MARTENSITIC TRANSFORMATIONS IN TI-NI-CU ALLOYS ANNEALED

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Abstract. *Alloys with shape memory effect have immense potential for applications in robotics, automotive and aeronautics industry, medicine and in the production of miniaturized actuators. Initially prismatic bars of Ti-Ni_{50-x}-Cu_x (x =5, 6 e 7% at.Cu) had been produced by plasma fusion, and annealed 800ºC for 15 minutes. Caracterization by: DSC and XRD. The alloys showed phase transformations in single stage B2↔B19`. The transformation temperatures of the alloy Ti-Cu-Ni decrease with the increase of Cu.*

Keywords: *Smart Materials, Alloy Ti-Ni-Cu, Martensitic Transformation Temperatures*

1. INTRODUCTION

As Shape Memory Alloy develop from an interesting materials phenomena to products with useful engineering applications. The shape memory effect was first found in a Ti-Ni equiatomica (BUEHLER et al, 1963;. WANG et al., 1965). Although the same effect has been previously discovered in Au-alloys 47.5 at.% Cd and In-Ti (OTSUKA & REN, 2005), did not attract much attention from researchers. However, since Ni-Ti alloys have become well known after the discovery in part by publications made by researchers at the United States Naval Ordnance Laboratory (Naval Ordinance Laboratory English-USA) (OTSUKA & REN 2005). Typically only small concentrations (1-2%) of ternary elements are possible without the formation of second phases that are detrimental to the shape memory effect. Ternary TiNiCu alloys provide a number of useful modifications, principally in the fases martensitic and consequently the shape memory effect. Alloy NiTiCu substitution of >20% Cu in Ni. The addition of Cu results in a more narrow hysteresis between the temperatures of the austenite-manensite and manensite-to-austenite transformations. Such a narrow hysteresis has the advantage of causing a "quicker" shape change. requiring a smaller deviation during thermal cycling. hen the work was aimed at implementation and evaluation of Ti-Ni-Cu alloys, varying the concentration of copper (5, 6 and 7 at.%) in place of nickel (Ni) in order to obtain alloy SMA with the possibility of application in various areas of engineering.

2. EXPERIMENTAL

The aim of this study was to investigate, develop and manufacture materials with shape memory effect of Ti-Cu-Ni alloys produced by PPSP. The methodology used for the production of Ti-Cu-Ni alloys by fusion plasma (Plasma Skull Push-Pull), and Ti-Ni-Cu alloy characterization by: DSC (Differential Scanning Calorimetery) and XRD (X-ray diffraction). Initially prismatic bars of Ti-Ni50-x-Cux (x = 5, 6, 7 at. Cu%).

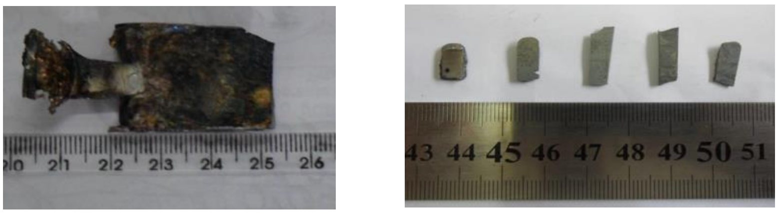
In order to know the properties of the alloy Ti-Ni-Cu system with regard to the effect of shape memory alloys were produced with the potential applications of the type microactuators and / or sensors, that is, processing temperatures in the range -10 ° C to 120 ° C. The alloys were produced by varying the concentration of Cu (copper) in the percentages of 5, 6 and 7% at.Cu, therefore, only substituting Ni (nickel) on Ti-Ni-Cu. The materials used to form the alloys were commercially pure nickel (> 99.9%), titanium biomedical ASTM F67-00 (grade 2) and commercial Copper. The amount of material for each alloy were weighed approximately 30 g.

The Ti-Ni-Cu alloys were manufactured from pure metals Ti, