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Quasi-Crystalline $Al_{70}Cu_{20}Fe_{10}$ by Thermal Explosion: Effect of AlCu Doping on Magnetic Properties

B. Bendjemil[a, b], J. Bougdira[d], N. Segheri[b], W. Ramdane[a], A. Hafs[a], S. Habes[b], and D. Vrel[c]

[a] *Laboratory LEREC, Department of Physics, Faculty of Sciences, University Badji-Mokhtar Annaba, B.P. 12, Annaba, 23000 Algeria*

[b] *Faculty of Sciences and Engineering, Department of Mechanical Engineering, University of Guelma, B.P. 401, Guelma, 24000 Algeria*

[c] *Laboratoire d'Ingénierie des Matériaux et des Hautes Pressions, UPR CNRS 1311-Université Paris Nord, Institut Galilée, 99 Av. Jean-Baptiste Clément, Villetaneuse, 93430 France*

[d] *Laboratoire de Physique des Milieux Ionisés et Applications, Equipe de Plasma Réactif et Couches Minces, UMR CNRS 7040, Faculté des Sciences, UHP Nancy I, B.P. 239, Vandoeuvre-lés-Nancy, Cedex, 54046 France*

e-mail: Badis23@yahoo.fr

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Abstract—Polycrystalline quasi-crystals of icosahedral $Al_{70}Cu_{20}Fe_{10}$(i-$Al_{70}Cu_{20}Fe_{10}$) were prepared by thermal explosion (TE) of mechanically activated mixture of Al, Cu, Fe powders doped with AlCu. The effect of AlCu dopant was studied by XRD, field emission scanning electron (FESEM), optical microscopy (OM), atomic emission spectroscopy (AES), and energy-dispersive X-ray microanalysis (EDX). The synthesized i-$Al_{70}Cu_{20}Fe_{10}$ and intermetallics (Al_3Fe, Al_2Cu) show soft ferromagnetic and paramagnetic properties, respectively.

Keywords: *thermal explosion, icosahedral $Al_{70}Cu_{20}Fe_{10}$, intermetallics, ferromagnetics*

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1. INTRODUCTION

Interest in AlCuFe alloys can be explained by their low cost and toxicity. To date, their fabrication has been well mastered [1]. The bulk materials as well as their thin films exhibit the surface properties of quasi-crystalline alloys and a low brittleness due to the presence of a substrate. The quasi-crystalline icosahedral AlCuFe alloy (hereinafter i-AlCuFe) shows such valued properties as high hardness, low friction [2], and high resistance to corrosion [3] and oxidation [4, 5]. The latter is very important for high-temperature applications.

Over the past years, much attention has been given to synthesis of advanced engineering materials—including metals, ceramics, intermetallics, alloys, and some composites—in their stable, metastable, crystalline, quasi-crystalline, and amorphous phases. Among these materials, quasi-crystalline alloys are known to exhibit a unique structure–property relationship. After the discovery of the i-phase with fivefold symmetry in rapidly solidified alloys [6, 7], many new Al-based binary, ternary, and quaternary icosahedral alloys have been discovered in their metastable and then in the stable form [8–11]. Since icosahedral phases are mostly metastable, they were prepared by rapid quenching or by some other nonequilibrium techniques. It is interesting to note that the composition $Al_6Cu_{20}Fe_{15}$ was formed in the metastable icosahedral alloy when prepared by melt spinning [11]. The preparation of the stable bulk i-AlCuFe alloy by conventional solidification technique is now well known [10] as well as by hot-rolling followed by the ECAE process [18].

Nevertheless, the preparation of thin i-AlCuFe quasi-crystalline films and especially very thin films (up to 0.1 μm) still meets some technical difficulties [16]. The i-AlCuFe coatings with the grain size below 400 nm were produced by electron-beam PVD.

Quasi-crystalline i-AlCuFe is known to exhibit soft magnetic properties, high mechanical strength, and good tribological characteristics in coatings and in bulk at the mean grain size about 50 μm [17].

The discovery of thermodynamically stable i-AlCuFe quasi-crystal opened up new horizons for its experimental investigation. The formation of i-phase in the same composition suggest that is a two-step process involving the diffusion of Al into Fe and formation of Al_3Fe at the first step followed by the formation of Al–Cu–Fe upon diffusion of Cu into Al_3Fe at the second step. Earlier, Al–Cu–Fe systems have been studied [12–15]—mainly for two nominal compositions,