# Growth of roughness features on the surface of a foil of the amorphous alloy $Fe_{70}Cr_{15}B_{15}$ as a response to a tensile stress

V. E. Korsukov, A. S. Luk'yanenko, B. A. Obidov, V. N. Svetlov, and E. V. Stepin

*A. F. Ioffe Physicotechnical Institute, Russian Academy of Sciences, 194021, St. Petersburg*

(Submitted 1 February 1993)
Pis'ma Zh. Eksp. Teor. Fiz. **57**, No. 6, 343–345 (25 March 1993)

Scanning tunneling microscopy has been used to study the growth kinetics of roughness features on a stretched surface of a foil of an amorphous iron alloy.

We have carried out a systematic study of the effect of tensile stress on the surface topography of foils of the amorphous alloy $Fe_{70}Cr_{15}B_{15}$ by scanning tunneling microscopy (STM). Amorphous alloys are convenient for studies of this sort, since they exhibit an elastic behavior over a wide stress range. This circumstance means in particular that the processes discussed below, which are observed on a surface with a fairly low stress, cannot be attributed to plasticity. On the contrary we believe that these processes are often the primary cause of the plastic flow of a material and, ultimately, of its fracture.

Working from the results of our observations, we can distinguish several scenarios for the sequence of events at a stretched $Fe_{70}Cr_{15}B_{15}$ surface. One of these scenarios was spelled out in Ref. 1. There, a progressive increase in the size of the roughness features over the entire monitored area ($7 \times 5\ \mu m$) of a stretched surface was interrupted (or terminated) by the appearance of a system of crack-like formations oriented perpendicular to the loading axis. It was suggested in that paper that the growth of the roughness features was a quasielastic effect in the sense that the roughness features shrink rapidly when the load is relieved (at the instant at which the crack-like formations arise). This response of the $Fe_{70}Cr_{15}B_{15}$ surface to a load is completely analogous to that which we have observed[2] on Ge (111). We get the impression that this quasielastic response of a surface to a load is fairly general.

In support of, and as a further development of, this hypothesis, we present in the present letter yet another series of experiments on a stretched $Fe_{70}Cr_{15}B_{15}$ surface, in this case at a slightly lower stress, $\sigma = 30$ kgf/mm$^2$. At this stress level the transformation of the $Fe_{70}Cr_{15}B_{15}$ surface is not accompanied by abrupt changes of the type which were described in Ref. 1 and which can be classified as plastic effects. The dynamics of the relief is either quasiperiodic, with the appearance and healing of local irregularities of the surface relief (with a temporal period on the order of an hour), or complex, involving the onset of saturation over a time on the order of a few hours.

The experimental procedure is described in our previous papers.[1,2] The tip of the scanning tunneling microscope was held at a potential $U = +20$ mV. The tunneling

  

