Development of texture and morphology in Cu-Ag thin nanocomposite films on Si

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1. Introduction
The formation and morphological development of two phase composite films still has a number of open questions. E.g. metal–metal (nano)composites are posing many unsolved growth problems. Especially the basic processes of morphological and texture development in them needs to be further clarified [1, 2, 3]. The texture formation in Cu and Cu-Ag films grown on (100)Si substrate has been investigated.

2. Experiments
Films of 50 and 400 nm thickness were prepared by co-deposition of thermally evaporated Cu and Ag in vacuum of 10^-7-10^-8 mbar onto cleaned (in 10% HF) (100)Si wafers, held at room temperature. The composition of the films corresponded to Cu, Cu_9Ag_1, Cu_4Ag_6(eutectic) and Ag in agreement with the physical and morphological properties of these films [4]. The deposition rate of the films was set to 1nm/s.
The films were investigated by X-ray diffraction, where pole figures of <111>, <100> and <110> directions were recorded. TEM and XTEM were used to determine the morphological properties of the films.

3. Results and discussion
A thin film of Cu grown on (100)Si displays very faint or practically no texture as long as the thickness is 50 nm. The evaluation of the pole figures (Fig.1a.) is possible in terms of weak, simultaneously occurring textures of <111>, <100> and <110> at least. However, crystallographic considerations suggest, that epitaxy of Cu on (100)Si must occur resulting in biaxial <100> texture.

In Cu/(100)Si films grown to 400 nm thickness a strong \{100\}Cu\|(100)Si and <100>Cu\|[011]Si biaxial texture appears (Fig. 1b). Consequently, this texture is the result of the selection processes [2] leading to the strengthening of the weak <100> texture detected in the thin sample (Fig. 1a). The selection takes place due to the interaction of the growing grains with oxygen and copper-oxide formation.

Cu and Ag are practically immiscible and Ag is surfactant for Cu, consequently, in the Cu-Ag films changes in growth morphology and texture development compared to Cu films can be expected.

The pole figure recorded in Cu\{111\} reflections (Fig.2a) shows relatively strong two axis <100> texture for the 50 nm thick Cu_9Ag_1 film. Simultaneously a weak <111> wire texture is observed. Comparison to Cu films (Fig. 1a) tells, that Ag co-deposition with Cu enhances both the epitaxial growth of Cu on (100)Si and the <111> wire texture in thin (50 nm) films. Increasing the thickness to 400 nm (Fig. 2b) preserves the biaxial <100> texture. No further selection processes are effective above 50 nm film thickness. Morphologically both the thin and thick Cu_9Ag_1 films belong to the Zone III structure (Fig. 2c)

Only wire textures were observed in the eutectic (60 at% Ag) films, characterised also by very small grain size (Fig. 3c). Both the thin (50 nm) and thick (400 nm) films have a pronounced <111> wire texture which is observed for both Ag and Cu. (Fig. 3a and 3b).
Summarising, in thin and thick films of Cu$_9$Ag$_1$ composition Ag enhances the development of biaxial $<100>$ texture through the selection processes [1, 2] and the formation of a $<111>$ wire texture. In the films of eutectic composition (Cu$_4$Ag$_6$) formation of $<111>$ wire texture takes place. The selection processes favouring the growth of $<100>$ Cu crystallites are suppressed due to the very small grain size in these films.

Figure 1. $<111>$ pole figures of Cu films of 50 nm thickness (a), 400 nm thickness (b) and TEM bright field cross section image of the 400 nm thick film (c).

Figure 2. $<111>$ pole figures of Cu 10at%Ag films of 50 nm thickness (a), 400 nm thickness (b) and TEM dark field cross section image of the 400 nm thick film (c).

Figure 3. $<111>$ pole figures of Cu-Ag films of eutectic composition of 50 nm thickness (a), 400 nm thickness (b) and TEM dark field cross section image of the 400 nm thick film (c).

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References