Percolation analysis of nonequilibrium cluster structures formed by paramagnetic particles

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We experimentally investigate nonequilibrium cluster structures formed in a thin layer of a colloidal solution composed of 1.05 μm paramagnetic particles dispersed in water. A dc magnetic field generated with a solenoid coil and a dc power supply is applied in the direction perpendicular to the solution layer and the cluster structures formed by the particles are observed from both the top and bottom sides of the solution layer using an optical microscope. The paramagnetic particles form chain clusters along the field direction. Furthermore, the chain clusters aggregate in the lateral direction to form bent wall structures when the magnetic field is applied rapidly. As the volume fraction of particles increases, the cluster size in the direction parallel to the solution layer increases and when the volume fraction exceeds a certain value, percolation clusters, that is, clusters whose size reaches the system size, are formed. We perform digital image analysis on both top and bottom view images of the cluster structures and estimate the percolation threshold volume fraction. We show that if the thickness of the solution layer increases, the percolation threshold volume fraction decreases since the particles form longer chains, which aggregate in the lateral direction more actively.