Texture and grain size in Ti-microalloyed non-oriented electrical steel

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Fine precipitates in the range of 100 nm are known to increase the hysteresis loss in non-oriented electrical steel (NOES) as they interact with magnetic domain walls hindering the alignment of ferromagnetic moments during magnetization cycle [1]. Such precipitates can form in NOES during the processing steps, as well as during operational life-time of the final product, the latter case being known as magnetic aging.
A European RFCS project, STabilized ELectrical Steels for Electric Mobility (STeELS-EM) is being conducted to explore the possibility to optimize the precipitation in NOES by microalloying. Ti microalloying was chosen, as Ti carbides and nitrides are expected to form at high temperatures and therefore to exceed the unfavourable size. This communication presents intermediate results related exclusively to the effect of Ti addition on the evolution of crystallographic texture and grain size through the NOES processing. The precipitation analysis results are to be published in a separate contribution.
Reference materials without Ti addition and Ti-microalloyed materials were manufactured according to the typical industrial practices of NOES production using state-of-the-art laboratory materials processing equipment. The chemical composition is shown in Table 1, the processing route is presented schematically in Figure 1. The grain size and texture were measured by means of EBSD analysis on 2x4 mm areas in the RD-TD plane at 1/4th thickness of sheets.

Table 1. Content of main alloying elements, wt.%

	Si	C	N	Al	Mn	S	Ti	Cu	P
Ref Low Si	1.02	0.0060	0.0047	0.51	0.30	0.002	-	0.014	0.014
Ref High Si	2.92	0.0060	0.0037	0.98	0.30	0.002	-	0.015	0.014
Ti Low Si	1.53	0.0053	0.0032	0.51	0.27	0.002	0.20	<0.015	0.011
Ti High Si	2.97	0.0061	0.0036	0.99	0.32	0.002	0.20	<0.015	0.012

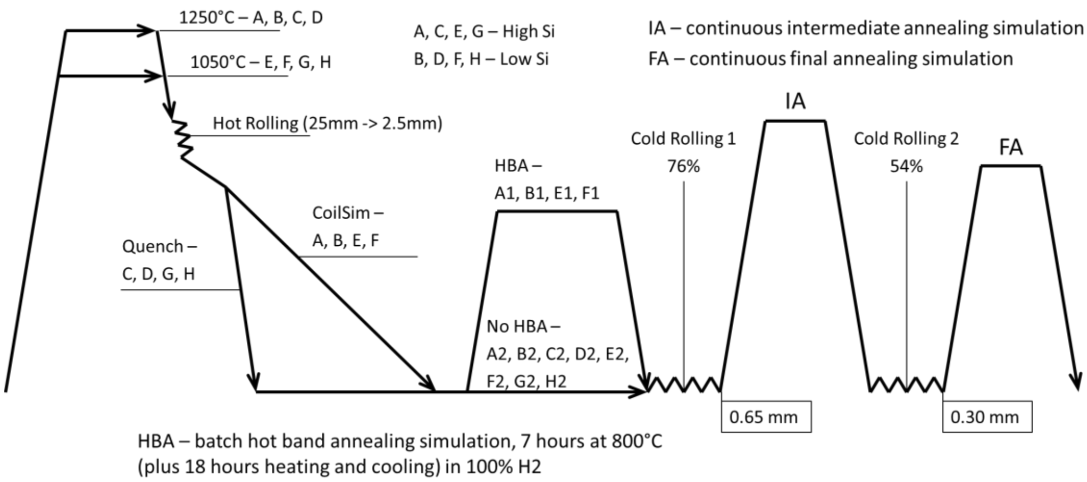

Figure 1. Schematic of the material processing followed within STeELS-EM project

The materials processing was adapted to modify the precipitation state and to improve final texture. Among the processing parameters which varied, were the hot rolling reheating temperature and cooling strategy below the finish rolling temperature. Furthermore, two downstream processing routes were selected with and without a hot band annealing. The chosen two-stage cold rolling and annealing schedule allows to avoid extensive sharpening of the γ-fibre texture in the final condition despite the increased susceptibility to form this fibre in the Ti-added materials due to the reduced interstitials content [2] (Figure 2). The pronounced Goss component in the final texture is possibly related to the large content of shear bands formed by the cold rolling step within large grains that were present after the intermediate annealing.
It is suggested that the main factors contributing to grain growth suppression are the Ti addition and the initial reheating temperature. Ti addition and higher reheating temperature result in a stronger suppression of grain growth (Figure 3).

