

STUDY OF LANTHANUM ON TUNGSTEN FIELD EMITTER

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ABSTRACT - Activation energy for surface self-diffusion of lanthanum was measured on La epitaxial crystal grown on a surface of tungsten field emitter. A possible influence of an electric field during the course of the diffusion as well as in the case of the zero-field activation energy was investigated.

Epitaxial single crystals grown from vapour in a field emission microscope /FEM/ under ultra-high vacuum conditions show an extremely high level of purity and appear to be a suitable object in investigation of surface processes. Epitaxy and surface self-diffusion of a series of rare-earth elements, such as Y [1], Dy [2], Gd [3] and Er [4,5] was in the past investigated using the FEM technique. This paper presents preliminary results of measurement of the surface self-diffusion activation energy of lanthanum which was carried out on an epitaxial La crystal grown from vapour on a surface of the field emitter of tungsten. Fig. 1a shows an FEM pattern of the tungsten substrate surface, obtained at liquid nitrogen temperature.

The lanthanum source was a piece of lanthanum placed in a conical coil basket of a tungsten wire which could be resistively heated. The ambient pressure during the deposition of lanthanum was lower than 3×10^{-8} Pa. The temperature of the substrate field emitter was controlled by means of an electronic temperature controller and determined with an accuracy of ± 5 K by using the resistance thermometry method [6]. A lanthanum epitaxial single crystal obtained at a temperature of 780-790 K after a 3 hr evaporation of lanthanum is shown in fig. 1b. Similarly as in the case of Gd [3] and Er [4] the nucleation of lanthanum started on the terraces of a 110 plane of tungsten and required a precoverage. The growth of La crystals was made in a few stages of evaporation involving quenching to liquid nitrogen temperature after stage.

The activation energies for surface self-diffusion of La were computed from Arrhenius-type dependences of $\ln t$ vs $1/T$ obtained from measurements using the method described by Melmed [7]. A small reproducible deformation /build-up/ of the crystal shape was first made at a temperature of 640 K with an electric field /of straight or reverse polarity/ applied to the tungsten substrate, see fig. 1c. Then the time, t , required to smooth the surface of the crystal was measured at various temperatures, T /in the range 550 K to 620 K/ with no applied electric field. The initial and final states of the shape of the deformed and smoothed crystal were characterized by the relevant values of the field emission current at a fixed voltage. Then zero-field activation energies were

computed from such two sets of data. To examine the effect of electric field on the activation energy this procedure was repeated measuring the time of deforming in the same temperature range but with an applied electric field, for both polarities. In this way another two sets of data for the activation energy were measured. The result is shown in fig. 2. The values of the activation energy, $Q_3=1.45$ eV/atom and $Q_4=1.52$ eV/atom, for the surface self-diffusion of lanthanum with an applied electric field are close to that, $Q_2=1.43$ eV/atom, for the diffusion with no applied field after the straight build-up /i.e. when it was made with a negative potential applied to the substrate tip/. The case of the zero-field activation energy, $Q_1=1.24 \pm 0.10$ eV/atom, for the build-up produced with a reverse field /with a positive potential to the substrate/ probably reflects a "field memory" effect similar to the case of erbium [5]. It was supposed for erbium that the field-induced build-up process changes the binding energy of topmost atoms of the crystal and that these changes are conserved after removal of the electric field, which affects the value of the activation energy for the surface self-diffusion with no applied field. It should be noted, however, that in the present case the "field memory" effect of lanthanum caused a decrease of activation energy rather than increase as in the erbium case.

It was mentioned above that the build-up was induced both in a straight and reverse field at 640 K which is some 55 K higher than the temperature of the phase transition from -La/hcp/ to -La/fcc/. Though, observation of field emission patterns made in the temperature range 550 K to 630 K during the course of measurement of the diffusion times with an applied straight electric field /which was sufficiently high for FEM imaging/ - gave no evidence for a change in the symmetry of the lanthanum crystal across the transition temperature.

