Reactivation of Mechanical Aftereffect of Iron Single Crystals by Discontinuous Change of External Magnetic Field

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(Z. Naturforsch. 27 a, 371—372 [1972]; received 3 January 1972)

First experiments on iron single crystals are outlined demonstrating that the mechanical aftereffect can be reactivated remarkably by discontinuous changes in superimposed magnetic fields. As magnetostrictive effects not only are very much smaller but can also be separated experimentally, it appears to be necessary to interpret the observed phenomena by interactions between domain walls and dislocations having mutual orientations suitable to enable reactivation of disclocation glide caused by the repulsive interaction forces of the domain walls.

§ 1. Introduction

In 1956 BLANK [1] reported on a strange but noteworthy experiment: suppose a nickel single crystal has been plastically deformed to some percent strain by uniaxial, constant tensile stress applied either without or during superposition of a constant external magnetic field parallel to the stress axis. After waiting for some minutes the rate of strain occuring under constant stress due to the mechanical aftereffect, has decreased to a negligible degree. But if now the external magnetic field is either applied or switched off, or changed discontinuously, in any case a reactivation of the mechanical aftereffect will be observed.

Although obviously very interesting, this unexpected result did not find any resonance in the subsequent literature, probably because it was in striking disagreement with one of the most important postulates of all theories of the magnetization curve seriously discussed at that time as well as later on and until to-day: the postulate that during the magnetization process all dislocations and dislocation segments should behave stiff and rigid and remain fixed at their respective places in the crystal lattice even in the very moments when domain walls interacting with them, under the influence of an external magnetic field, just are moving across them.

For the above reason BLANK's [1] experiment as well as a similar one carried out by CULLITY and ALLEN [2] were fallen into oblivion until 1970, when MARKERT [3, 4] showed them to be two of the most impressive proofs of his new theory of the magnetization curve of plastically deformed f.c.c. crystals of single slip orientation. As the validity range of that theory includes not only materials as for instance magnetite, but according to MARKERT [3], can be extended at least qualitatively also to b.c.c. crystals such as iron, it follows that Blank's experiment should work on iron and on magnetite samples too. In order to prove this prediction, a series of measurements had been startet recently, the first results of which shall be outlined in the present paper.

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§ 2. Experimental Results

As in the near future the measurements shall be carried out also on magnetite single crystals, for experimental simplicity we prefered to use constant uniaxial pressure instead of tensile stress. First results have been got on two iron single crystals orientied as shown in Fig. 1 and containing 3.5% silicon each. Because of the positive magnetostriction of iron it was necessary carefully to avoid those mechanisms of reactivating the mechanical aftereffect which simply have their origin in the additional magnetostrictive pressure arising in our hydraulic press (which was locked in a way not to allow any increase in length of the sample) when an external magnetic field is applied or increased discontinuously. Thus the experiments under discussion were confined to the following two kinds of measurements that should yield at least some lower limits of the total effects expected:

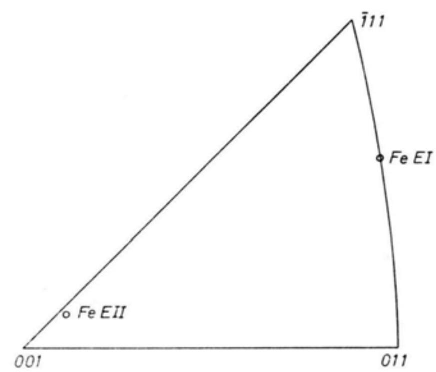
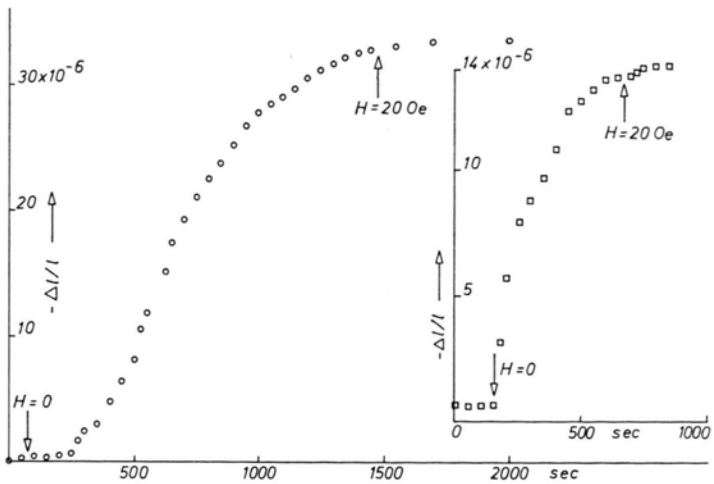


Fig. 1. Crystallographic orientation of the samples used.

