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ON THE ROLE OF GRAIN BOUNDARIES ON THE BARKHAUSEN EFFECT IN ORIENTED TRANSFORMER SHEETS*

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In the present paper the irreversible changes of magnetization, registered as Barkhausen jumps, are studied on the single crystal, bi-crystalline and tri-crystalline sample of the transformer sheet. The dependence of the number of the registered Barkhausen jumps on the time of the magnetization reversal at the grain boundaries, resp. in individual grains, has been found. The results are discussed in relation to the role of grain boundaries in the magnetization process and also in relation to the possible rearrangement of the domain structure and to the clustering of the Barkhausen jumps.

О ВЛИЯНИИ ГРАНИЦ ЗЕРЕН НА ЭФФЕКТ БАРКГАУЗЕНА В ОРИЕНТИРОВАННЫХ ТРАНСФОРМАТОРНЫХ ПЛАСТИНАХ

В работе исследованы необратимые изменения намагниченности, зарегистрированые в виде баркгаузеновских скачков, для образцов трансформаторных пластин, имеющих монокристаллическую, бикристаллическую и трикристаллическую структуру. Обнаружена зависимость числа зарегистрированных баркгаузеновских скачков от времени изменения намагничивания на границах зерен или же в отдельных зеренах. Проведено обсуждение результатов с точки зрения влиянии границ зерен на процесс намагничивания, а также с точки зрения возможной перестройки доменной структуры и кластерирования при образовании баркгаузеновских скачков.

I. INTRODUCTION

The study of the domain structure behaviour at the dynamic magnetization reversal is very important for explaining the physical reasons of the magnetization losses in the oriented transformer sheets. It is kown that the character of the dynamic magnetization processes substantially differs from that of the quasistatio-

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nary ones, as indicated by the results obtained on the single-crystal samples [1—5]. Besides, in oriented transformer sheets the grain boundaries may influence the magnetization process, too [6]. The present paper presents the study of the influence of grain boundaries on the irreversible magnetization processes, registered as Barkhausen jumps on the selected samples of transformer sheets.

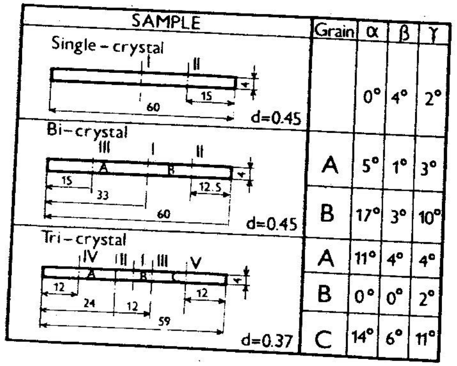

Fig. 1. Geometrical and crystallographical orientations of the samples.

II. EXPERIMENTAL

Experiments were made on Fe-3 % Si samples with dimensions 4 mm × 0.45 mm × 60 mm; resp. 4 mm × 0.37 mm × 59 mm; one sample was a single crystal, the second one contained one grain boundary and the third one contained two grain boundaries. Geometrical and crystallographical orientations of the samples are given in Fig. 1 (α — angle between [001] and the sample axis in the surface plane; β — angle between [001] and the sample axis in the plane perpendicular to the sample surface; γ — angle between (110) and the sample surface).

The Barkhausen effect was studied using the apparatus with the time resolution of 10^{-6} s, described in [7]. The number of Barkhausen pulses during one the magnetization cycle in dependence upon the time of magnetization reversal and in various parts of the sample was measured. The number of jumps was registered during the magnetization of samples in the applied external field which varied linearly with time from -5 kA/m to $+5$ kA/m. The width of the pick-up coil was 5 mm, which enabled to detect the irreversible changes of magnetization in the relatively small volumes of the sample.

