Numerous studies of the \( \beta \rightarrow \alpha \) transformation in titanium by means of high-temperature microscopy have been reported in the literature \([1,2]\). Such studies can also be made by means of emission microscopy, which makes it possible to obtain more comprehensive data. In high-temperature microscopy the contrast is due mainly to the geometric profile of the surface resulting from thermal etching or volume changes, while in emission microscopy the contrast is due also to the constants of the material (work function or coefficient of secondary electrons). This factor varies with the phase composition, orientation, and temperature of the specimen \([3]\). The actual contrast of the material and the high resolving power, not depending on the temperature of the specimen, and large depth of field are of decisive importance.

In this work the EF-6 Karl Zeiss Jena electron-optical apparatus \([4,5]\) was used to investigate the \( \beta \rightarrow \alpha \) transformation in commercially pure titanium.

The samples were subjected to wet grinding, electropolishing, and final chemical etching. The methods of thermal and electron emission excited by ions or electron bombardment were combined; the specimen can be observed in the course of heating to approximately 2000°C.

The original titanium had a typical equiaxed polyhedral structure (Fig. 1a). Heating to temperatures near the polymorphous \( \beta \rightarrow \alpha \) transformation (\( \sim 880^\circ \)) changes the structural relief (Fig. 1b).

Acicular precipitates disappear completely as the result of chemical etching, while the grain boundaries, easily visible in Fig. 1a, are indistinct because of the shadow effect, the high emission density, and the strong etching. Considerable grain growth occurs with further heating in the \( \beta \) range. During cooling of titanium from the \( \beta \) range the \( \beta \rightarrow \alpha \) transformation occurs rapidly, with formation of an acicular microstructure similar to martensite in steels. As the temperature drops the needles or platelets increase in size.

The acicular structure (Fig. 2) may revert to polyhedral after substantial deformation at temperatures below the \( \alpha \rightarrow \beta \) transformation temperature and subsequent recrystallization \([6]\). Volume changes

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**Fig. 1.** Microstructure of commercially pure titanium. Micrograph made with secondary electrons. a) At 20°C; b) same section at 880°C.
Fig. 2. Acicular $\alpha$ titanium obtained by sharp cooling of $\beta$ titanium.

Fig. 3. Distortion of the surface due to changes in volume in the $\beta \rightarrow \alpha$ transformation. a) At 20°C; b) 880°C.

during the $\beta \rightarrow \alpha$ transformation induce considerable distortion of the surface, particularly in grain boundaries (Fig. 3a). With cooling to room temperature the banding observed in the $\beta$ range at grain boundaries is almost completely retained. With heating to 880°C (Fig. 3b) banding occurs again, and the small unevennesses in the surface are evened out; with increasing holding time at 880°C the surface becomes smoother due to diffusion. The banding observed consists of stepped relief that occurs only at certain temperatures during heating [7].

With regard to the appearance of the stepped relief, the following reasons are given:

1. A difference in the adsorption of oxygen in separate sections of the surface. The oxygen concentration in the residual atmosphere (pressure $1 \cdot 10^{-6}$ mm Hg) is sufficient to reveal this effect.

2. Internal stresses resulting from the transformation due to the difference in volume of the hexagonal and cubic modifications.

Fig. 4. Surface of titanium after gas nitriding (a) and after carburizing (b).