Coupled dynamical phase transitions in driven disk packings

Akash Ghosh[1], Jaikumar Radhakrishnan[2], Paul Chaikin[3], Dov Levine[4], Shankar Ghosh[1]
[1]Department of Condensed Matter Physics and Material Sciences, Tata Institute Of Fundamental Research, Mumbai, India, [2]International Centre for Theoretical Sciences, Bengaluru, India, [3]Center for Soft Matter Research and Department of Physics, New York University, United States of America, [4]Technion-IIT, Haifa, Israel

Active-absorbing phase transition has been studied in variety of models and experimentally in a system of colloids suspended in viscous medium. The transition is characterized by a critical point where long range correlations are manifested. Beyond the critical point, the system usually remains dynamic whereas below the transition, the dynamics ceases. Cessation of dynamics typically occurs when the system achieves some local goal, such as being non-overlapping or having no near neighbor. Order parameter of this transition is the fraction of particles which are active(α) between two consecutive cycles. On one side of the transition α=0, (absorbing state) whereas on the other side, α>0 (active state). In our experiment, a two dimensional assembly of monodisperse particles driven by oscillatory shear, manifests the active absorbing transition. The entire assembly is kept at an angle with respect to the gravity to ensure that the constitutive relation of stress and strain holds true. When analyzed stroboscopically, it is observed that below a critical shear amplitude (γ_c), all the disks come to its previous position(within some error bars), whereas above the transition they don't. Trajectories of the particles also become interesting in the absorbing state as they tend to follow some non-trivial loops breaking time reversal symmetry. Number of cycles required for the system to reach the steady state follows power law with divergence at γ=γ_c. Observation of such a transition in granular systems is non-intuitive in a sense that unlike the suspension of colloidal particles, granular interactions involve dry friction and also it's impossible to avoid collisions among the particles for the system to reach the quiescent state. Since the particles are of similar size, it is expected of them to form a single crystalline state in the steady state. But surprisingly, that's not what we observed. For small shear amplitudes, the particles form polycrystalline configurations with defects forming grain boundaries across the system. As the shear amplitude approaches γ_c (≈0.065), number of defects in the system starts to decrease and eventually the entire system forms a single crystalline configuration at γ_c. Isolated clusters of defects again start appearing beyond the critical point. Number of cycles required for the system to reach the state with constant defect density also shows similar power law dependence with maximum shear amplitude. Hence the two transitions are coupled to each other. Typically, the absorbing states studied theoretically or observed experimentally are disordered and hyperuniform, but our experiment exhibits an ordered crystalline configuration at the critical point. Since the system is kept under gravity, there exists a pressure gradient along the direction of gravity. Therefore, beyond the transition, only a part of the system become active. As we go more and more away from the transition, the length of the active region grows, eventually covering the entire assembly. The length scale of the active region grows linearly with γ .