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Microstructure and segregation profiles of nitrogen-atomized Al-2.56 wt. % Fe powders

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From a technological point of view, it is important to know the conditions under which a microstructure will be produced, because the resulting microstructure after solidification, which is accompanied by a segregation profile, frequently controls the properties and the quality of the final product. Experimental studies performed on dilute alloys have determined the conditions under which planar and banded interfaces, cells, dendrites or eutectics are formed [1]. For instance, during rapid solidification, the solidification front velocity of the solid/liquid interface can be high enough to generate a microstructure and a distribution of solute, different than that obtained under normal solidification conditions. Moreover, if the atomic movement responsible for the advance of the interface, is faster than the needed for the solute to reach the interface, the resulting microstructure will be free of microsegregation.

The present study reports the resulting microstructure of a atomized Al-2.56 wt. % Fe alloy, and the associated segregation profile. Details of the experimental techniques for nitrogen atomization and microstructure characterization were reported in a previous paper [2]. In order to obtain the segregation profiles of the resulting microstructures, line scanning was performed on thin foils, by using a high resolution scanning transmission electron microscope Jeol 2100, operated at 200 kV. The Fe-content quantified by this technique, showed a maximum error of ±5%, which was determined in an Al-2.5 wt. % Fe master alloy annealed under a constant flux of argon at 500 °C for 24 h.

The microstructures observed in Al-Fe nitrogen atomized powders with diameters between 10 to 40 μm consisted of pre-dendritic (Fig. 1a), microcellular (Fig. 2a), cellular (Fig. 3a) and dendritic (Fig. 4a). With regards to the pre-dendritic microstructure, this has been mathematically predicted, according to the theory of dendrite growth into undercooled alloy melts, for the case of large undercoolings [3], and has been observed in Al-Cu [4] and Al-Mn [5] alloys. For the special case of the Al-Fe system, it has been documented [6] that two types of microstructures coexists in the Al-Fe powders, and are represented by the

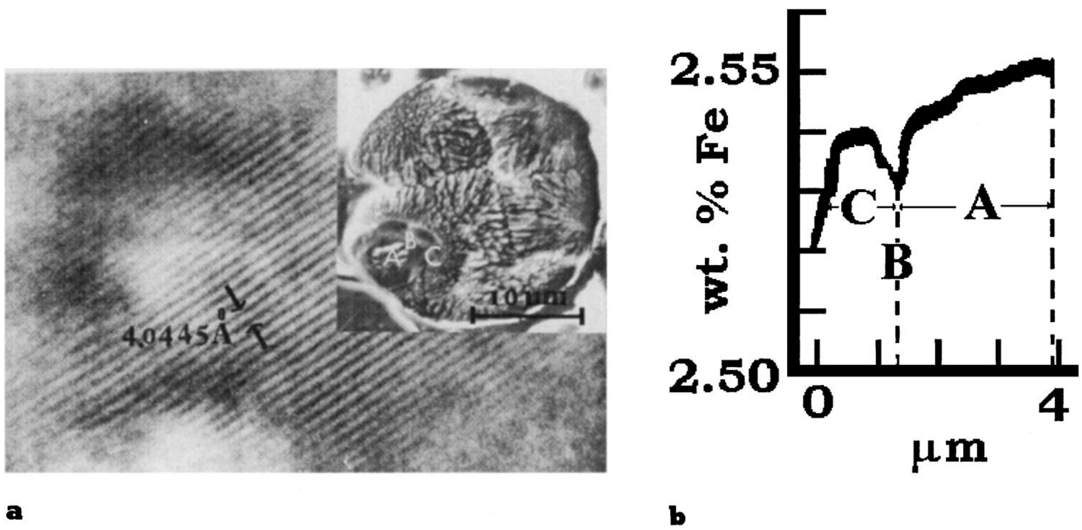

Figure 1 (a) The inset shows a pre-dendritic microstructure where regions A (circle), B (interface A/C) and C (ring) are dented. The main figure shows a high resolution transmission electron micrograph of region B. (b) Segregation profile of Fe in α-Al solid solution.

