FORMATION OF A NANOSTRUCTURED Eu–Si–O LAYER DURING HIGH-TEMPERATURE DIFFUSION OF EUROPIUM INTO SILICON

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This work presents the results of a comprehensive structural and spectroscopic study of europium diffusion into KEF-80 grade silicon under high-temperature diffusion (HTD) conditions. The diffusion process was carried out in the temperature range of 1100–1300 °C, leading to the formation of an inhomogeneous Eu–Si–O diffusion layer comprising nanocrystalline $EuSi_2$ phases, residual oxide components Eu_2O_3, and amorphized near-surface regions. X-ray diffraction revealed a set of intense peaks corresponding to the (001), (100), (101), (002), and (111) orientations of the $EuSi_2$ phase, as well as individual reflections of Eu_2O_3. Analysis of the full width at half maximum (FWHM) and crystallite size calculations using the Scherrer equation showed that the average $EuSi_2$ crystallite size is approximately 50–65 nm, which is consistent with morphological data (Figs. 1, 2(a,b), Table 1) [1,2].

Raman spectra demonstrate pronounced reconstruction of vibrational modes, including a shift and broadening of the Si–TO peak and the appearance of additional modes associated with the formation of nanocrystallites and Eu-containing phases. Morphological studies confirm the nanogranular structure of the diffusion layer with characteristic surface agglomerate sizes of 40–100 nm.

X-RAY DIFFRACTION ANALYSIS

The phase composition and crystalline parameters of the Eu-modified layer were investigated by X-ray diffraction (XRD) using a Shimadzu XRD-6100 diffractometer. Measurements were performed in the 2θ range of 10–80° using Cu Kα radiation (λ = 1.5406 Å) with a step size of 0.02°, providing high accuracy in the determination of diffraction peak positions. Identification of the $EuSi_2$ and Eu_2O_3 phases was carried out using the PDF-2/PDF-4 databases. The peak widths (FWHM) were corrected for instrumental broadening, after which the $EuSi_2$ crystallite sizes were calculated using the Scherrer formula. This approach enables a reliable assessment of the nanocrystalline nature and degree of amorphization of the Eu–Si–O layer.

RAMAN SPECTROSCOPY AND MORPHOLOGY OF KEF-80 SILICON AFTER HIGH-TEMPERATURE DIFFUSION

Raman spectra were recorded using a Renishaw inVia confocal microspectrometer with 532 nm excitation. The spectral resolution was approximately 1 cm⁻¹, allowing detection of shifts and broadening of the Si–TO mode (~520 cm⁻¹). Spectra were collected in the range of 100–3200 cm⁻¹, and the silicon peak position was calibrated against the standard value of 520.7 cm⁻¹. To assess the inhomogeneity of the diffusion layer, two-dimensional Raman mapping was performed with a step size of 0.5–1.0 µm, providing spatial resolution comparable to the thickness of the Eu-modified region.

The resulting maps revealed stressed regions, areas of local amorphization, and the distribution of Eu-containing phases, which correlate well with XRD and morphological data [3,4]. High-temperature diffusion of europium at 1100–1300 °C leads to the formation of a nanostructured Eu–Si–O layer containing $EuSi_2$ and oxide components.

CONCLUSIONS

High-temperature diffusion of europium results in the formation of a nanostructured Eu–Si–O layer containing $EuSi_2$ and Eu_2O_3 phases. The crystallite parameters, stress distribution, and morphological features show good agreement between XRD, Raman spectroscopy, and AFM analyses. These structures demonstrate strong potential for applications in optoelectronics and sensing devices.

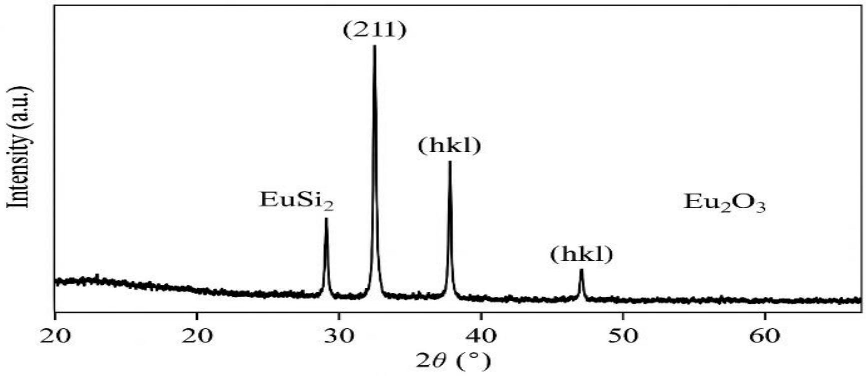

Figure 1. X-ray diffraction pattern of the Eu diffusion layer in KEF-80 silicon. The main reflections of $EuSi_2$ and Eu_2O_3 are indicated.

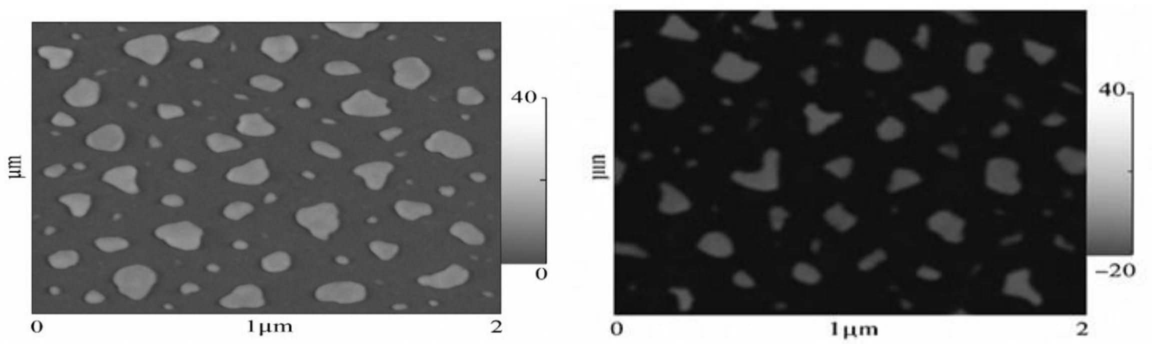

Figure 2. Morphology of KEF-80 after HTD: distribution of silicide islands with heights of 5–40 nm (a); contrast between $EuSi_2$ (rigid domains) and Eu_2O_3 (b).

TABLE 1. Morphological parameters of the Eu layer

Parameter	Value
Average height of $EuSi_2$ domains	5–40 nm
Lateral domain size	80–250 nm
Roughness Rq (inter-domain regions)	1.5–3.5 nm
Domain density (estimate)	~10^8–10^9 m^{-2}

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