Partially ordered systems:

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Granular materials and suspensions. — The flow rate of a granulate out of a cylindrical container was studied as a function of particle shape for flat and elongated ellipsoids experimentally and numerically. We found a nonmonotonic dependence of the flow rate on the grain aspect ratio a/b (see Figure 1). Starting from spheres the flow rate grows and has two maxima around the aspect ratios of $a/b \approx 0.6$ (lentil-like ellipsoids) and $a/b \approx 1.5$ (ricelike ellipsoids) reaching a flow rate increase of about 15% for lentils compared to spheres. For even more anisometric shapes ($a/b = 0.25$ and $a/b = 4$) the flow rate drops [1]. In another work we studied the rotation dynamics of a nonspherical particle placed in a sheared liquid in the presence of added noise in 3 dimensions. The Jeffery orbits of elongated (uniaxial, prolate) particles subject to noise were explored using Langevin simulations and a Fokker-Planck equation. We examined how the probability distribution of particle orientation changes when changing the rotation diffusion coefficient D (see figure). Various quantities (nematic ordering, biaxiality) are measured as a function of particle elongation and external noise [2].

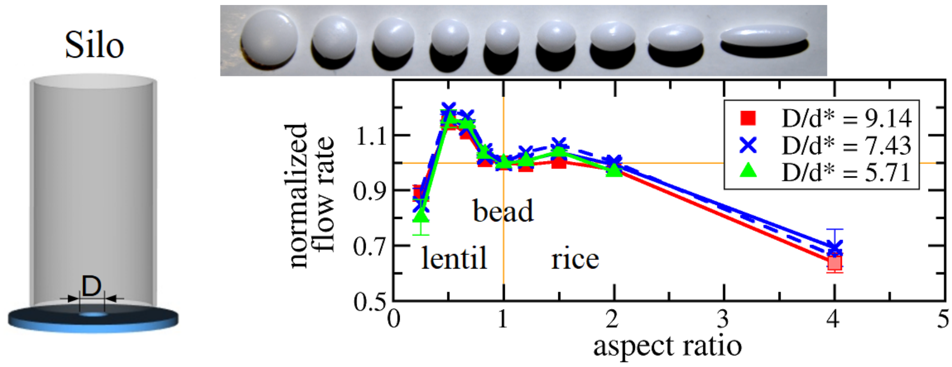

Figure 1. Silo discharge: flow rate of a granular material as a function of grain shape [1].

Electrodeposited nanostructures. — For electroplating of multiple principal element alloy layers, we developed a cell configuration that made it possible to synthesize gradient composition deposits. The asymmetric cathode arrangement led to a monotonically varying transport rate along the sample surface, which affected the local composition of the deposit. Hence, Co–Fe–Ni–Zn alloy films with local Zn content of 16-44 at.% could be produced by plating as few as 4 samples [3]. The change of the Zn content was compensated by a near-proportional change of the other alloy components, hence allowing the study of the impact of the Zn content. The deposit was of face-centered cubic structure in which the lattice constant varied linearly with the Zn content. Though the crystallite size in the entire composition range was about 18 ± 2 nm, the root-mean-square deposit surface roughness increased from 13 to 26 nm in the 16-44 at.% Zn range. Hardness value with > 4 GPa and Young modulus with values > 120 GPa prevailed between 24-44 at.% Zn content. In insensitivity of the mechanical properties to the composition is an evidence for the "coctail effect" characteristic of the multicomponent alloys. Also, the good mechanical properties irrespectively of the concentration is a prerequisite for practical applications where accurate composition of the deposit cannot be provided due to the unfavourable current distribution in the electroplating process.

Liquid crystals. - We discovered that ferroelectric nematic fluids undergo various interfacial instabilities in the presence of electric field [4]. In a specific range of frequency and voltage, the ferroelectric droplets move as active interacting particles resembling living organisms like swarming insects, microbes or microrobots (Figure 2a). The motion is accompanied by sound emission, as a consequence of piezoelectricity and electrostriction. Statistical analysis of the active particles reveals that the movement can be controlled by the applied voltage, which implies the possible application of the system in new types of microfluidic devices. We presented the first demonstration of converse piezoelectricity in 3D fluids by measuring a linear electromechanical effect in ferroelectric nematic liquid crystals [5] (Figure 2b). The observed piezoelectric coupling constant below 6 kHz electric field is larger than 1 nC/N, comparable to, or better than, values for the strongest solid piezoelectric materials. Understanding the electromechanical response of ferroelectric nematics will enable mechanical energy harvesting and open up a new avenue for developing fluid actuators, micro positioners, and electrically tunable optical lenses.

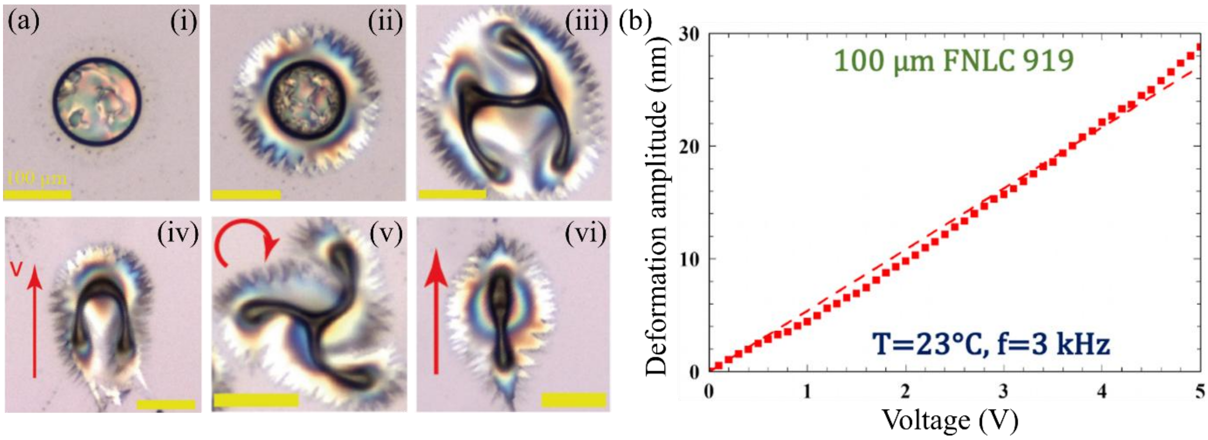

Figure 2. (a) Ferroelectric nematic droplets: basic state (i), electric field induced static ramification (ii) and labyrinth (iii) instability. Various shapes of moving droplets (iv-vi). (b) The deformation amplitude of a ferroelectric nematic fluid slab as a function of applied voltage.

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