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AL-U BASED AMORPHOUS ALLOYS OBTAINED BY MELT SPINNING METHOD

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Abstract. New Al-U based glassy alloys are reported and their glass forming ability is discussed in the frame of the existing GFA criteria. Uranium is a good glass former in binary, ternary and quaternary compositions although the atomic size mismatch condition is not satisfied.

The understanding of glass forming ability (GFA) is one of the most important themes in the metallurgy of non-equilibrium alloys. This is particularly true for the Al based amorphous alloys used as precursor material for bulk nano - crystalline compounds. Since 1988, following the discovery of ductile Al glasses [1,2] an increasing number of ductile Al based amorphous alloys (with Al content more than 85 at.%) have been created following some empirical rules: i) the averaged atomic size difference expressed by the Egami's λ parameter [3] should be higher than 0.1; ii) the heat of mixing should be negative and iii) the GFA, in general, is increasing with the number elements satisfying the former two conditions.

The most popular compositions are ternary $Al_{100-x-y}LT_xRE_y$ ($5<x<10$, $2<y<10$), where LT stands for late transition elements Ni, Co, Fe or a combination of them and RE stands for Y and rare earth elements or mischmetal.

In this work we put the question whether one can replace the lanthanide element with an actinide in the above binary and ternary formulas. We report, first in the literature, on $Al_{100-x}U_x$ and $Al_{100-x-y}Ni_xU_y$ type glassy alloys prepared by melt spinning. The 3 mm wide and 25 μm ribbons were cast under Ar atmosphere. The peripheral velocity of the wheel was 40 m/s. The amorphousness was checked by X-ray diffraction using CuK_α radiation. We have obtained fully glassy states for x =8 binary alloys and for (x=5, y=5) and (x =10, y = 2) ternary alloys. Quaternary alloys $Al_{85}Y_5Ni_8Co_2$ and $Al_{85}U_8Ni_5Co_2$ without low temperature DSC pre-peak (below 300 °C) have been also prepared.

Crystallization kinetics was examined by differential scanning calorimetry (DSC) in continuous scanning mode. The results are summarized in Table 1, where the activation energies for the first and second peaks are also indicated for some of the alloys.

The GFA for the Al-U based alloys are discussed in terms of the following criteria:

i) The atomic size mismatch was calculated using the following metallic radii 1.43; 1.56; 1.24 and 1.25 Å for Al, U, Ni and Co, respectively. The criteria of Egami and Waseda [3]:

$$\lambda = C_B\left|1-\left(\frac{R_B}{R_A}\right)^3\right| + C_C\left|1-\left(\frac{R_C}{R_A}\right)^3\right|,$$

where C is the atomic fraction and R is the metallic radius, is satisfied for $\lambda > 0.1$.

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Table 1. DSC and GFA parameters.

Composition	T_{x1} (K)	T_{x2} (K)	ΔE Kissinger eV	Λ Egami-Waseda	α Mondal-Murty	σ Park and Kim
$Al_{92}U_8$	512	515	1.49 1.66	0.025	0.531	0.013
$Al_{90}U_{10}$	510	516	-	0.032	0.546	0.016
$Al_{90}Ni_5U_5$	499	614	1.06 1.79	0.033	0.530	0.016
$Al_{88}Ni_{10}U_2$	454	572	1.5	0.040	0.521	0.022
$Al_{85}Ni_8Co_2U_5$		618		0.050		
$Al_{85}Ni_5Co_2U_8$		623		0.047		

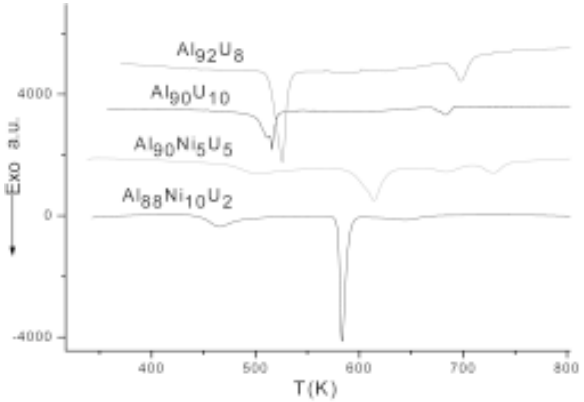

Fig. 1. DSC diagrams for the as cast samples, β = 40 K/ min.