Overall the Ti-materials have a less favourable combination of grain size and texture compared to the reference materials (Figure 3). While the texture deterioration (A-parameter increase) was expected and can probably be tolerated, the grain growth inhibition implies that the Ti precipitates did not reach the desired size, and this should be addressed in the next processing trials. A somewhat negative effect of Ti microalloying on texture can be compensated by an improved resistance to the magnetic ageing, which is the main objective of the project.

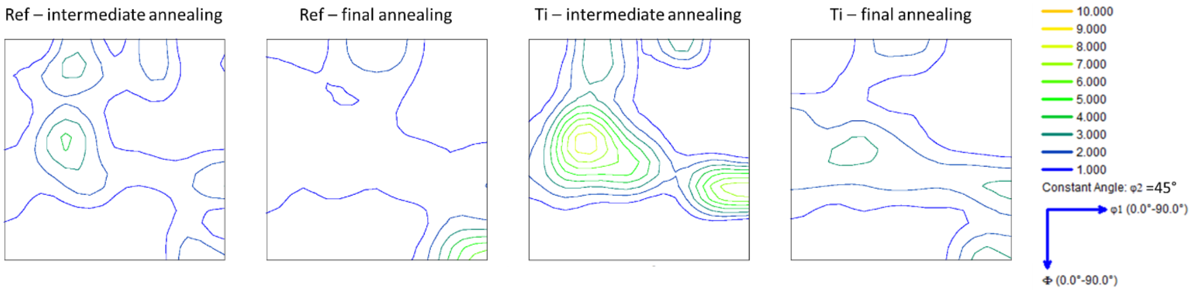

Figure 2. Typical crystallographic texture after annealing steps of processing with and without Ti addition. φ_2=45° ODF sections

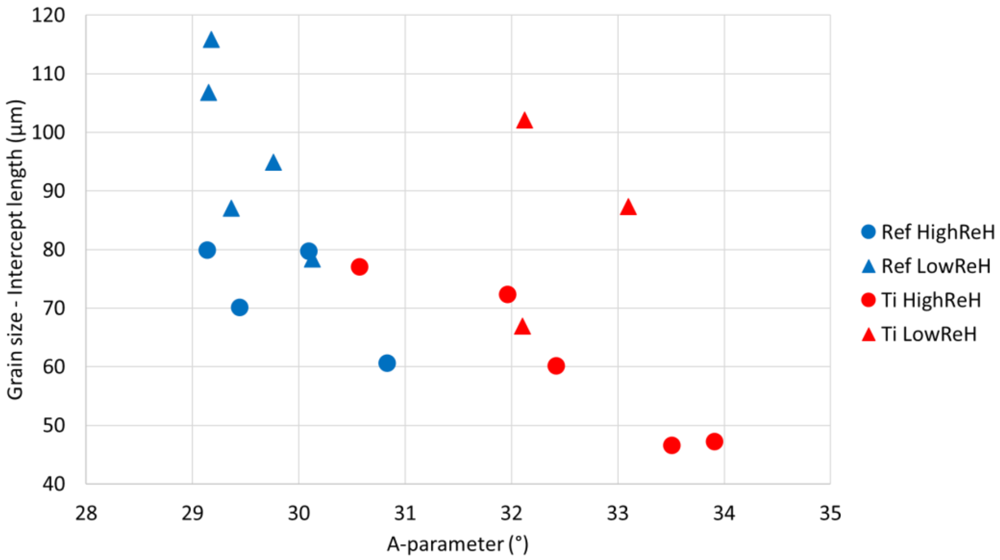

Figure 3. Grain size and A-parameter values for the final condition of the materials studied

References

[1] Chih-Wen Chen, Magnetism and metallurgy of soft magnetic materials, Courier Corporation, 2013.
[2] L. A. I. Kestens, H. Pirgazi, Texture formation in metal alloys with cubic crystal structures, Materials Science and Technology, 32(13), 2016, 1303–1315

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