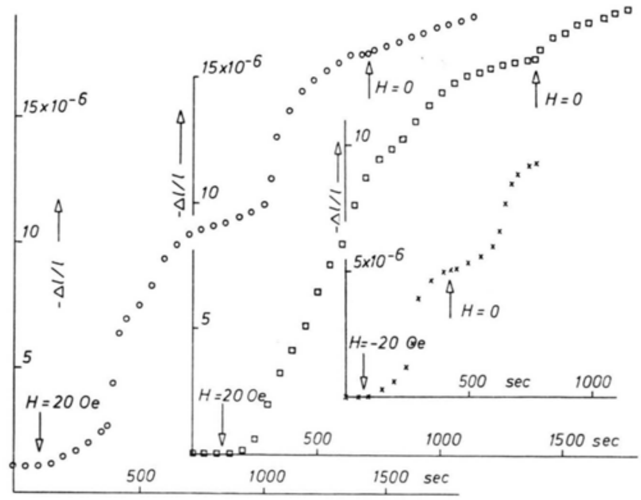
1. After annealing, the crystals had been exposed to a constant external magnetic field of 20 Oe parallel to the axis of the pressure to be applied. Then, under the influence of the superimposed magnetic field, the samples were deformed plastically by application of a given constant uniaxial pressure. When the measuring curve discribing the mechanical aftereffect, i. e. the (logarithmically) decreasing rate of contraction still observable after the pressure has been kept constant, was flattened to a nearly horizontal run, the external magnetic field had been switched off, as shown in Figure 2. The intention thereby was to cause a reactivation of the mechanical aftereffect that then should be the expected non-magnetostrictive one. After it had really set in and again decreased to negligible values, an external magnetic field of 20 Oe should be applied antiparallel to its former direction in order to reactivate once more that mechanical aftereffect.

2. The crystals had been deformed plastically in zero magnetic field by application of constant uniaxial pressure. When the mechanical aftereffect had decreased



← Fig. 2. Reactivation of the mechanical aftereffect of the sample Fe E II due to the kind of experimental conditions described under point 1. of the text. The right-hand curve corresponds to a constant applied pressure of 21.2 kp/mm², the left one was measured under constant pressure of 28 kp/mm².

Fig. 3. Reactivation of the mechanical aftereffect of samples Fe E I and Fe E II due to the kind of experimental conditions outlined under point 2. of the text. The left-hand curve as well as the right-hand one show measurements carried out on sample Fe E I under constant pressure of 19.7 kp/mm² and 26.7 kp/mm², respectively. The third curve in the middle represents the corresponding results got on sample Fe E II under constant pressure of 19.4 kp/mm². →



to negligible rates of contraction, an external magnetic field of 20 Oe parallel to the axis of pressure was switched on, see Fig. 3, in order to reactivate the mechanical aftereffect. When it again had decreased to a sufficiently small amount, the switching off of the magnetic field was another test to prove whether, according to Blank's experiment on nickel and to Markert's supposition [3] concerning the qualitative validity of his new theory even with regard to iron, a second non-magnetostrictive reactivation of the mechanical aftereffect would either set in or not.

Although the outlined experiments still are rather incomplete, obviously it follows from Figs. 2 and 3 that both iron single crystals studied show a behaviour very similar to the one described by BLANK [1] with respect to nickel single crystals. In particular it is clear that the observed effects of reactivation of mechanical aftereffects by discontinuous variation of the magnetic field cannot be attributed to magnetostrictive coupling because of at least two main reasons:

a) Magnetostrictive contractions due to field changes of 20 Oe are of the order of about 10^{-7}, i. e. very much smaller than the effects observed. Further, if magnetostrictive contractions really take place, they occur as quickly as the field changes and cannot cause the typ of aftereffect shown in Fig. 3 at the points where the external field was switched off.

b) If the effects under discussion were magnetostrictive ones, they could not be independent of whether the field was increased or decreased.

Thus the qualitative applicability of the quoted [3, 4] new theory of the magnetization curve of plastically deformed crystals appears to become probable even with regard to iron single crystals.

Acknowledgements

The author is very indebted to Prof. Dr. G. ANGEIHEISTER in whose „Institut für Angewandte Geophysik" in Munich the reported experiments had been caried out, and to Dipl.-Phys. O. SCHERBER for generous leaving of the crystals used.

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Verantwortlich für den Inhalt: A. KLEMM
Satz und Druck: Konrad Triltsch, Würzburg