Microstructural characterization of Fe40Al5Cr (% at.) intermetallic alloy produced by rapid solidification.

[1]R. Rodríguez, [2]J. Colín, [3]J. Arenas-Alatorre and [1]J.A. Juárez-Islas
[1]Instituto de Investigaciones en Materiales, UNAM, Circuito Exterior S/N, Cd. Universitaria, México, DF 04510, México.
[2]Facultad de Química, Universidad Autónoma del Estado de Morelos, Av. Universidad 1001. Col. Chamilpa. Cuernavaca, Morelos. C. P. 62209
Cuernavaca, México.
[3] Instituto de Física, UNAM, Circuito Exterior S/N, Cd. Universitaria, México, DF 04510, México.

Iron aluminides exhibit a great number of desirable properties that include low density, resistance at high temperature, stiffness, oxidation and sulfidation resistance [1, 2]. However, these intermetallics have limited applications because of its low ductility at room temperature and low impact failure resistance [3]. In order to reduce fragilization mechanism and improve the ductility of these materials, methodologies have been developed, such as macro and micro alloying with elements that induce passivity that include (Ti, V, Nb, Ta, Cr, Mo, W, Si y Ni) [4].

The production of intermetallics by Rapid Solidification has the following potential advantages: Refinement of microstructure, so that any composition segregation occurs only through short distances needing short thermal treatments to achieve uniformity; The potential for extend solid solubility of ternary elements beyond equilibrium compositions.

In this work results are presented regarding to the microstructural characterization of melt-spun intermetallic compound Fe40Al5Cr (% at.) produced by rapid solidification employing melt spinning technique at two different tangential wheel speeds (12, 16 ms^{-1}). Melt spun ribbons were characterized by Optical and Scanning Electron Microscopy (SEM) in order to observe grain size and morphology, besides EDS coupled to SEM was employed to perform punctual and scan line chemical analyses on samples, X-Ray Diffraction (XRD) was utilized to determinate crystal structure and phases and Transmission Electron Microscopy (TEM) was employed to confirm crystal structure and also to characterize nanopores formed by vacancy clustering.

Figure 1 shows melt-spun Fe40Al5Cr (at. %) ribbons produced at 12 and 20 m/s. Where the melt spun ribbon produced at 12 (m/s) exhibit three types of grain (chill, columnar and equiaxial). While the other ribbon produced at 20 m/s showed only equiaxial and columnar grains. The size of equiaxial grains of this ternary ribbons, exhibited a diminution from 24.7 μm to 6.61 μm as the wheel speed increased from 12 to 20 m/s. Besides, the thickness of the ribbons underwent a considerable reduction from 75.9 to 25.5 μm.

XRD analyses showed fundamental and superlattice peaks, indicating that Cr does not modify the B2 ordered structure independently of wheel speed or cooling rate employed to produce the ribbons. Besides, additional peaks pertaining to second phases were not detected, indicating also that Cr enters in solid solution in the intermetallic matrix. Ternary FeAlCr ribbons exhibit all diffraction peaks without a notorious orientation, related to a microstructure refinement.

In the same way, A. Argawal et. al. [4] observed that Cr and Ti additions were completely dissolved in a Fe_3Al intermetallic matrix, without forming second phases or precipitates.

A line scanning chemical analysis performed in as spun Fe40Al5Cr (at. %) ribbons along a length of 83 μm (4 grains) revealed a uniform distribution of Al, Cr and Fe along the line as is shown in figure 4. Thus it is evident that Cr is uniformly distributed in FeAl matrix. So it can be deduced that Cr still remains in solid solution after the rapid solidification. Besides, it is well known that rapid solidification processing produces an extended solid solubility of ternary element beyond equilibrium compositions [5].

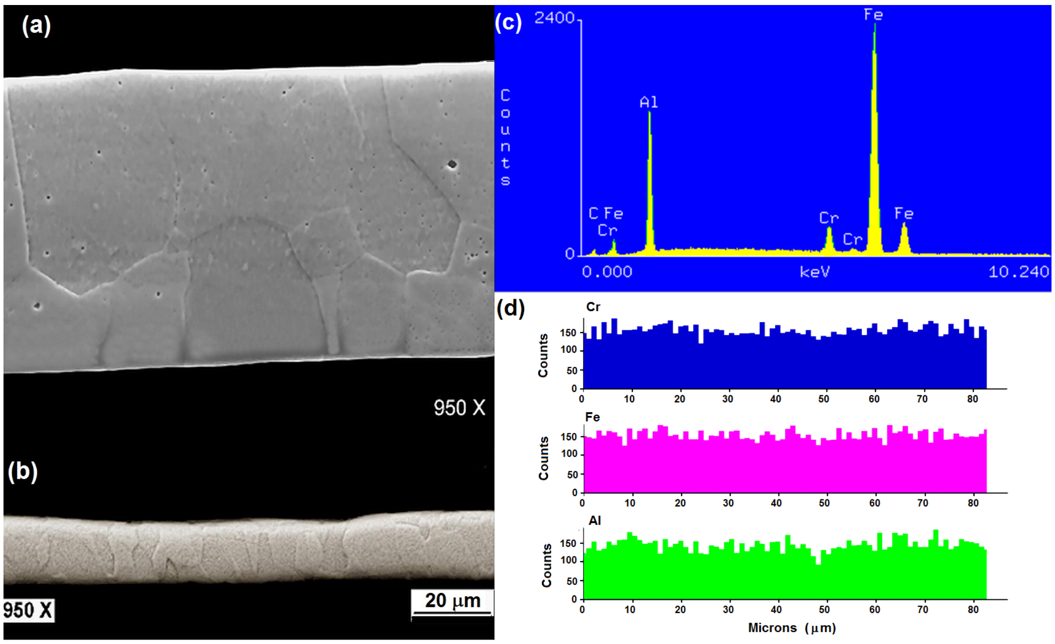

Figure 1 Scanning electron micrographs of melt spun Fe40Al5Cr (at. %) ribbons, produced at: a) 12 m/s and b) 20 m/s, c) punctual chemical analysis and, d) scan line chemical analysis along a line of 83 μm (4 grains) permorfed both in melt spun Fe40Al5Cr (at. %) ribbon.