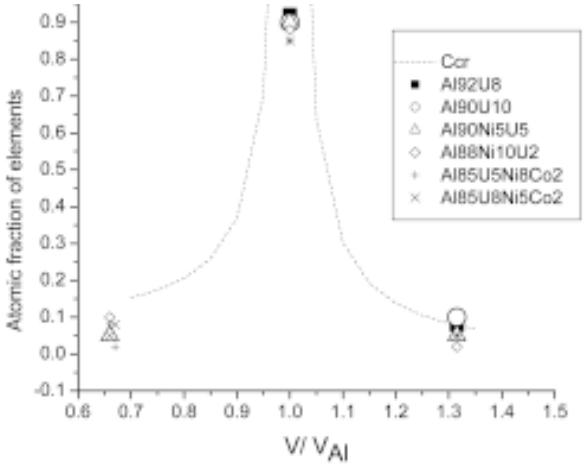

Fig. 2. Miracle plot for the new Al-U based alloys.

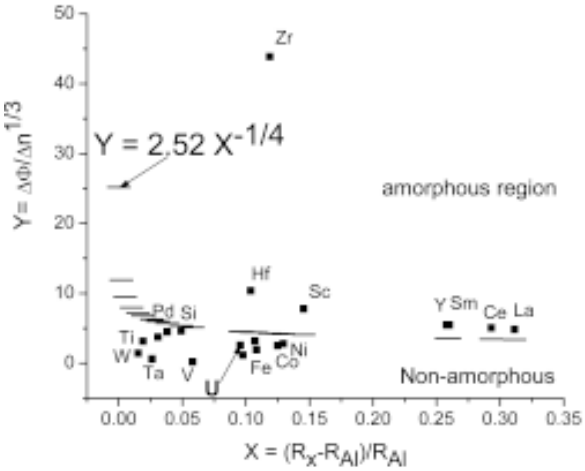

Fig. 3. Zhang Bangwei diagram for Al-X alloys.

ii) The atomic fraction of the elements are represented in Miracle plot [4] as a function of the relative atomic volume in Fig. 2. Amorphous state is expected above the critical concentration: C_{cr} = 0.1/abs(V_x-V_{Al}/V_{Al}). Excepting the binary alloys, much higher concentrations of smaller or larger atoms would be required to produce a topological instability in these multicomponent Al based alloys.

iii) In the absence of T_g for the Al-U based alloys, the g parameter of Lu and Liu [5] is defined as, $\gamma = T_x/(T_x+T_m)$. For good GFA γ >0.33, which is equivalent to $T_x > T_m/2$, where T_m is the melting temperature. This condition is fulfilled for all the Al-U based alloys.

iv) a similar but somewhat stronger condition is that of Mondal and Murty [6], $T_x > T_l/2$, where T_l is the liquidus temperature. This condition is also fulfilled for all the Al-U based alloys.

v) The parameter σ of Park and Kim [7] combines the fractional depress of T_l, ΔT, and the effective atomic mismatch of each solute atom, P as $\sigma = \Delta TP$. The values for s given in Table 1 are all well below the good GFA limit of 0.1.

vi) Zhang Bangwei diagram [8] combines the Miedema parameters with the atomic mismatch in Fig. 3. The Al-U alloy is situated in the non-amorphous region.

As a conclusion we can state that experimental results of this paper satisfy the GFA criteria iii) and iv) only. Nevertheless, the Uranium as an actinide element forms stable binary, ternary and quaternary Al based metallic glasses similar to the lanthanide elements.

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