TEM of Crystallizing Amorphous Films: Novel *"Transrotational"* Structure on the Scale Micro – Meso – Nano

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Keywords: novel microstructure, amorphous films, crystal growth

In recent 20 years the growing interest has been observed to the studies, preparation and application of unusual (for condensed matter physics) structures: quasi-crystals, fullerenes, nanotubes and derivatives thereof. In this paper we present our TEM findings for other less known unusual crystal-like aggregates: "transrotational" crystals with regular internal lattice bending observed in films of different chemical nature (chalcogenides, chalcogenide compounds, Ge-based compounds, several metals and alloys, some other substances), produced by various methods (thermal, e-beam and laser evaporation, solid state amorphization, pyrolysis). The main data are obtained by TEM, primarily bend-contour method [1] involving SAD, *in situ* studies, and HREM (EDX, EELS, CBED used in due cases). Some microinterferometry and AFM was also performed.

Unusual **"transrotational"** atom ordering (translation accompanied by small rotation, see fig. 7b [2]) results in strong (up to 200° per μm) regular, dislocation independent **internal bending of the crystal lattice planes** during crystal growth (in the range 10^{-2} - 10^{3} μm/s) in amorphous film, figure 1 (substances are indicated). It takes place mainly around the axes lying in the film plane and corresponds to strong elastic deformations (peaks 2-4% in the surface layers, possible values for thin perfect crystals).

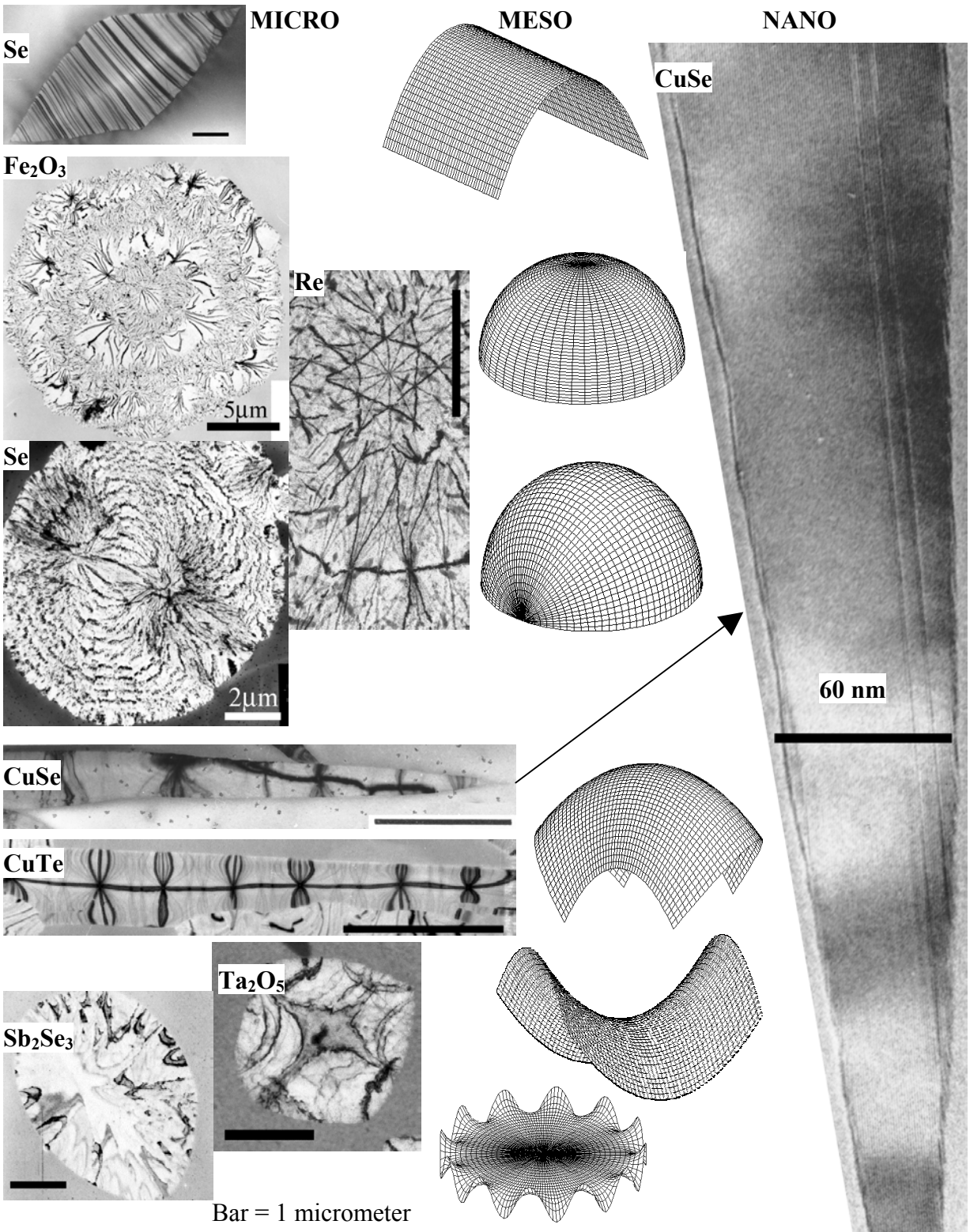
The geometry (cylindrical, ellipsoidal, toroidal, saddle-like, etc., Figure 2) and the magnitude of lattice bending ("transrotation") depend upon the substance, film preparation and crystallization conditions, orientation of the crystal nucleus and lattice symmetry, sublayers, composition and film thickness.

HREM proves that none of traditional imperfections or amorphous inclusions can be observed in the nucleation center, other single crystal areas and amorphous-crystalline interface at the front of a growing transrotational crystal, Figure 3. Regular decrease of the HREM contrast for atomic rows as the film gets thinner corresponds to our earlier model.

The most distinctive features of the structure appear at the meso scale (100-1000 nm) where strong regular rotation of the lattice is attained. At the nano scale and at the micro scale it is often difficult (for lattice bending around and above 60° per μm) to distinguish such structure by TEM from the normal deformed lattice (misorientations are too small) and fine-grained textured structure (disorientations are too large) accordingly.

Concluding and methodological remarks, based on the above studies [3]:
- new solid state order in thin films is revealed and studied by TEM bend contour technique;
- bend contour pattern, being a diffraction information written over the image of a specimen, is in fact a topography map of crystal orientations, ready for detailed analysis, worth doing;
- strong either lattice or crystal bending cause useful distortions of SAD and bend contours;
- orientational gradients (indicated by bend contours, as well as stresses) should be taken into account in parallel with traditional imperfections (vacancies, dislocations, etc.) in TEM.

1. V. Yu. Kolosov Proc. XII ICEM, Seattle, San Francisco Press, **v.1** (1990), p. 574.
2. V.Yu. Kolosov and A.R. Tholen, Acta Mater. **v. 48** (2000), p. 1829.
3. This work is partially supported by INTAS (00-100), pending support from RFBR (04-02-96072/16656).



Bar = 1 micrometer

Figure 1. TEM images of crystals with bend contour patterns

Figure 2. Corresponding schemes for the geometry of lattice bending

Figure 3. HREM (axial lattice fringes can be seen at the top and at the bottom)