to create, characterize, and control the architectures of nanocrystal-based materials that transcend the structure and function of translationally periodic nanocrystal assemblies that have dominated the research landscape to date. In creating synthetic materials, we typically aim for perfection, preparing pure and periodic materials that are easy to model and measure. However, an opportunity exists for the self- and directed-assembly of nanocrystals that break from perfection by exploiting additional degrees of design freedom that are unavailable in atomic systems. The team will explore combinations of surface chemistry and geometrical cues that trigger and direct the formation of compositional defects, aperiodicity, and heterogeneity in nanocrystal assemblies in "hard" fabricated and "soft" liquid crystal templates. Targeted imperfection will unlock a palette of configurable and reconfigurable architectures with new functions that are not possible in traditionally "perfect" assemblies. In this way we aspire to create pluperfect nanocrystal architectures, i.e., complex, beyond-perfect, or literally "more than perfect" nanocrystal assemblies, that impart novel optical and magnetic responses.



Shared Experimental Facilities (SEFs)



Materials characterization often demands sophisticated and expensive equipment that is difficult for an individual to purchase and maintain. MRSEC resources provide the "glue" for LRSM to develop and maintain the state-of-the-art SEFs needed by IRG investigators and used by scientists from the community at-large for independent and collaborative research (including via the Materials Research Facilities Network). Every year, literally hundreds of graduate students, undergraduates, high school students and teachers, post-docs, faculty, and visiting scientists from industry, academe, and government use our MRSEC-supported SEFs with capabilities that include X-ray scattering, electron & optical microscopies, transport, spectroscopy, rheology and more. For more information see: www.lrsm.upenn.edu/facilities/

OUTREACH

The LRSM-MRSEC utilizes its cutting-edge interdisciplinary research communities to host programs that target all ages, with emphasis on underrepresented minorities and women. K-12 students are engaged through multiple programs, including an intensive four-week-long materials-based summer camp for high school students and a week-long camp for hearing impaired and low income middle school students. High school teachers and college undergraduates spend their summers working in MRSEC-affiliated research labs getting hands-on experience. A partnership with the University of Puerto Rico has led to programs for all ages and bidirectional impactful visits between our sites by high school students, undergraduates, staff, and faculty. Finally, *Science Cafés* attract and educate the general public about materials research. Through these myriad programs, LRSM-associated faculty, staff, and students widen the STEM pipeline by enriching participants' knowledge and appreciation of the materials science and engineering. For more information on these outreach programs, or to get involved, contact **Mark Licurse**, Director of Education (mlicurse@lrsm.upenn.edu).

More information about the outreach at the LRSM, Penn's MRSEC, can be found at: www.lrsm.upenn.edu/outreach/

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