Figure 2 a) shows an electron micrograph at higher magnification corresponding to Fe40Al5Cr (% at.) that was produces at a tangential wheel speed of 12 m/s, where it is showed triangular mesopores with a pore size fluctuating between 240 to 940 nm. Figure 2 b) shows a pore surface size distribution, where it can be noted that the highest percent of surface area, fluctuates among $60x10^3$ nm^2 to $100x10^3nm^2$. Various workers have reported pore or mesopore formation inside solid B2 intermetallics, such as NiAl [6], CoGa [7] and FeAl [8]. Pore formation inside melt-spun ribbons, can be originated from vacancy clusters generated during rapid solidification. Vacancy clusters must be stable even at high temperatures because the vacancy binding energy is positive in FeAl [8].

Figure 3 a) shows features observed inside grains that corresponds to nano pore formation by vacancy clustering. The selected area diffraction patterns confirmed that these rectangular shape features do not correspond to precipitates or inclusions, according to figure 3 b). The figure 3 a) viewed from [001] zone axis exhibits nano pores with quasi rectangular morphology together with straight border dislocations with burgers vectors parallel to <001>. One side of the rectangles showed in figure () is parallel to (100) plane and the other side is parallel to (010) plane.

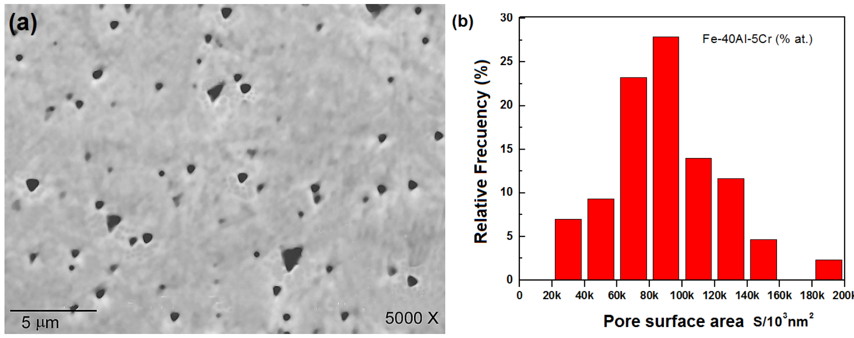

Figure 2 (a) Triangular nano porosity observed in surface of melt spun Fe40Al5Cr ribbons produced at 12 m/s, (b) pore surface size distribution obtained by image analysis.

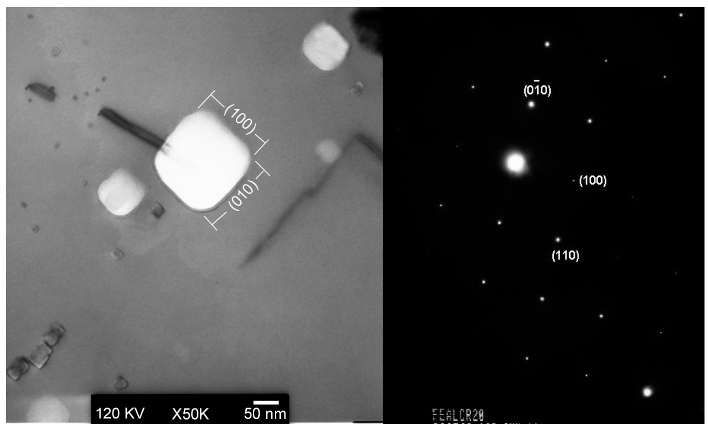

Figure 3 Transmission electron micrograph of melt spun Fe40Al5Cr (at. %) ribbon produced at 20 ms^{-1} wheel speed. (a) micropore formation by vacancy clustering together with <001> dislocations, (b) electron difraction pattern viewed from [001] zone axis corresponding to micropore.

The grain size and ribbon thickness showed a considerable reduction when the wheel employed by melt spinning technique was increased from 12 to 20 ms^{-1}.

Cr element remain in solid solution in FeAl matrix, just as revealed by XRD analyses, besides chromium is uniformly distributed among the whole melt spun FeAlCr ribbon, just as was noted by the scan line chemical analysis. Nano pore formation was generated by vacancy clustering.

References

[1] C.G. McKamey, J. Devan, P. Tortorelli, V.K. Sikka, J. Mat. Res. 6 1991 1779.
[2] J.H. Devan, P.F. Tortorelli, Corrosion Sci. 35 8 1993 1065.
[3] N.S. Stoloff, V.K. Sikka, Physical Metallurgy and Processing of Intermetallic Compounds, Chapman & Hall, 1996, pp. 56-89
[4] A. Argarwal, R. Balasubramaniam, J. Mat. Sci. 31 (1996) 5207.
[5] Jones H. Rapid Solidification of Metals and Alloys. The Institute of Metallurgist. Monograph No. 8: 1982.
[6] Y. Yang, R. A. Dodd and P. R. Strutt, Metall. Trans. 3 1972 2049.
[7] R. Schwab and V. Gerold, Acta Metall. 28 1980 433.
[8] M. A. Morris, O. George, and D. G. Morris, Mat. Sci and Eng. A 258 1998 99.