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“Formation of thin films of Mg_2Si on Si (111) and investigation of their electronic properties"

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Abstract. Under ultrahigh vacuum conditions, two samples were formed by the SPE method on Si(111) substrates: the first by co-deposition of Si and Mg at room temperature, and the second by layer-by-layer deposition of Si and Mg at a substrate temperature of 195 °C. The Si and Mg deposition process was controlled in-situ by Auger electron spectroscopy (AES) method. By the X-ray Phase Analysis method, after the formation of films, it was found that Mg is part of the film of only the second sample, while it has changed lattice parameters

Experimental The silicon substrate for the samples was cut from an industrial KEF–100 Si (111) n-type conductivity wafer with a resistivity from 2 to 15 W*cm. The source of magnesium (Mg) was Mg chips with a purity of 99.999%, placed in a tantalum tube with a puncture.Si (111) substrates were subjected to RCA cleaning before loading into the chamber, and after loading, they were heated at T = 600 ° C for 1 hour and at T= 1250 ° C for 3 seconds 3 times with intervals of 10 minutes.The deposition rate of Mg and Si was measured using a quartz sensor in the UHV chamber connected to a Sycon Instruments device, the rate was 4 nm/min for Mg and 0.24 nm/min for Si when deposited on the first sample; 2.6 nm/min for Mg and 0.35 nm/min for Si when deposited on the second sample. All samples were formed by the SPE method. The temperature of the substrates was different: for the first sample – room temperature, and for the second - T = 195 °C. The first step was to form a buffer layer of silicon with a thickness of 60 mm on both Si (111) substrates.
Further, the experiment was carried out in different ways for each sample. For the first sample, a 1.5 nm thick Mg seed layer was deposited on the silicon buffer layer and then Mg and Si were co-deposited with a velocity ratio of 16:1. For the second sample, layers of magnesium and silicon with a thickness of 15 and 5 nm were alternately deposited on the buffer layer, respectively. The deposition of these layers was repeated three times. As a result, a thin film with a thickness of 100 nm was formed for the first sample, and 60 nm for the second.

Results and discussion

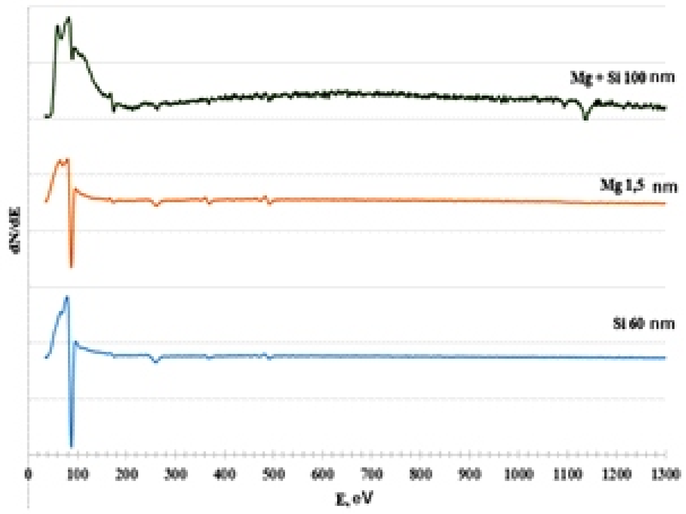

Figure 1. Spectra of Auger electrons of the first sample

Control over the formation of films was carried out in situ by Auger electron spectroscopy (AES) and electron energy loss spectroscopy (EELS). At the beginning, the formed films were examined by the AES method. The AES spectra obtained at all stages of the formation of the first sample are shown in Figure 1

In Figure 1, the AES peak of high intensity with energy of 92 eV belonging to Si is observed. At the stage of co-deposition of Mg and Si (upper spectrum), a peak with energy of 1186 eV is observed, indicating the presence of Mg atoms in the composition of the sample surface. Figure 2 shows the AES spectra obtained at all stages of the formation of the second sample. It also clearly shows a AES peak with energy of 92 eV, corresponding to pure silicon. At the formation stage of the first magnesium layer, the sample has a peak of high intensity at 45 eV and low intensity peak at 92 eV, belonging to Mg and Si, respectively. At the formation stage of the second layer (Si with a thickness of 5 nm), only the AES peak of high intensity at 92 eV belonging to Si is noticeably observed. At the formation stage of the third layer (Mg with a thickness of 15 nm), one AES peak of high intensity at 45 eV, belonging to Mg, is visible. A similar patterns of Auger electron spectra is preserved for subsequent layers.

