

TEXTURE IN SPRAY-FORMED Fe-3.5WT%Si + 3WT%Si_p COMPOSITE AFTER HOT ROLLING

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The addition of silicon to iron improves the latter's magnetic properties by increasing the material's electrical resistivity and decreasing its magnetic anisotropy constant and magnetostriction [1]. However, at concentrations above 3.5wt%, silicon strongly decreases the ductility of Fe-Si-alloys, rendering the material too brittle to be cold or hot rolled without cracking during the production of thin sheets for electromagnetic applications [2]. Viala et al. [3] reported that, at cooling rates below 1000°C/min, the ductile-fragile transition of Fe-6.5wt%Si occurred by B2 phase ordering, which led to the formation of super-lattice dislocation. Moreover, the magnetic properties of Fe-Si alloys are affected by order-disorder transitions, a dependence that has been investigated by several authors [4, 5]. The DO3 phase has been observed only in low cooling rate processing. According to the results of Luborsky and Livingston [6], the addition of a small amount of about 0.3wt% of Al improves the ductility of Fe-Si alloys without loss of their magnetic properties.

The spray-forming (SF) process is a variant of rapid solidification processes and is based on the atomization of a liquid metal stream by an inert gas [7]. In this process, the atomized droplets are consolidated into a dense deposit on a substrate. Our group is investigating the possibility of keeping the A2-disordered phase metastable at a temperature below 973 K by adding Al to spray-form deposits of Fe-Si alloys, which could allow these deposits to be rolled without cracking [8, 9]. However, the addition of aluminum to the alloy is associated with the formation of enhanced inclusions that impair its magnetic properties. Therefore, efforts have focused on the fabrication of an Al-free alloy. To overcome the lack of ductility, the Fe-6,5%wt%Si alloy was developed as a composite: Fe-3,5%Si + 3%Si_p produced by spray forming and thus being determinant in the development of the texture. For the improvement of the magnetic properties the presence of texture after annealing, such as the $\langle 110 \rangle$ // rolling plane is desirable [8]. The aim of this work was to analyze the crystallographic texture of a SF Fe-3.5WT%Si + 3WT%Si_p after rolling operation for thin sheets production.

The methodology and equipment details to produce the deposits are described elsewhere [9]. The SF deposit was warm-rolled to the final thickness of 0.45mm, corresponding to a total reduction of 91.3% and heat treated to obtain the final microstructure. Microstructural, chemical and texture analysis were performed by using a Philips, XL30-FEG-SEM, equipped with an Oxford, Link ISIS 300 EDS and an EBSD from TSL systems, respectively. Table 1 shows the chemical composition of the matrix and particulate used for composite, determined by SEM-EDS. The reference systems used to perform this analysis is shown in figure 1a and φ_2 -45° ODF section (Bunge's notation) are used to display the textures and the locations of the important orientations in this nomenclature are given in figure 1b. Particular mention should be made of the RD (rolling direction) and ND fibres because they contain most of the important orientations in steels that have been cold rolled and annealed. These fibres are composed of groups of orientations that have their $\langle 110 \rangle$ axis parallel to the rolling direction in the former or the $\langle 111 \rangle$ axis parallel to the normal direction in the latter case.

Figure 2a shows the EBSD image quality and Fig. 2b the φ_2 -45° ODF section. From Fig.2a it is possible to observe the recrystallized and grown grains after heat treatment and that the Si particles are practically totally dissolved in matrix. Fig. 2b shows that the final texture tends to the Goss direction $\{011\} \langle 100 \rangle$ that appear in this composite after annealing in turn to be associated with nucleation of the desirable texture component.

In conclusion: (i) The production of composite material with co-injection of Silicon particles into the spray-forming was possible, (ii) The desired role of rolling and heat treatment for produce a main Goss component must be found and will be the subject of a new study in this alloy.

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References:

- [1] R.M. Bozorth, Ferromagnetism: Iron-Silicon Alloys, Van Nostrand, New York, 1993, p. 67-101.
- [2] Y. Takada, M. Abe, S.Masuda, J.Inagaki, J. App. Phys, 6410, (1988), 5367-5369.
- [3] B.Viala, J. Degauque, M. Fagot, M. Baricco, E. Ferrara, F. Fiorillo, M. Sci. Eng. A212 (1996)62-68.
- [4] D.Bouchara, M. Agot, J. Degauque and J. Bras, JMMM 83 (1990)377-382.
- [5] J. Decaugue et al., IEEE Trans. Mag. 26(1990)274-280.
- [6] F.E.Luborsky and J.D.Livingston. Magnetic properties of metals and alloys. In: Cahn, R. W.; Haasen, P. Physical Metallurgy. Amsterdam: Elsevier Science, 1996. v.3.
- [7] A.R. Singer, Int. J. Powder Met. & Pow.Met., 21 (1985) 219-234.
- [8] B. Boer, J. Wieting, Scripta Mater. 37 (1997) 753.
- [9] R. D. Cava, W. J. Botta, C. S. Kiminami, M. Olzon-Dionysio, S. D. Souza, A. M. Jorge Jr., C. Bolfarini, J. of Alloy and Comp., in press (2009).

