HRTEM characterization of erbium silicide formed in ultra-high vacuum

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Erbium silicide exhibits one of the lowest electrical work function amongst the rare-earth (RE) metals already used for low Schottky barrier applications [1]. Therefore, erbium silicide is a very promising material as a silicide source/drain in n-channel Schottky Barrier (SB) MOSFETs [2].

In order to form erbium silicide, a 25 nm thick erbium film was deposited by electron-beam evaporation on the silicon substrate and then annealed at 630 °C for 30 min. Because RE metals react with oxygen, a capping layer is usually used. To omit the capping layer, the formation of erbium silicide was performed under special conditions, which protect well against oxidation. Namely, the annealing was carried out under ultra-high vacuum (UHV) conditions, without breaking the vacuum between processes of deposition and annealing. Transmission electron microscopy (TEM) studies were focused on microstructural observations of the silicide layer and silicide/Si interfaces at an atomic scale by high-resolution TEM (HRTEM), as well as on the identification of the formed silicide phase using selected area electron diffraction (SAED) technique. The types of phases and the quality of the silicide layers have impact on the electrical performance of silicide contacts [3].

HRTEM image revealed that during annealing at 630 °C for 30 min, the Er layer reacts with silicon, forming a crystalline silicide layer with a thickness of about 25-28 nm (Fig. 1a). However, the lower part of the silicide layer (about 3 nm), close to silicon, is amorphous. Microtwins are observed in the crystalline part of erbium silicide layer. The interface between silicide and silicon is rough. At the top of the annealed structure a 5-7 nm thick layer is visible. This is a part of the erbium layer, which was not fully transformed into silicide. The interface between the silicide and the unreacted Er layer is more rough than the silicide/silicon interface.

The rest of the Er layer visible on the top of structure (Fig. 1a) is unnecessary for Schottky contacts and should be removed. In the structure shown in Fig. 1b an unreacted Er layer was removed by sulfuric peroxide mixture (SPM). However, SPM affects the erbium silicide layer as well. This effect is visible in the form of the amorphous layer (about 5 nm thick) on top of the silicide surface, which is marked by the dashed lines in the HRTEM image (Fig. 1b).

SAED pattern revealed (Fig. 1c) that the crystalline silicide consists of the $ErSi_{2-x}$ phase with a composition close to $ErSi_{1.7}$, corresponding to the hexagonal AlB_2 type [4-5].

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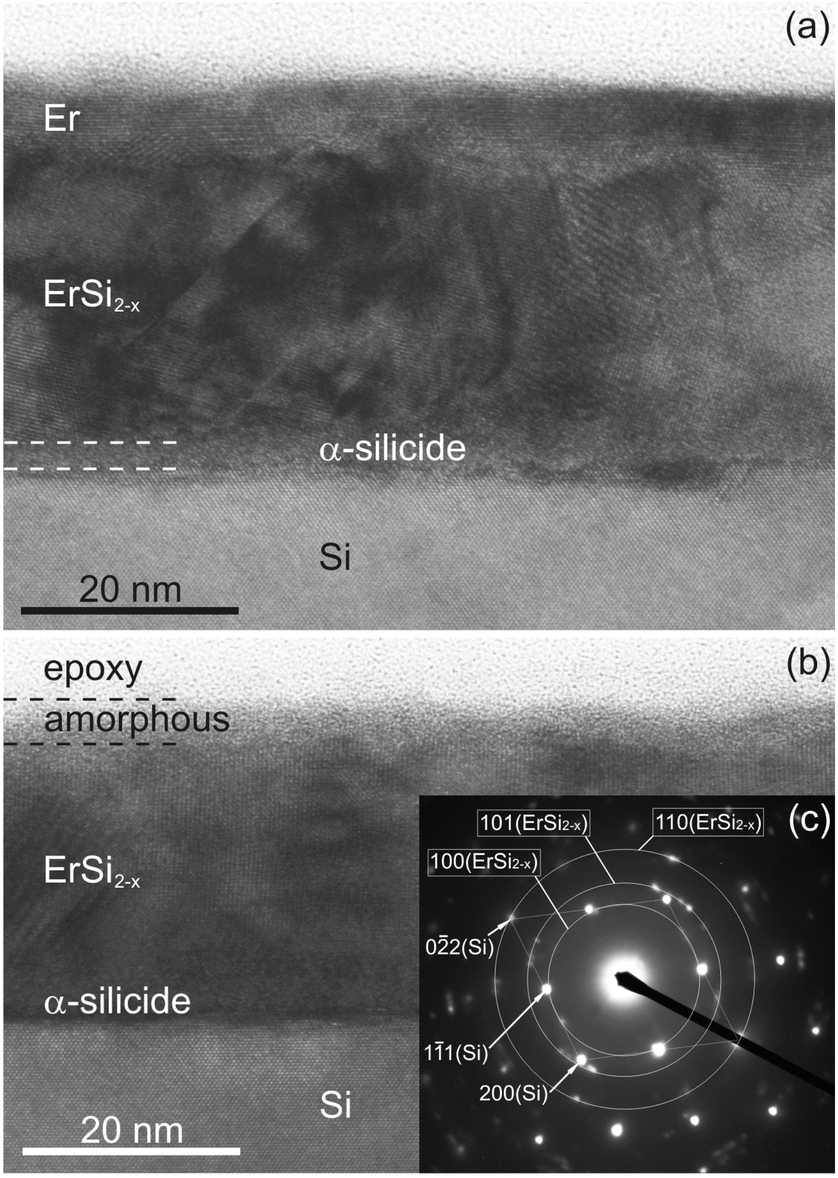

Figure 1. Er/Si structure annealed at 630 °C for 30 min: (a) HRTEM image of the structure, (b) HRTEM image of the structure after removing of excessive erbium with SPM and (c) SAED pattern in [011] orientation corresponding to Si and with poly-rings corresponding to the hexagonal $ErSi_{2-x}$ phase (described by the three-index system [5]).

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