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Physics

Special Topic: Glasses—Materials and Physics

Preface: physics of disorder, non-equilibrium and non-linearity

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Amorphous materials, as indicated by the name, lack long-range crystalline order in their atomic arrangements. Amorphous materials are ubiquitous in nature and our daily life; examples include glasses, colloidal suspensions, granular matter, polymers, active matter and various biomaterials. However, our understanding of such systems lags significantly behind their ordered, crystalline counterparts. As a consequence, the study of amorphous materials is emerging as an exciting branch of modern physics. The essence of research in this field is evidenced by two recent events: the receipt of the 2021 Nobel Prize in physics by Giorgio Parisi for his groundbreaking contributions to the theory of disordered systems, in particular, spin glasses, and the celebration of the year 2022 as the *International Year of Glass* by United Nations.

Here we organize a special topic on “Glasses—Materials and Physics”, which includes five articles covering the following three subjects: (i) the search for “hidden order” in disordered structures, (ii) the understanding of non-equilibrium phase transitions, and (iii) the description of non-linear, stochastic responses.

Despite the absence of long-range order, amorphous solids can have certain short-range and medium-range order, which is often invisible using standard crystallographic techniques. A direct way to identify the hidden order is by analyzing atomic arrangement—information challenging to obtain in experiments. In a review [1], Xie *et al*. summarize the latest techniques for characterizing three-dimensional atomic structures of amorphous solids, highlighting the state-of-art atomic resolution electron tomography method. The advance in methodology provides a promising opportunity to deepen our understanding of the structure of amorphous solids at the atomic level.

A liquid turns into a crystal via a first-order equilibrium phase transition, e.g., water freezing into crystalline ice. If the liquid is cooled fast enough to avoid crystallization, it falls out of equilibrium and becomes a glass, a procedure known as the liquid-to-glass transition. The non-equilibrium liquid-to-glass transition can have a complex connection to equilibrium phase transitions. Certain glass formers, including several molecular liquids and metallic melts, display an equilibrium liquid-to-liquid transition. Vitrifying the second

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liquid produces a novel type of glass, called "glacial glass". In a review [2], Shen *et al*. discuss the history, kinetic behavior and other properties of metallic glacial glasses. The reverse procedure of crystallization, i.e., the melting of a crystal into a liquid, can also be replaced by a non-equilibrium transition, called crystal-to-glass transition. In a research article [3], Chen *et al*. report a compression-induced crystal-to-glass transition in a glass consisting of poly-disperse soft colloidal particles; different from melting, which is caused by the diffusion of defects, the crystal-to-glass transition is related to the nucleation of the disordered phase.

The mechanical response of crystalline solids to small external forces (e.g., shear) is elastic. In amorphous materials, this linear response picture generally breaks down, due to stochastic plastic events, or "avalanches". At larger deformations, the solid phase is terminated by yielding, beyond which the material breaks or begins to flow. In a research article [4], Peng *et al*. study the avalanche statistics of dry granular materials in a rotating drum; the results could be relevant to understanding realistic granular avalanches in nature, e.g., landslides and earthquakes. In another research article [5], Xu *et al*. study the dependence of the yield stress on the grain diameter and the grain boundary thickness in simulated two-dimensional glass-crystal composites, generalizing the Hall-Petch and inverse Hall-Petch effects previously observed in poly-crystals.

We are grateful to all the authors, and sincerely hope that their work will motivate and inspire future breakthroughs in the field. We appreciate the reviewers, editorial board members, and *National Science Open*'s production staff for their contributions to ensuring the high standards of the publications.

Conflict of interest

The authors declare no conflict of interest.

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