III. EXPERIMENTAL RESULTS AND DISCUSSION

Figs. 2, 3, 4 show dependences of the number of Barkhausen pulses registered along one branch of the hysteresis loop upon the time of the magnetization reversal in various parts of the sample as shown diagrammatically in Fig. 1. The apparatus registered Barkhausen pulses corresponding to the changes of the magnetic moment $\Delta m \geq 1.3 \times 10^{-15}$ Wbm. These figures show clearly the influence of the time of the magnetization reversal and that of the grain boundaries on the number of the registered Barkhausen pulses. As seen from Fig. 2, for the time of the

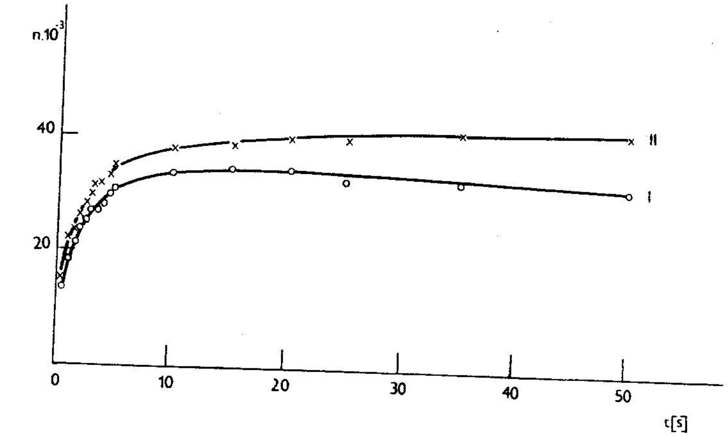

Fig. 2. Number of Barkhausen jumps vs. time of magnetization reversal on the single-crystal sample ($\Delta m \geq 1.3 \times 10^{-15}$ Wb m).

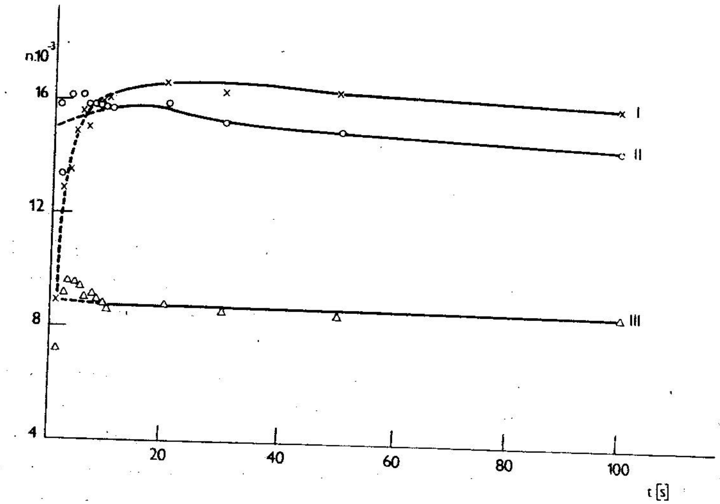

Fig. 3. Number of Barkhausen jumps vs. time of magnetization reversal on the bi-crystalline sample ($\Delta m \geq 1.3 \times 10^{-15}$ Wb m).

magnetization reversal $t>10$ s the magnetization process may be considered as a quasistatic one, while for $t<10$ s the number of the registered pulses significantly changes. The behaviour of the dependence $n(t)$ is the same for both parts of the sample, where the pulses were registered. A larger number of jumps in part II may be connected with the free ends of the sample, which act as a source of the

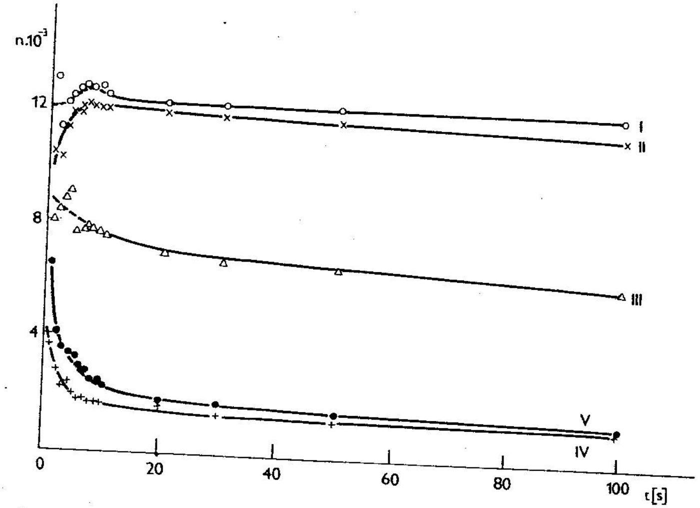

Fig. 4. Number of Barkhausen jumps vs. time of magnetization reversal on the tri-crystalline sample ($\Delta m \geq 1.3 \times 10^{-15}$ Wb m).