Table 1 – Chemical composition of the matrix alloy and particulate used in this work

Elements		Fe	Si	C	Ca	Al
wt%	Matrix	Bal.	3,51	0,004	-	-
	Particulate	----	99.4	0,004	0,33	0,08

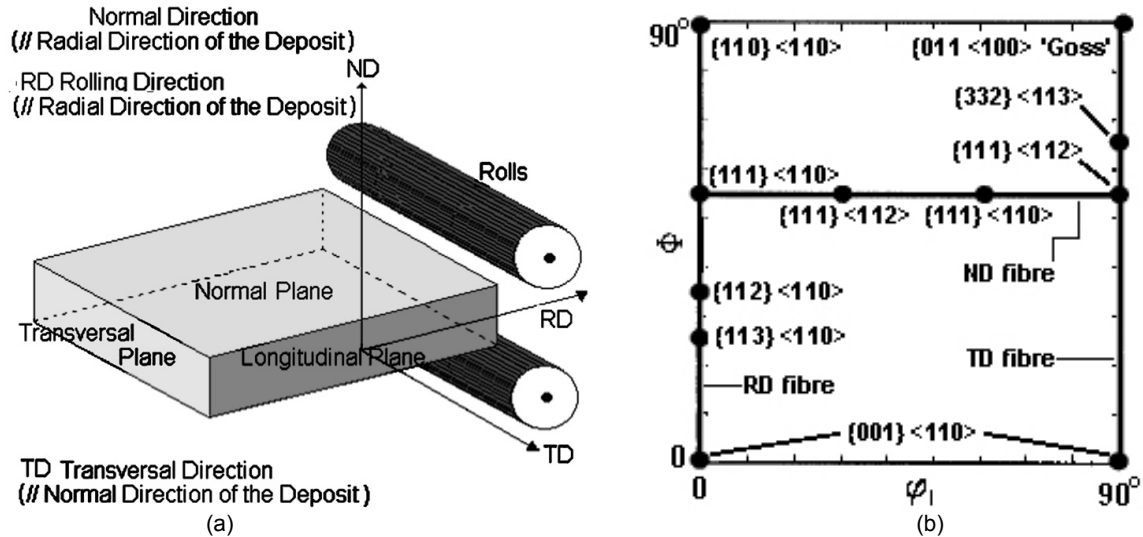


Figure 1 (a) Sample and Deposit Reference Systems. (b) $\phi_2=45^\circ$ ODF plot showing the positions of the main rolling orientations along with the RD, TD and ND fibres.

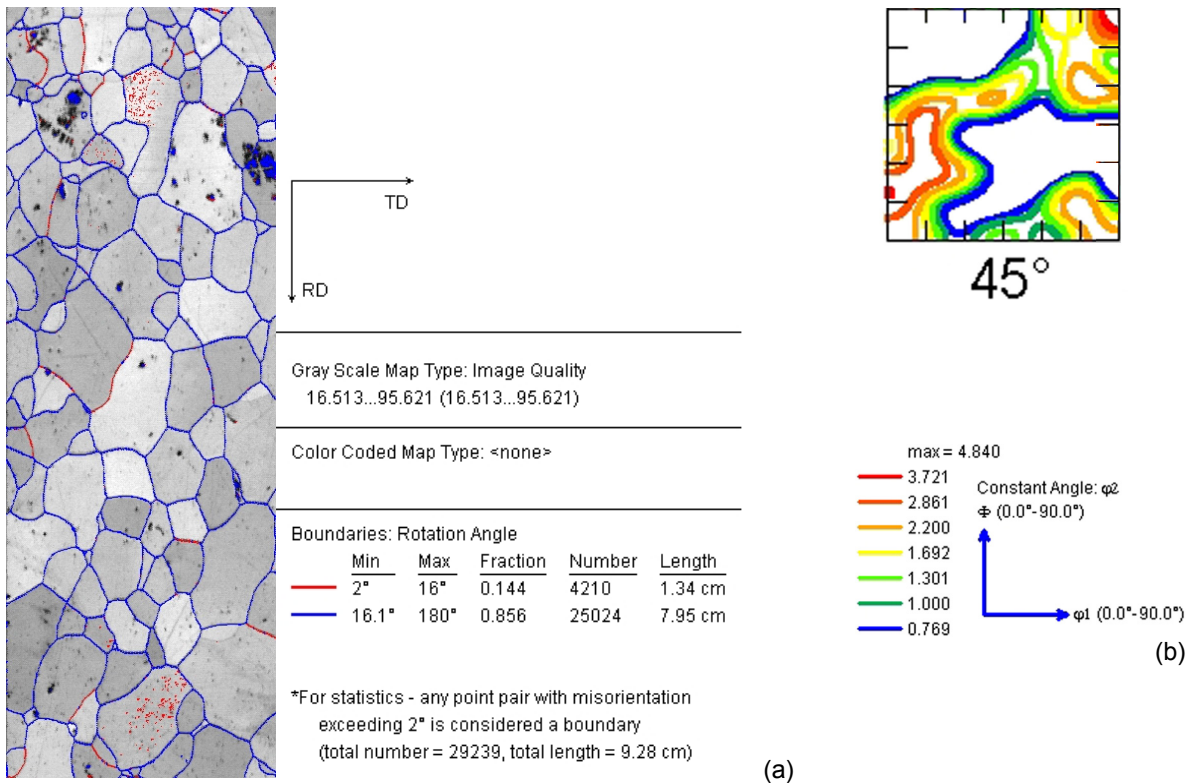


Figure 2 (a) EBSD image quality and (b) $\phi_2=45^\circ$ ODF section.