Magnetization processes of Fe(Si,Al)-steels with homogeneous and inhomogeneous distribution of (Si,Al).

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Recently there has been a lot of activity trying to produce steel with an increased concentration of Si and/or Al (over 3-wt%). Materials with homogeneous as well as inhomogeneous spatial distribution of (Si,Al) have been obtained. We will discuss in the paper aspects of the magnetization processes in these new types of materials. We will compare the resulting structure properties and magnetization behavior for samples with homogeneous and inhomogeneous distribution of (Si,Al) across the width of the strips.

A concentration increase of (Si and/or Al) may be obtained by surface deposition of Si and/or Al by hot dipping followed by a diffusion annealing, whereby homogeneous or inhomogeneous distributions of (Si,Al) across the width of the strips like for CVD followed by diffusion annealing are obtained. Normally the substrate is an Fe(Si-Al)-alloy without phase transformation. It was demonstrated by us that these techniques may also be applied to substrates with low, medium and high (Si-Al)-content to obtain materials with higher (Si,Al) content and homogeneous or inhomogeneous distributions of (Si,Al) across the width. It was found that the material after dipping may be cold rolled to get the desired final thickness, especially thin electrical steels with thickness smaller than 0.35mm.

In the following the structure and the magnetization behaviour of dipped and diffusion annealed samples using FeSi-substrates without phase transformation will be regarded. To discuss the magnetization processes in these materials with homogeneous or inhomogeneous (Si,Al) distribution across the width we have to take into account that there are spatial fluctuations of the value of the fundamental parameters exchange energy (exchange constant A), anisotropy energy (anisotropy constant K), and magnetostriiction (magnetostriiction constant λ). This will affect the domain wall energy ($ED \approx AK$) and the domain wall width ($dW \approx A/K$). In addition, the roughness of these samples is relatively large, which gives additional local demagnetizing fields in the surface region. These facts are reflected in the shape of the hysteresis loops for the same samples and in the unintegrated hysteresis loops, which indicate the distribution of the critical fields for domain wall motion at lower fields and domain wall rotation processes at higher values of the applied external field, respectively.

The B vs. H loops at low frequencies indicate low values of the remanence, that means a more or less isotropic behaviour, and a broad range of the field for the approach to saturation. The broad range of critical fields for domain processes appears in the samples with homogeneous as well as inhomogeneous (Si,Al) distribution across the width. The behaviour of the investigated samples is similar to that of amorphous samples. The unintegrated hysteresis loops for homogeneous as well as inhomogeneous samples are rather similar, which point to similar magnetization processes in samples with homogeneous as well as inhomogeneous distribution of (Si,Al) across the thickness. There appears no double peak in the distribution of the critical fields for domain processes of the samples with quite different (Si,Al)-content in the surface region and in the middle of the samples, which would indicate a superposition of two magnetically different materials.

The frequency dependence of the coercive force may be used to characterize the dynamic magnetic behaviour. Regarding the domain wall spacing L the dynamic coercive force H_{dc} is proportional to $L^{1/2}$ and to the frequency $f^{1/2}$. If L is a function of frequency, deviations from the fact that H_{dc} is proportional to the square root of f may be observed. The observed behaviour for the investigated

ed samples indicates a variation of L with f , which means a variation of the number of moving walls with f .

With respect to the magnetic properties in the range up to 1000Hz it was found that the magnetization behaviour B vs. H as well as the magnetic losses P vs. B are practically the same for samples with homogeneous and inhomogeneous distribution of (Si,Al). The permeability exhibits the typical dependence as a function of the applied magnetic field and frequency. At much higher frequencies of 10kHz or higher the permeability is small and may be regarded as a constant like in the classic formulae for the skin depth. In this case the values of the permeability are finally determined mainly by the magnitude of order of the electrical resistivity, which is increased by increasing the (Si,Al) content, and the thickness of the material.

This brief discussion may indicate that the magnetization behaviour of the dipped and diffusion annealed samples may be well understood on the basis of the known relations between the parameters for the magnetization behaviour and the fundamental magnetic parameters A , K , and λ as well as the structure sensitive properties L (domain spacing), dW (domain wall width), and surface roughness. There appears no difference in the behaviour of samples with homogeneous or inhomogeneous (Si,Al) distribution across the width of the strips. The spatial fluctuations of the (Si,Al) content seem to be not remarkably relevant for the magnetization behaviour.