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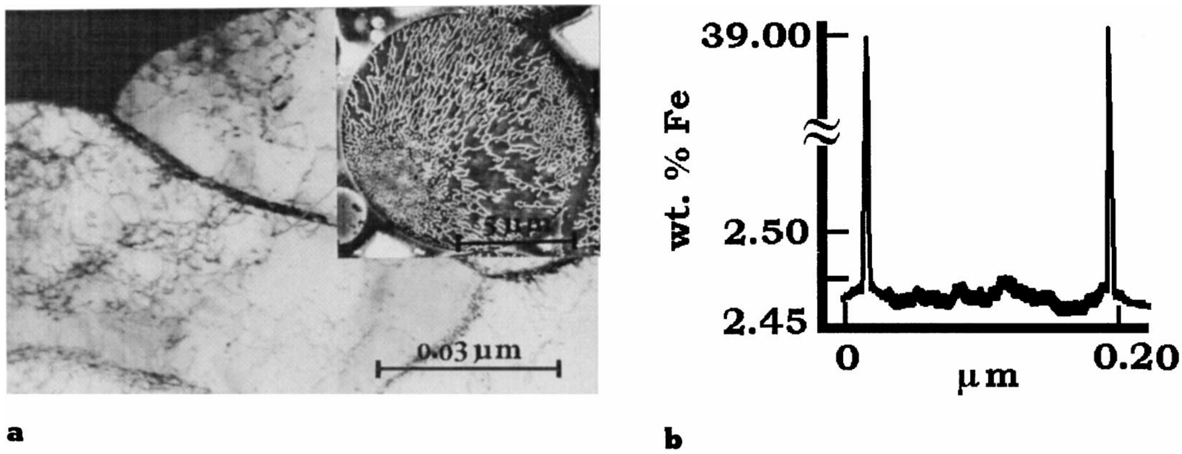

Figure 2 (a) The inset shows a powder where the microcellular microstructure was observed. The main figure shows microcellular regions where the microanalyses were carried out. (b) Segregation profile of Fe in α-Al solid solution.

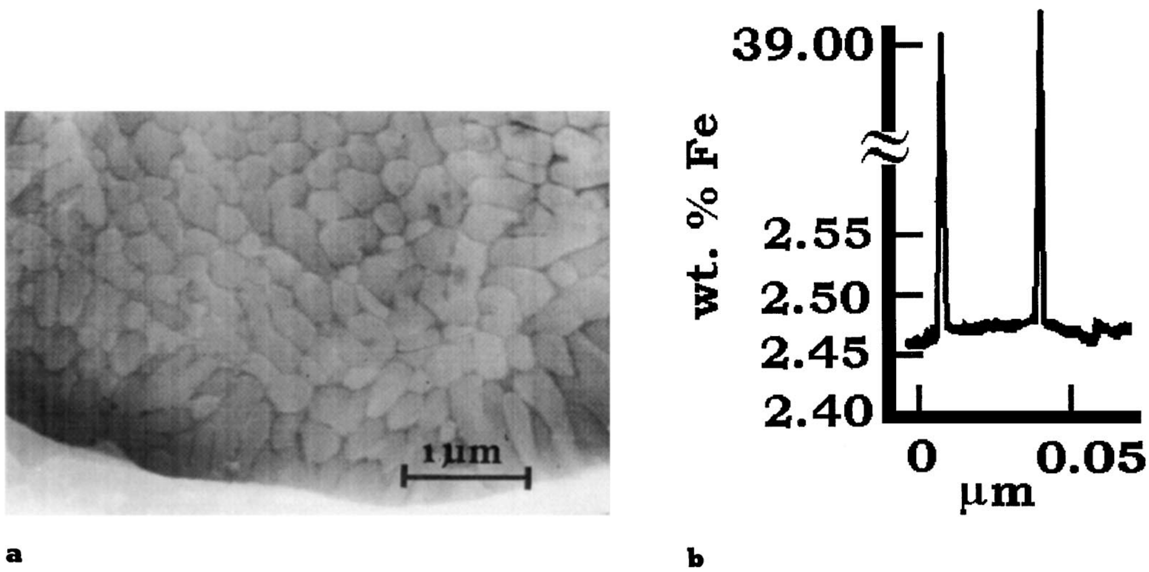

Figure 3 (a) Cellular structure observed in atomized powders. (b) Segregation profile of Fe in α-Al solid solution.

