Plastic Flow in Two-Dimensional Solids

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Part 1

A time-dependent Ginzburg-Landau model of plastic deformation in two-dimensional solids is presented. The fundamental dynamic variables are the displacement field $\boldsymbol{u}$ and the lattice velocity $\boldsymbol{v} = \partial \boldsymbol{u}/\partial t$. Damping is assumed to arise from the shear viscosity in the momentum equation. The elastic energy density is a periodic function of the shear and tetragonal strains, which enables formation of slips at large strains. In this work we neglect defects such as vacancies, interstitials, or grain boundaries. The simplest slip consists of two edge dislocations with opposite Burgers vectors. The formation energy of a slip is minimized if its orientation is parallel or perpendicular to the flow in simple shear deformation and if it makes angles of $\pm\pi/4$ with respect to the stretched direction in uniaxial stretching. High-density dislocations produced in plastic flow do not disappear even if the flow is stopped. Thus large applied strains give rise to metastable, structurally disordered states. We divide the elastic energy into an elastic part due to affine deformation and a defect part. The latter represents degree of disorder and is nearly constant in plastic flow under cyclic straining.@ In Figs.1 and 2 we show elastic deformations in shear and uniaxial stretching.

Part 2

We try to consider glassy dynamics by extending the nonlinear strain model mentioned above.

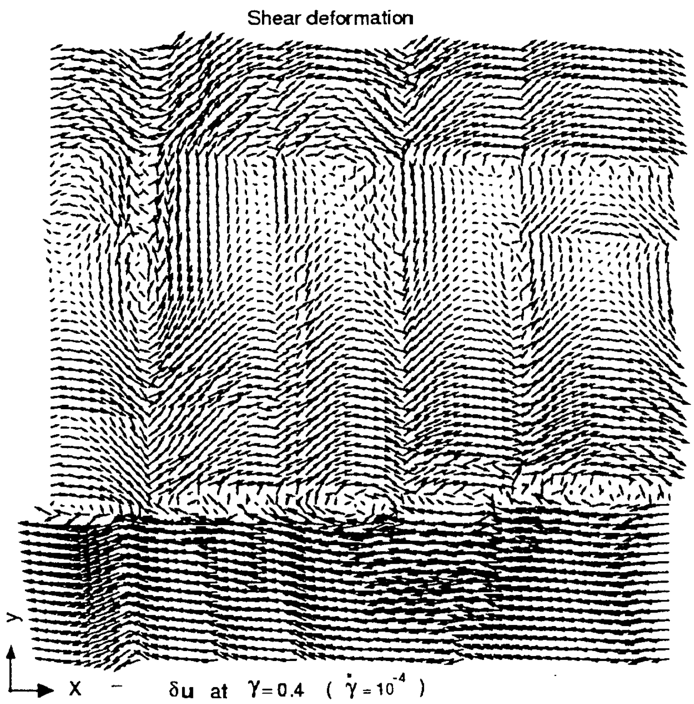

FIG. 1: The displacement deviation $\delta\boldsymbol{u} = \boldsymbol{u} - (\gamma y, 0)$ in the plastic flow regime under shear strain at $\gamma = 0.4$ with $\dot{\gamma} = 10^{-4}$. A 1/4 region (64×64) of the total system is shown. The arrows are from the original position at $t = 0$ in a perfect crystal to the displaced position in plastic flow.

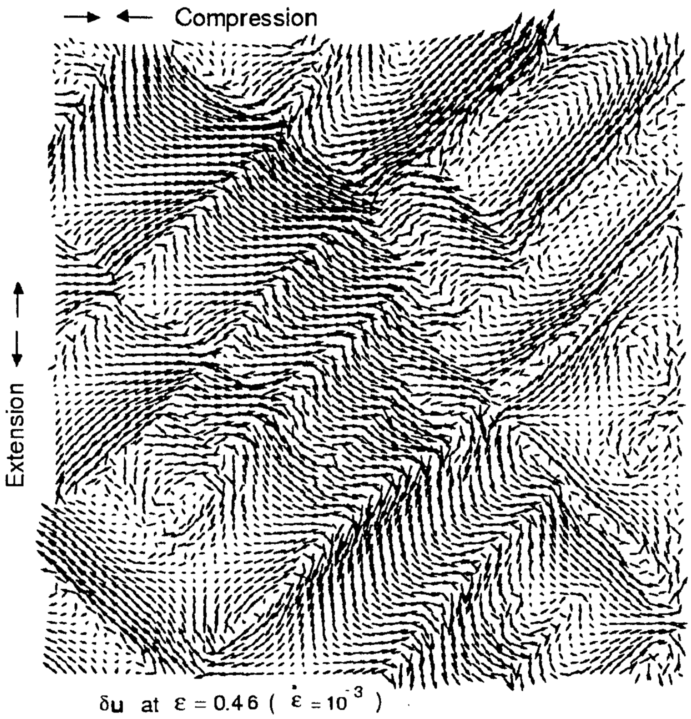

FIG. 2: The displacement deviation $\delta \boldsymbol{u} = \boldsymbol{u} - (\epsilon x/2, -\epsilon y/2)$ in the plastic flow regime under uniaxial stretching at $\epsilon = 0.46$ with $\epsilon = 10^{-3}$. A 1/4 region (64×64) of the total system is shown. The arrows are from the original position at $t = 0$ in a perfect crystal to the displaced position in plastic flow.