In conclusion, we have found the nucleation and crystal growth of lanthanum to be similar as for other rare-earth metals. Evaporation was made at a high temperature of 780 K by stages followed by quenching to 78 K resulting with an La crystal. Over the phase-transition temperature of lanthanum the field emission pattern revealed no change of symmetry of the crystal. The zero-field activation energy for surface self-diffusion of lanthanum shows a "field memory" effect after deformation induced by the "reverse" field at 640 K whereas no influence of an electric field applied during the diffusion on the activation energies was found within the accuracy of the measurement.

ACKNOWLEDGEMENTS

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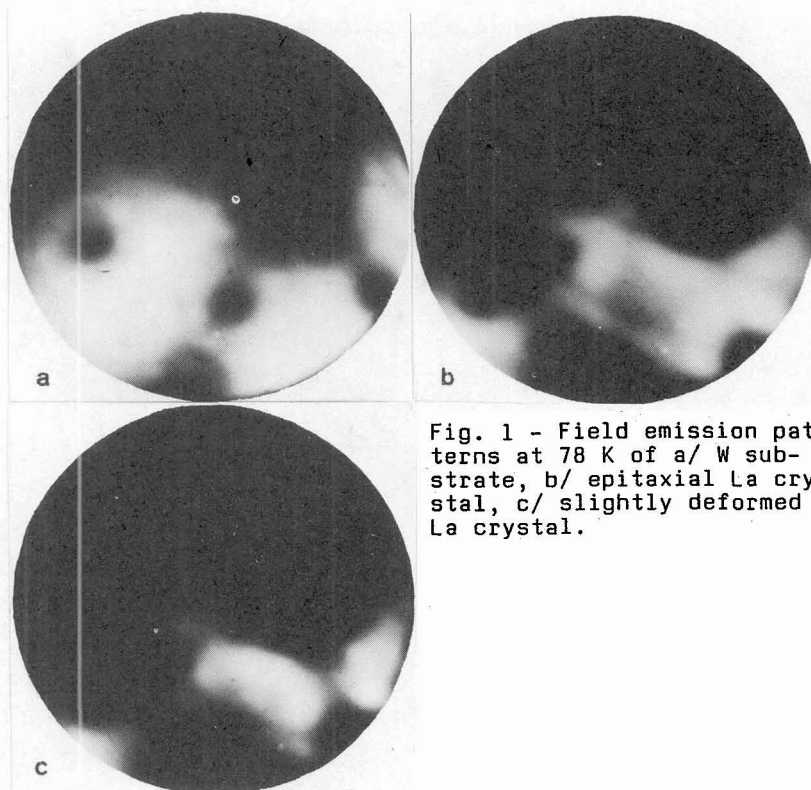


Fig. 1 - Field emission patterns at 78 K of a/ W substrate, b/ epitaxial La crystal, c/ slightly deformed La crystal.

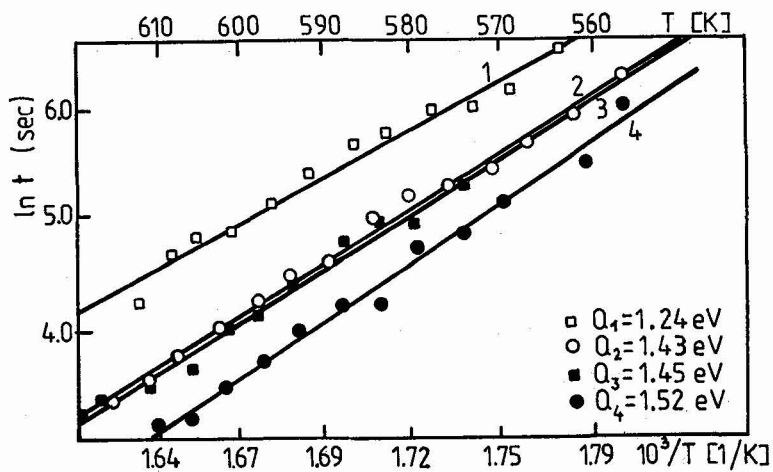


Fig. 2 - Arrhenius plots for surface self-diffusion of La at 550-620 K. Curves: 1 - diffusion with no applied field, after reverse build-up, 2 - no field, after straight build-up, 3 - diffusion with applied reverse field, 4 - diffusion with applied straight field.