SFB 767 Colloquium

Universität Konstanz

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Coffee and tea 15:15
Talk 15:30
P 603

When do solids flow?

It is widely believed that flow in a solid can be only induced via the application of a finite stress. As a consequence, in the limit of zero strain rate, the steady-state stress of a deformed solid would not go to zero as in a Newtonian fluid, but it would approach a finite value (the yield stress). This would imply that under the application of an infinitesimal stress the solid is in a rigid, non-flowing state. However, fundamental arguments [1,2] show that the appearance of a rigid solid is a kinetic phenomenon, associated with finite time scales. If one waits sufficiently long, any solid would eventually flow as a response to an infinitesimal stress.
We present a framework [3] in which rigid crystalline solids are possible. The key to such states is an external field h that is conjugate to a variable X, which is associated with non-affine displacements with respect to a reference state. Using Monte-Carlo simulation techniques, we are able to study a two-dimensional Lennard-Jones crystal in the limit of zero strain rate. For finite negative h fields we observe a line of first-order phase transitions where a deformed rigid crystal coexists with a stress-free crystal (here, the variable X acts as an order parameter). This line ends at $h = 0$ and zero strain where we also find a first-order transition. In the latter case, a crystal is transformed into a crystal with an identical structure [3]. For any finite strain rates at $h = 0$, one observes kinetic decay processes of the metastable rigid crystal into a stress-free solid. We study these kinetic processes using molecular dynamics computer simulations. The rigidity of amorphous solids, i.e. glasses, is due to the shift of the Newtonian regime to inaccessible long time scales. In the light of our results on the crystalline solids, we critically discuss recent studies on the deformation of glasses.

[1] O. Penrose, Markov Processes Relat. Fields 8, 351 (2002). [2] F. Sausset, G. Biroli, and J. Kurchan, J. Stat. Phys. 140, 718 (2010). [3] P. Nath, S. Ganguly, J. Horbach, P. Sollich, S. Karmakar, and S. Sengupta, PNAS 115, E4322 (2018).

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