magnetization nuclei. At a quasistatic magnetization the grain boudaries may also act as a source of the magnetization nuclei. On the bi-crystalline sample (Fig. 3) the largest number of jumps at the quasistatic magnetization reversal was registered just on the grain's boundary. The influence of the grain boundaries (Fig. 4) as sources of magnetization nuclei on the tri-crystalline sample was very apparent (the largest number of jumps during the quasistatic magnetization reversal was registered in the middle of the sample — place I). The boundaries of the adjacent grain A—B, resp. B—C (Fig. 1), are quite near this place. Even on the tri-crystalline sample the influence of its ends (see Fig. 2) is also detectable in parts IV and V, the smallest number of jumps was registered in these places.

At the magnetization reversal for the time $t<5$ s, which — in comparison with the quasistatic magnetization reversal — shows a different number of the registered Barkhausen pulses, the grain boundaries have various effects. On the bi-crystalline sample the number of the registered pulses at the grain boundaries apparently decreases with the decrease of the time of the magnetization reversal. Less apparent changes may be observed on adjacent grains (in places II and III). The

boundary A—B (place II) on the tri-crystalline sample shows qualitatively the same character of the dependence $n(t)$. A different behaviour is observed for the grain boundary B—C (place III).

When explaining the mechanism of the magnetization reversal in the region of the magnetization times $t<5$ s, an important role should be attributed to the

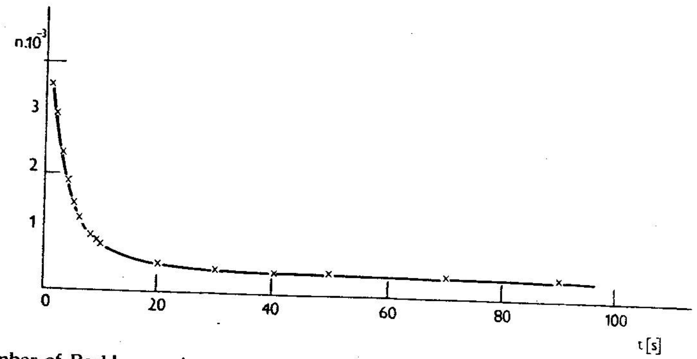

Fig. 5. Number of Barkhausen jumps vs. time of magnetization reversal on the bi-crystalline sample ($\Delta m \geq 1.3 \times 10^{-15}$ Wb m).

character of the ireversible displacements of the domain walls, with which the possibility of the clustering of several jumps into one registered pulse is connected. The changes in the statistical distribution of the fields of the irreversible growth of the magnetization nuclei [8], whose formation is characterized by the nucleation field [9], may also be of influence. An important role is played by the structure of the grain boundary itself, which usually creates favourable conditions for the formation of the magnetization nuclei. The changes in the number of the registered pulses at short magnetizing times may also be influenced by the process of the domain structure rearrangement [3], with which the changes of the secondary domain structure are connected.

The clustering of several jumps near the grain's boundary is indicated by the dependences $n(t)$ on the bi-crystalline sample, when the measurements were made with a varying resolution of the apparatus. Fig. 5 shows the dependence $n(t)$ for $\Delta m \geq 3.2 \times 10^{-15}$ Wb m. The number of jumps apparently decreases when the time of the magnetization reversal decreases. This indicates that the total decrease of the number of the registered Barkhausen pulses is connected with the clustering of several jumps into one registered pulse. As shown by the measurements, qualitatively the same situation as in Fig. 5 is on the tricrystalline sample at both grain boundaries. However, the number of the registered pulses (for $\Delta m \geq 3.2 \times 10^{-15}$ Wb m) is much smaller here.

The process of the domain structure rearrangement may result in the decrease of the total number of the registered pulses in such a case where the jumps originating during this process are smaller than the adjusted resolution of the apparatus (for example Fig. 2 and 3), and vice versa — the result is the increase of the total number of jumps when the apparatus is able to register the jumps which originated during the domain wall rearrangement (for example Fig. 4) place III on the boundary B—C, places IV and V in grains A and C).

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