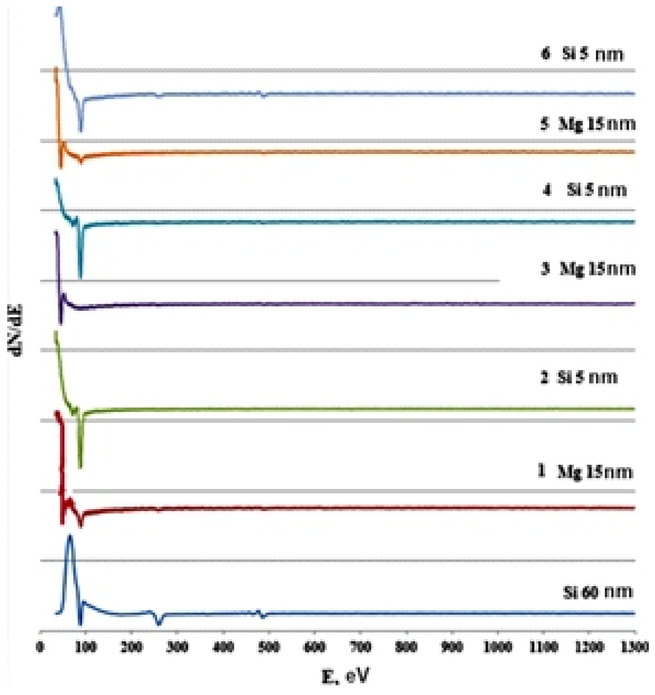

Figure 2. Spectra of Auger electrons of the second sample

Further, the formed samples, after extraction from the growth chamber, were examined by X-ray phase analysis. The X-ray diffraction patterns (XRD) of the samples are shown in Figures 3 and 4

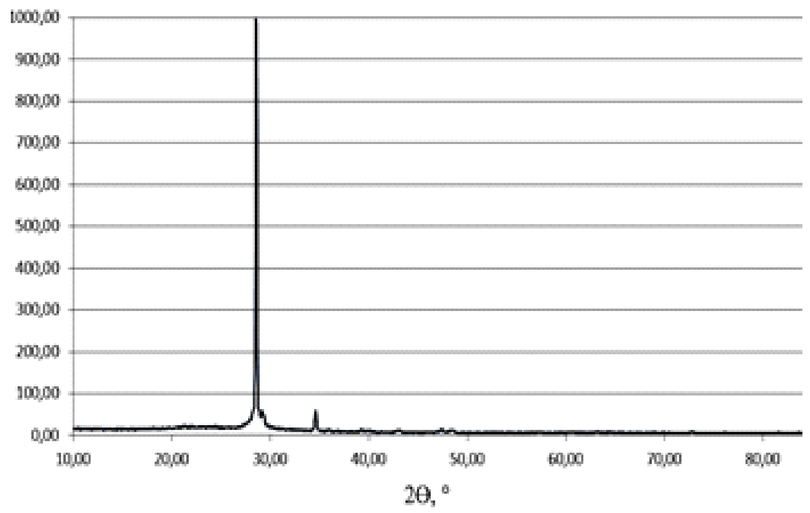

Figure 3. Diffractogram of the first sample

On the XRD spectra of both samples, the peak of the highest intensity (2Θ=28°, which corresponds to the interplane distance d = 3.12 Å) belongs to the substrate material - Si (111).

Magnesium silicides were not detected in the XRD spectrum of the first sample with known diffraction data (Mg2Si, Mg5Si6, Mg6Si3 or Mg9Si5). In the spectrum of the second sample, in addition to silicon, another reflex was noted (2Θ=35.8°, which corresponds to the interplane distance d = 2.504 Å). This peak does not belong to the Mg2Si phase. It can be attributed to the Mg5Si6 compound (with oriented growth along one crystallographic direction), but it is more likely that it is Mg with strained lattice parameters.

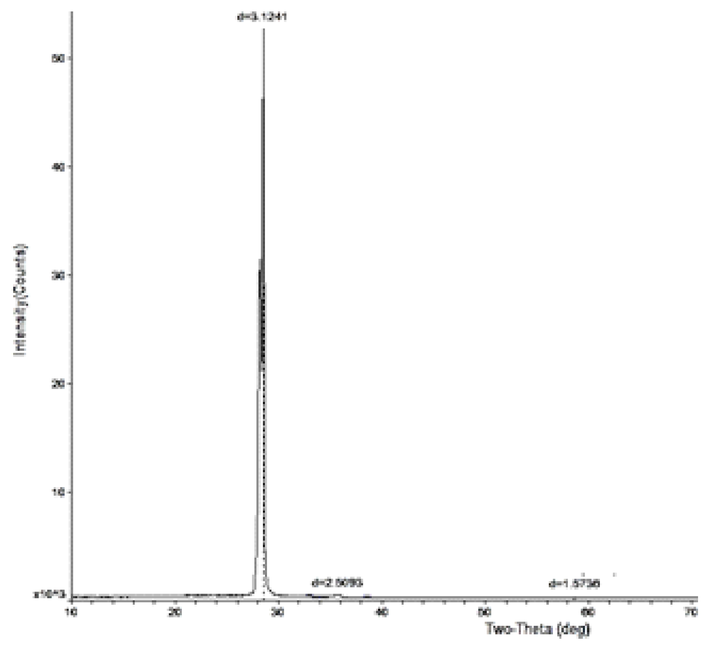

Figure. 4. Diffractogram of the second sample

Conclusions

Thus, as a result of the growth experiments carried out, two samples were formed by the SPE method: the first by co-deposition of Si and Mg at room temperature, and the second by layer-by-layer deposition of Si and Mg at a substrate temperature of 195°C. The Si and Mg deposition process was controlled in-situ by AES and EELS methods. By the X-ray Phase Analysis method, after the formation of films, it was found that Mg is part of the film of only the second sample, while it has changed lattice parameters.