Length-scale dependent aging and plasticity of a colloidal polycrystal under cyclic shear

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Most solids like metals and ceramics are polycrystals, i.e. aggregates of crystalline grains separated by 2D defects, the grain boundaries (GBs). Although GBs sliding is believed to be involved in the irreversible deformation (plasticity) of polycrystalline solids, the microscopic mechanisms at play are still poorly understood. We propose a colloidal analog of atomic polycrystals obtained by doping a copolymer micellar crystal with nanoparticles (NPs) [1, 2]. During the crystallization NPs are partially expelled from the lattice and segregated into the GBs allowing one to probe their structure with microscopy (fig.1) or light scattering.

We investigate plasticity in the colloidal polycrystal by using confocal microscopy (fig.2) and time-resolved light scattering performed using a novel light scattering apparatus [3] specifically designed to access the dynamics of the GBs at different q vectors. We follow the evolution of the GBs network as the sample is submitted to a large number of shear deformation cycles. The dynamics associated with plasticity are found to be ballistic (fig.3a) and to slow down until a steady state is reached after a large number of shear cycles.

Surprisingly, the cross-over time between the initial aging regime and the steady state decreases with increasing probed length scale (fig.3b), hinting at a hierarchical organization of the GBs dynamics.

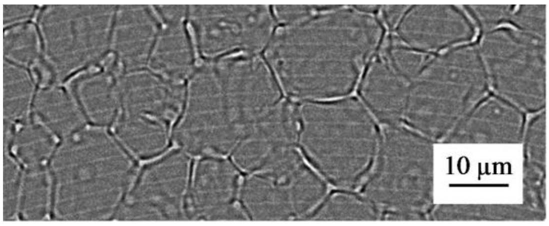

Fig.1: light microscopy image of the GB network of a colloidal polycrystal doped with nanoparticles.

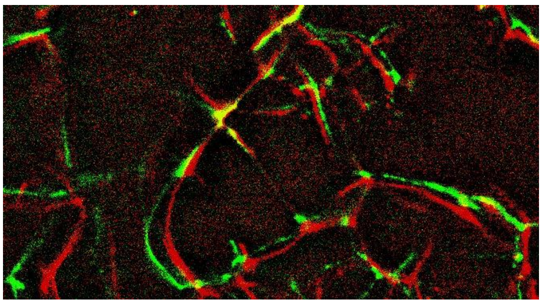

Fig.2: overlay of two confocal images of the GB network taken after 1 (red) and 2617 (green) shear cycles. The images overlap perfectly the zone highlighted by the white circle. However, in most of the field of view, the GB network does not overlap, revealing an evolution of the polycrystalline microstructure.

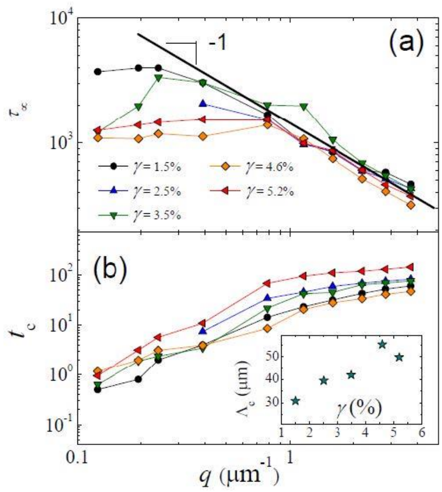

Fig3: (a) q dependence of the relaxation time of the steady state showing that the dynamics associated with plasticity is ballistic. (b) q dependence of the crossover time between the initial aging regime and the steady state. The cross-over time decreases with increasing probed length scale. Data are labelled by the strain amplitude, as indicated in the legend.

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[2] N. Ghofraniha, E. Tamborini, J. Oberdisse, L. Cipelletti, and L. Ramos, Soft Matter 8, 6214 (2012)
[3] E. Tamborini, and L. Cipelletti, Rev. Sci. Inst. 83, 093106 (2012)