Production and Mechanical Properties of Nanocrystalline Intermetallics Based on TiAl$_3$-X

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ABSTRACT

Production of intermetallic materials in the system TiAl$_3$-X (X = Cr, Mn, Fe) has been achieved by means of mechanical milling and sintering techniques. Spark plasma sintering is used since it reduces time at high temperature and inhibits grain growth. The produced materials have grain sizes in the nano and microscale depending on the material and processing variables. The TiAl$_3$-X alloys are formed mostly by the cubic L1$_2$ phase. The average grain size ranges between 30 and 50 nm in the as sintered condition. Aging at elevated temperature has been used to promote grain growth. Compression tests have been performed to evaluate mechanical properties as a function of temperature and grain size. In all cases yield stresses higher that 700 MPa are obtained together with a ductility that depends upon temperature and grain size. No ductility is found for the smallest grains sizes tested (30 nm) at room temperature. Above 673 K, these materials show ductility and additionally they present a quasi superplastic behavior at temperatures higher that 973 K. On the other hand ductility can also be developed in the TiAl$_3$-X alloys by inducing grain growth via annealing. Alloys with grains sizes around 500 nm show high ductility and a large density of microcracks after deformation suggesting that the yield strength becomes lower than the stress to propagate the cracks. In such materials, a considerably high strength is retained up to 873 K.

INTRODUCTION

Ti-Al alloys have been thoroughly investigated for high-temperature applications because of their low density, good corrosion resistance, and mechanical properties. Nevertheless, TiAl and TiAl$_3$ based intermetallic materials are brittle at ambient temperature. Different approaches have been attempted to increase the room temperature ductility of these alloys. For example, modification of the chemical composition by alloying with substitutional elements (e.g. V, Cr, Nb, W, Mn and Si), promotes higher ductility and fracture toughness [1]. Additionally thermomechanical treatment achieves excellent results concerning high strength and ductility at moderate and high temperatures through the development of lamellar microstructures [e.g. 2]. On the other hand, TiAl$_3$ based alloys with addition of some transition metals develop a L1$_2$ ordered structure [3]. The higher number of independent slip systems in the cubic L1$_2$ structure should promote a higher ductility but this has not been observed yet. An increase of ductility could also be achieved by reducing the grain size. It has been predicted that nanograin intermetallic materials will show both higher strength and ductility [3]. Nevertheless, mechanical testing in these materials has rendered modest results in the systems TiAl [4] and NiAl [5]. It is likely that such results can be explained on the basis of artifacts related to specimen preparation. For example, porosity and particle debonding has been reported as a major source of brittleness in materials processed by powder metallurgy methods. However, little is known regarding the deformation mechanisms and especially the dislocation activity in this type of materials. Thus research aimed to the production of nanocrystalline materials by improved experimental techniques is relevant. There has been