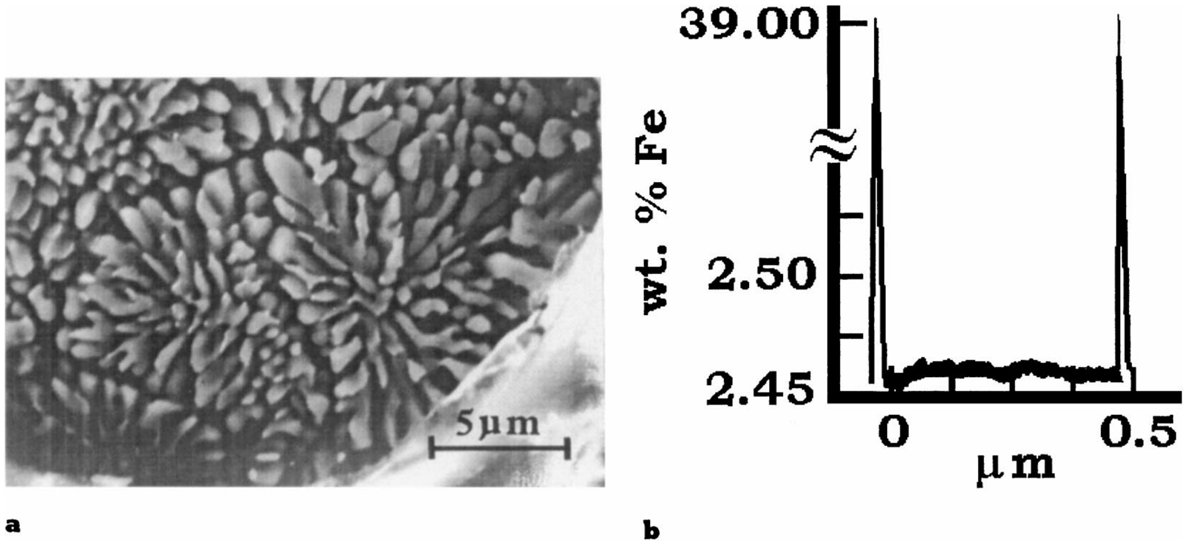

Figure 4 (a) Dendritic structure observed in atomized powders. (b) Segregation profile of Fe in α-Al solid solution.

microeutectic or microcellular structures and cellular or dendrites structures. In a previous study [7], the presence of these four microstructures was reported, but no details were given regarding solute distribution.

Fig. 1b shows a profile for the distribution of solute obtained in pre-dendritic regions. As can be observed, the distribution of Fe in the α-Al solid solution reached a maximum in region A of Fig. 1a, followed by a continuous decrease, until a minimum (2.53 wt. % Fe) was detected, in regions where a perturbation in the structure was observed. These regions corresponded to the interface A/C, denoted by the letter B. Then, the concentration of Fe started to increase, reaching a maximum of 2.54 wt. % Fe in region C, followed by a continuous decrease, until a minimum of 2.52 wt. % Fe was detected in regions where the microcellular microstructure started to growth. The corresponding solute profile for the microcellular microstructure is shown in Fig. 2b, where is observed that the amount of Fe in the α-Al matrix was almost constant, at between 2.46 to 2.48 wt. % Fe. When the line scanning touched the intercellular regions, the amount of solute reached wt. % Fe. When the line scanning touched the intercellular regions, the amount of solute reached values close to 39 wt. % Fe, close to the eutectic $\alpha + Al_{13}Fe_4$. Fig. 3b shows the segregation profile obtained in the cellular microstructure. As can be observed, the distribution of solute in the α-Al matrix was similar to that observed in the microcellular microstructure. The Fe content was between 2.46 to 2.47 wt. %. In the intercellular region a sharp increase in the amount of Fe was detected, corresponding to the eutectic $\alpha + Al_{13}Fe_4$. Finally, Fig. 4b shows the distribution of solute in the dendritic microstructure. The Fe content in the α-Al solid solution showed an uniform distribution, but the amount of Fe was lower than that detected in cellular or microcellular microstructures.

Regarding the amount of Fe retained in solid solution, it has been reported [8] that the maximum solid solubility of Fe in aluminum at equilibrium is 0.0122 wt. %. In this work, according to the microanalysis results and under the present solidification conditions, the retained Fe content in the α-Al solid solution was 2.1×10^2 times higher than the retained under normal solidification conditions, where local equilibrium can be assumed.

As mentioned before, several studies have been directed towards the ability, to produce or to predict growth morphologies and phases under normal or rapid solidification conditions, with the aim of choosing the most efficient one for a certain solidification condition, which is a desirable goal for the designer of improved materials and processes. In the case of dendritic growth, a comprehensive treatment had required accurate tracking of the solutal field during solidification [9, 10]. As it was presented in this work, important details regarding solute concentration of Fe in Al were given for four different microstructures, with the aim that these solute profiles could contribute to the better understanding of existing growth models.

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