Morphologies, due to growth process induced segregation in two component thin films

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The growth process induced segregation [1] plays a very important role in morphological development of thin films. Besides of surface morphological and structural effects influencing grain structure and texture, changes of local composition are brought to existence resulting in formation of new phases as well as phase separation mechanisms. Understanding of these processes and related effects can benefit the application of thin films especially when multifunctional structures should be created in one technological step. Typical examples of surface and bulk morphologies related to process induced segregation of excess species are introduced.

The growth process induced segregation involves redistribution of excess surface adatoms by the driving force of moving growth steps. Excess adatoms can be considered those, which are on the surface as components of the growing films or contaminants from the ambient atmosphere and can not be incorporated into the growing film at the given growth conditions. Nevertheless, these excess adatoms can substantionally contribute to morphology and physical properties of the thin films. Diverse selforganized structures can develop as a result of their effect.

Direct observation of the excess adatoms is difficult. However, at special conditions, indirect evidences of their participation in the growth processes can be obtained. The presence of excess oxygen adatoms can be evidenced by detecting oxide particles on the growth surfaces. Growth steps on the growing Cu crystals roll the oxygen species along the surface as long as they form oxide particles, pinning the steps. The pinning points and bowing growth steps between them are clearly visible in fig. 1a. This can be considered as indirect proof of the growth process induced segregation of oxygen adatoms on Cu growth surface [2].

The growth process induced segregation provides a mechanism for the formation of versatile and unexpected morphologies in two component films. For example, in the Ag-C system layers of Ag crystallites embedded in amorphous carbon matrix form at the bottom of the film. With increasing thickness, the size of the crystallites increases, still preserving the composite structure (fig. 1b).

Moreover, the growth process induced segregation can produce suitable conditions for other separation mechanisms as well. By this process in Cu-Ag films at the grain boundaries of growing Cu grains the composition, enabling spinodal decomposition, can be formed. As a result a two phase nanograin structure is observed in the Cu grain boundaries. This hinders the competing growth of Cu crystals and results in their smaller grain size, reduced texture, repeated nucleation and bimodal grain structure (fig. 2a) [3].

The growth process induced segregation can also generate conditions for the oxidation of excess adatoms. The Al-Sn system provides an example for this effect. The periodic oxidation of Sn segregated to the growth surface causes lamellar growth of Al crystals (fig. 2b) [4].

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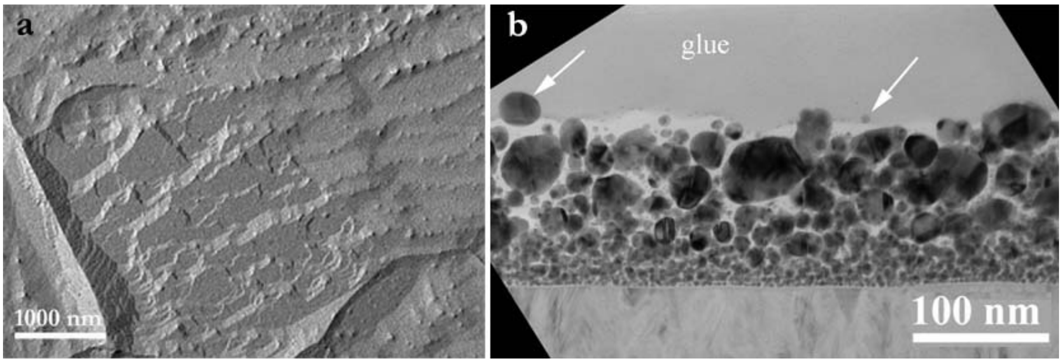

Figure 1. C-Pt replica showing the growth steps of a growing Cu grain pinned due to the growth process induced segregation of oxygen species. (a). TEM cross sectional image of a C-Ag film showing layers of Ag crystallites. Arrows mark Ag crystallites on the surface developed by repeated nucleation (b).

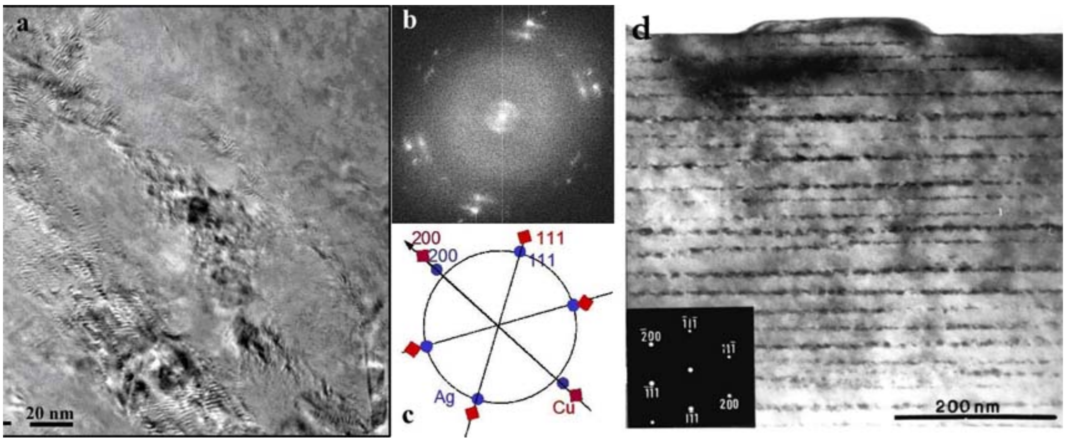

Figure 2. Cu-Ag alloy showing segregation of Ag to Cu grain boundaries and forming there an epitaxial eutectic nanocomposite due to spinodal decomposition (a), diffraction pattern (b) and its indexing (c). Selforganized layered growth of Al crystallite as a result of periodic oxidation of Sn in the Al-Sn–O system (d).

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