From transrotational microcrystals and nanostructures to novel amorphous models

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Exotic thin crystals with unexpected transrotational nanostructures [1] have been discovered by transmission electron microscopy (TEM) for crystal growth in thin (10-100 nm) amorphous films of different chemical nature (oxides, chalcogenides, metals and alloys) prepared by various methods. Primarily we use TEM bend-contour method [2] combined with selected area electron diffraction, bright and dark fields. HREM, AFM and optical microinterferometry were used in due cases preferentially as correlative microscopy.

The unusual phenomenon for some samples can be traced in situ in TEM column (during e-beam illumination): regular (dislocation independent) internal bending of crystal lattice planes in a growing crystal. It can take place also as result of annealing or aging. Such transrotation (translation of the unit cell is complicated by small rotation realized round an axis lying in the film plane) can result in strong regular lattice orientation gradients (up to 300 degrees per 1 μm) of different geometries: cylindrical, ellipsoidal, toroidal, saddle, etc. The geometry and the magnitude of transrotation depends upon the substance, film preparation and crystallization conditions, orientation of the crystal nucleus, presence of the sublayers, composition and film thickness. Transrotation is strongly increasing as the film gets thinner. Transrotational crystal nucleus (or local area of larger microcrystal) resembles ideal single crystal enclosed in a curved space [3]. Some transrotational crystal types have bending of atom/lattice planes similar (but much lower) to that of nanotubes, e.g. for Se, Fig. 1a. Complex skyrmion-like lattice orientation texture is revealed in some spherulite transrotational crystals, e.g. for Fe O , Fig.1c. Atomistic model (based on mathematical instrument of conformal transformations) for the atom positions in transrotational “single crystal” and possible mechanisms of the phenomenon are discussed, Fig. 1b. Transrotational micro crystals have been eventually recognized by different authors in some thin film materials vital in applications, i.e. phase change materials (PCM) for memory (DVD RW, RAM), silicides for microelectronics, ferroelectrics.

Transrotational microcrystals show us the unusual ways of atom packing in low-dimensional areas with curved “crystal” planes. On this base, we propose new hypothetical nanocrystalline models of amorphous state: fine-grained structures with lattice curvature (like transrotation) in grains schematically show at Fig.1d (yellow, 2 slightly changed models). Thus, in the static model the great variety of different transrotational lattice geometries inside fine crystal grains (e.g., complying with different kinds of conformal transformations of normal lattice described mathematically for 2D case) with diverse statistics corresponds to different amorphous structures. Such structures, hardly distinguished by usual methods, inevitably carry some distinct physical properties. Going further to crystalline like 3D clusters of positive and negative curvature and dynamics we propose the hypothesis of “dilatons”, “contractons” and their combinations moving and/or breathing in amorphous state (at least for evaporated amorphous films). Similar features may be also appropriate for glass/liquid.

Fig. 1. Transrotational microcrystals: TEM for Se (a) and Fe O (c), crystal growth model (b) and novel amorphous model (d).

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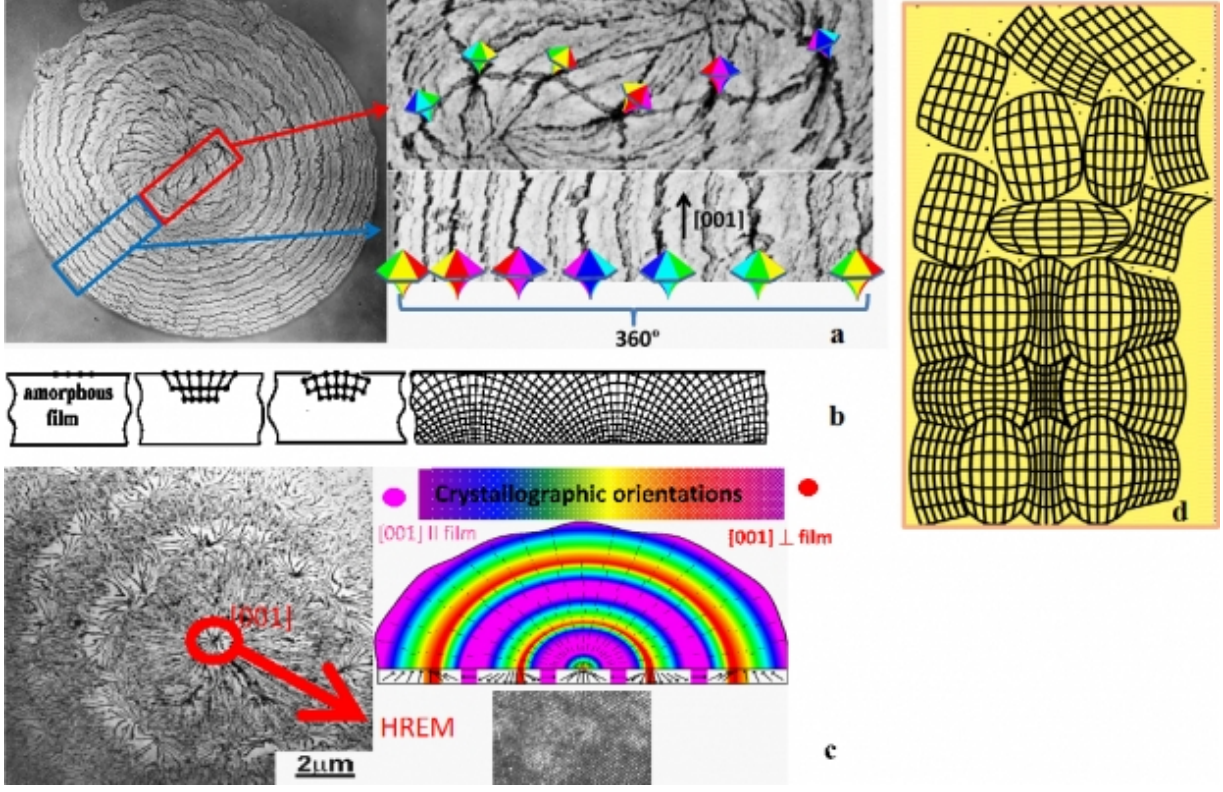

Keywords: novel crystals in thin films, transmission diffraction electron microscopy, amorphous structure and transformations