Materials Science & Engineering

seminar

Disordered Hyperuniform Materials: New States of Amorphous Matter

April 22, 2016 at 1:30pm in SCOB 101

abstract

While there are four commonly observed states of matter (solid crystal, liquid, gas, and plasma), we have known for some time now that there exist many other forms of matter. For example, both quasicrystals and liquid crystals are states of matter that possess properties that are intermediate between those of crystals and conventional liquids. The focus of my talk will be disordered hyperuniform many-body systems, which can be regarded to be new states of disordered matter in that they behave more like crystals or quasicrystals in the manner in which they suppress large-scale density fluctuations, and yet are also like liquids and glasses because they are statistically isotropic structures with no Bragg peaks. Thus, disordered hyperuniform systems can be regarded to possess a "hidden order" that is not apparent on short length scales, while being structurally rotationally invariant. I will describe a variety of different examples of such disordered states of matter that arise in physics, materials science, mathematics and biology. Among other results, I will describe classical ground states that are disordered, hyperuniform and highly degenerate over a wide range of densities up to some critical density, below which the system undergoes a phase transition to ordered states. Disordered hyperuniform systems appear to be endowed with novel physical properties, including complete photonic band gaps comparable in size to those in photonic crystals and improved electronic band-gap properties. Moreover, we have recently shown that photoreceptor cell patterns (responsible for detecting light) in avian retina have evolved to be disordered and hyperuniform.

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biosketch

Salvatore Torquato is a Professor in Chemistry and the Princeton Institute for the Science and Technology of Materials. He is also affiliated with three other departments: Physics, Applied and Computational Mathematics, and Mechanical and Aerospace Engineering. He has been a Senior Faculty Fellow in the Princeton Center for Theoretical Science. Torquato's research work in theoretical physics is centered in statistical mechanics and soft condensed matter theory. A common theme of his research is the search for unifying and rigorous principles to elucidate a broad range of physical phenomena. His current work focuses on self-assembly theory, disordered and ordered particle packings, liquids, glasses, quasicrystals, crystals, optimal multifunctional material design, random media, and cancer modeling. He has published over 370 journal refereed articles and a book entitled "Random Heterogeneous Materials." Among other awards and honors, he is a Fellow of the American Physical Society (APS), Society for Industrial and Applied Mathematics (SIAM) and American Society of Mechanical Engineers (ASME). He has been the recipient of the APS David Adler Lectureship Award in Material Physics, SIAM Ralph E. Kleinman Prize, Society of Engineering Science William Prager Medal and ASME Richards Memorial Award. He was a Guggenheim Fellow and was thrice a Member of the Institute for Advanced Study. He recently received a Simons Foundation Fellowship in Theoretical Physics.