Bull. Mater. Sci., Vol. 10, Nos 1 & 2, March 1988, pp. 75–76. © Printed in India.

The nature of dislocation motion in quasicrystals

SRIRAM RAMASWAMY
Department of Physics, Indian Institute of Science, Bangalore 560 012, India.

Abstract. Calculations in a hydrodynamic model of quasicrystal dynamics show that dislocation motion in these systems is impeded by a drag far greater than that in crystals.

Keywords. Dislocation motion; quasicrystal.

This work was done while the author was at the University of Pennsylvania. The details are already in print (Lubensky *et al* 1985, 1986; see also Levine *et al* 1985). Only a brief summary will be given here.

Our approach to the problem consisted of three steps. First, we answered the question, "what is a quasicrystal dislocation?". Next we derived the equations of hydrodynamics for the long-wavelength, low-frequency excitations of a quasicrystal. And finally we used these equations along with the definition of a dislocation to understand the processes involved in moving a dislocation through a quasicrystal. The conclusion of this study was that—as an inevitable consequence of the absence of *periodic* crystalline order—a dislocation moving in *any* direction in a quasicrystal feels a drag force of the same order of magnitude as that felt by a dislocation moving in a *climb* direction in a conventional *periodic* crystal. This effectively rules out plastic deformation: quasicrystals, even if nearly perfect, should be exceedingly brittle. We present qualitative arguments to make our results plausible. The detailed derivation is given in Lubensky *et al* (1986). The techniques used are those of Dubois-Violette *et al* (1983).

The crucial difference between a three-dimensional crystal and an icosahedral quasicrystal, for our purposes, is that since the reciprocal lattice of the latter has six basis vectors, its elastic theory and long wavelength dynamics involve *six* broken-symmetry variables: a three-component "phonon" displacement field u, as in a crystal, and another three-component field w, called a "phason". The phason variables describe internal rearrangements, and thus, even at zero wave-vector, involve relative motion of atoms. They are thus diffusive, with a diffusion constant of the same order as that for vacancies (about 10^{-11} cm^2/sec), which means they relax exceedingly slowly. Dislocations are defined by a natural generalization of their definition in crystals. However, the quasiperiodic nature of the system also forces every dislocation to have a u-part and a w-part (if it had only a u-part, a simple analysis of a Burgers circuit would show that the system must be periodic). Thus, a moving dislocation must drag along a slow and unresponsive w-field. It is precisely as if the dislocation were always moving in a climb direction, since its motion requires the constant rearrangement of matter far from the core. It should therefore be no surprise that the mobility of a dislocation in these materials turns out to be

$$M_q \sim D/Ka^2 \sim (10^8 \text{poise})^{-1},$$

where D is a phason diffusion constant (of order vacancy diffusion constants in crystals), K is an elastic constant, and a is a unit cell size. By contrast, the mobility for *glide* in *periodic* crystals is

$$M_c \sim \eta^{-1} \sim (1 \text{ poise})^{-1},$$

where η is a "crystal viscosity", i.e. a sound damping coefficient.

The main consequence of this, as discussed earlier, is that plastic deformation should be practically impossible. It also probably means that the process of annealing out phason and dislocation strains in quasicrystals should be very slow, and that therefore even *large* single grains should have short translational correlation lengths. This seems to be in accord with recent experiments (Horn *et al* 1987).

References

Dubois-Violette E, Guazzelli E and Prost J 1983 *Philos. Mag.* **A48** 727

Horn P M, Heiney P A, Bancel P A, Gayle F W, Jordan J L, LaPlaca S and Angilello J 1987 *Science* (to appear)

Levine D, Lubensky T C, Ostlund S, Ramaswamy S, Steinhardt P J and Toner J 1985 *Phys. Rev. Lett.* **54** 1520

Lubensky T C, Ramaswamy S and Toner J 1985 *Phys. Rev.* **B32** 7444

Lubensky T C, Ramaswamy S and Toner J 1986 *Phys. Rev.* **B33** 7715