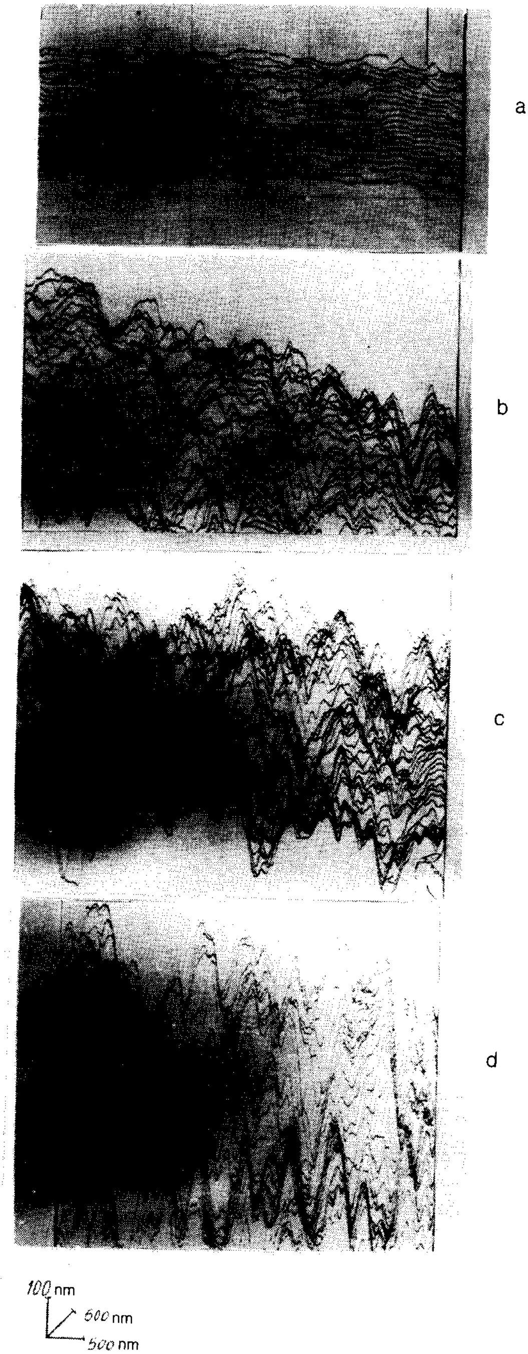


FIG. 1. Transformation of a stressed surface as time elapses. *a*—Original surface; *b*—after 15 min; *c*—40; *d*—155 min.

current was $I_t = 0.3$ nA and ruled out any experimentally significant effect of the surface-scanning process on the surface topography. We verified directly that the latter assertion was correct by carrying out a prolonged scan of one region of an unstressed surface. Figure 1 shows the results of the STM of a stretched $Fe_{70}Cr_{15}B_{15}$ surface ($\sigma = 30$ kgf/mm$^2$). We see that the initially smooth surface (Fig. 1a) becomes progressively rougher. The increase in the vertical dimensions of the roughness features is a complex kinetic process with a time scale on the order of 2 h. The maximum roughness level is $\sim$ 800 nm. In the lateral direction, along the loading axis, it is possible to make out a definite period of the roughness: on the order of 100 nm. This period remains essentially constant as time elapses. Skipping ahead a bit, and invoking some other series of experiments, we note that this lateral mode is intensely excited at all load levels and is thus a constant of the material. It is interesting to note the stabilization of extremely subtle relief features in the form of crests and valleys and the disappearance of the original randomness, which was also noted in Ref. 2. A random relief reflects a rapid restructuring. As in Ref. 1, we reach the conclusion that the tensile stress is the driving force for the increase in the size of the roughness features at the surface.

The most likely physical mechanism for this process, in our opinion, is a surface self-diffusion intensified by the tensile stress. This assertion can be understood by assuming that at a certain stress level the binding energy of the surface atoms (the surface tension) is lower in the natural depressions[3] than on the elevations, so a diffusion flux arises and causes a growth of the hills. Furthermore, the formation and growth of these hills lead to a concentration of stress, which intensifies the growth process. A similar mechanism was proposed in Ref. 4 in an effort to explain "island" epitaxy on a stretched surface. Since the experiment was carried out in air, we do not rule out the possibility that the atmosphere had a catalytic effect on the kinetic process which is observed.

We wish to thank S. N. Zhurkov, A. I. Slutsker, and A. M. Leksovskiĭ for cooperation in this study.

[1] S. N. Zhurkov, V. E. Korsukov, A. S. Luk'yanenko, *et al.*, Pis'ma Zh. Eksp. Teor. Fiz. **51**, 324 (1990) [JETP Lett. **51**, 370 (1990)].

[2] V. E. Korsukov, A. S. Luk'yanenko, B. A. Obidov, and V. N. Svetlov, Pis'ma Zh. Eksp. Teor. Fiz. **55**, 595 (1992) [JETP Lett. **55**, 621 (1992)].

[3] Ya. I. Frenkel', Zh. Eksp. Teor. Fiz. **16**, 39 (1946).

[4] C. W. Snyder, B. G. Orr, D. Kessler, and L. M. Sander, Phys. Rev. Lett. **66**, 3032 (1991).

Translated by D. Parsons