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Glass forming ability of Al-Ni-Gd alloys

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Abstract – In the present work the influence of the topology on the glass forming ability of Al-Ni-Gd alloys are discussed. The formation of the amorphous phase in the ternaries Al-Ni-Gd was evaluated in correlation with the λ-criterion. Alloy compositions were designed around the condition of $\lambda = 0.1$. The glass forming ability which can be associated with cluster configurations in the liquid alloy is discussed as a function of the kind of clusters formed among of the constitutive elements. Ingots were prepared by arc-melting into Ar atmosphere using pure (99.99 wt.%) Al, Ni, Gd elements. Amorphous ribbons were then obtained by melt-spinning with Cu-wheel (200 mm diameter) rotating at a peripheral velocity of 30 ms^{-1}. The ribbons 3 mm wide, about 35 μm thick and several tens of centimeters long were characterized by x-rays diffraction (XRD) and differential scanning calorimetry (DSC). The result from energy released on DSC as well as x-rays diffraction patterns shown that the glass forming ability is improving with the Gd content as well as the stability of the supercooled liquid region reach better values reaching 29 K in $Al_{86.5}Ni_5Gd_{8.5}$ alloy.

The formation of the amorphous phase in the ternary Al-Ni-Gd system was evaluated in correlation with the topological instability "λ-criterion" [1] and associated with cluster configurations in the liquid alloy as a function of the atomic radius and elastic constants of the constitutive elements. This approach is based in recent studies of molecular dynamics simulations on binary systems that suggest the possibility of atomic arrangements with different types of polyhedra in the same alloy into the context of "soft" atoms [2].

On the other hand, other thermodynamics computational studies show the importance of the elastic constants for the increase of the Gibbs free energy of the solid solution or intermetallic compounds which favors the stabilization of the supercooled liquid or amorphous phase.

Alloy compositions were designed around the condition of $\lambda = 0.1$ as shown in Fig. 1a and although all compositions have the same topological instability condition the solid structure and the crystallization behaviors are totally different as observed in Figs 1 b and 1 c. Among those differences the most noteworthy is the absence of a glass transition temperature T_g, marked by arrows in Fig. 1c; in samples containing more rare-earth element with the larger average atomic radius, a clear T_g is evidenced.

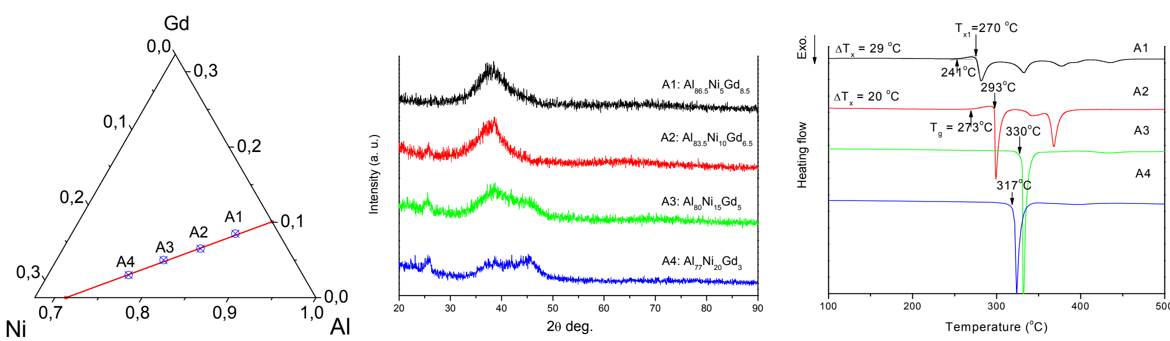

Figure 1: a) Schematic representation of Al-Gd-Ni system and the selected alloy compositions over the $\lambda = 0.1$ line. **b)** X-ray diffraction patterns from ribbons rapidly solidified by melt-spinning processing with cooper wheeler rotating at 30 $m.s^{-1}$ **c)** DSC thermograms from rapidly quenched ribbons obtained at the heating rate of 40 $K.min^{-1}$

[1] R. D. Sá Lisboa, C. Bolfarini, W. J. Botta F., and C. S. Kiminami, App. Phys. Letters 86, 211904 (2005).
[2] H. W. Sheng, W. K. Luo, F. M. Alamgir, J. M. Bai and E. Ma, Nature Vol. 439 (2006) 419.