AMORPHOUS AND NANOSTRUCTURED
Al-Fe AND Al-Ni BASED ALLOYS

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Abstract: Al-based systems allow obtaining microstructures composed of different combination
of several classes of phases: crystalline solid solutions, amorphous solid solutions, crystalline intermetallic compounds and quasicrystals. Many Al-Fe based systems are
icosahedral phase formers, but non icosahedral phase was reported in Al-Ni based
systems. The strong hetero-atomic interaction in the liquid of Al-based alloys appears
to have a big effect on the amorphous forming ability. In order to analyse the
amorphous forming ability and the amorphous structure of Al-Fe and Al-Ni based
alloys, series of samples were produced by melt spinning. The structure was
characterized by means of X-ray diffraction, Mössbauer spectroscopy and transmis-
sion electron microscopy. Clusters with medium range order in the Al-Fe based
alloys were found and the icosahedral short range order in the amorphous structure is
discussed. These alloys have a heterogeneous amorphous structure at nano-scale. The
relationship among the different phases obtained by rapid solidification in the Al-Fe
based systems is discussed considering the hetero-atomic interaction and the ability
for clusters formation in the liquid.

1. INTRODUCTION

Al-based alloys with very refined microstructures having great potential for techno-
logical applications have been developed in the last two decades. The technological
interest in these Al-alloys arises from their low density and the ability to produce several
kinds of microstructures with good combined properties. The Al-based systems give the
possibility to obtain microstructures composed of different combinations of several
classes of phases: crystalline solid solutions, amorphous solid solutions, crystalline
intermetallic compounds and quasicrystals [1-3].

Early in the 80s only few reports were published on fully amorphous Al-based alloys,
but all of them reported brittle failure of those alloys. Meanwhile the advantage of the
rapid solidification process for producing refined microstructures was used for elaborat-
ing the "nanocrystalline Al-based alloys" with high mechanical strength. The micro-
structure of those alloys basically consisted in a high volume fraction of small size
intermetallics dispersoids embedded in a rich solute content Al matrix. Al-Fe and Al-Ni
based alloys with different mechanical properties were developed [1, 4, 5].

In 1984, Shechtman et al. [6] published the first paper on a "quasicrystalline phase"
in the Al-Mn system. Since that report many papers focused on the structure and
properties of the quasicrystalline phases have been published [7].

In 1988, the first "ductile amorphous Al-based alloys" were reported by Shiflet et al.
systems. Also, ductile amorphous alloys with high strength were produced in Al-Fe-
ETM systems (with ETM: Zr, V or Nb), [1, 5].

The existence of ductile amorphous Al-based alloys gave a great impulse for
developing nanostructured alloys, particularly by crystallization process from an
amorphous precursor. In this way, microstructures composed of α-Al nanograins
embedded in an amorphous matrix can be produced [10]. These "nanostructured alloys
with amorphous matrix" have up to 50% higher tensile strength than the precursor
amorphous alloy [1], but they present a ductile-brittle transition related to the volume
fraction of the α-Al nanograins [11]. During the crystallization process, whereas the
α-Al nanograins grow, the average chemical composition of the remaining amorphous
matrix changes increasing the solute content which increase the mechanical strength [1,
11]. The resulting strength and the ductile-brittle transition have been explained, for the
Al-Ni-Y system, by the simple rule of mixtures involving the strengthened amorphous
matrix and the α-Al nanograins of ideal strength [11]. This kind of nanostructured alloys
can be produced from the solid state easily controlled by means of heat treatments;
however it has a limit temperature for application in order to avoid the ductile-brittle
transition.

Another class of nanostructured alloys are those called "nanoquasicrystalline alloys"
which are composed of icosahedral particles embedded in a crystalline α-Al matrix [1].
This kind of microstructure is produced directly from the liquid state. The first report
focused on the study of the microstructure and its properties could be that from Inoue et
al. [12] in 1992 on Al-Mn-Ce system. This kind of alloys was developed also in Al-Cr-
RE systems and more recently in the Al-Fe-Cr-ETM [3, 13, 14]. These alloys have
metastable phases, while the alloys from the latter system have a good stability of
the microstructure which allows to retain a high strength at temperatures ~350 C [13].

The "amorphous nanogranular Al-based alloys" are an intermediate class of nano-
structured alloys between nanostructured alloys with amorphous matrix and
nanoquasicrystalline alloys. These alloys have a microstructure composed of granules of
an amorphous phase with 2 to 5 nm sized embedded in an α-Al matrix [1, 3]. Also these
alloys are obtained directly from the liquid state, particularly in the Al-Fe-V and Al-Fe-
Ti systems [1]. It was suggested that the amorphous granules have an icosahedral short
range order [1, 3], which could be explained as an initial stage of a nanoquasicrystalline
alloy.

It is known that the transition metals in the liquid Al produce a strong hetero-atomic
interaction. This was earlier observed by Gebhardt et al. [15] in 1953 when they noted
that low Fe concentration increase the viscosity of liquid Al. Maret et al. [16] have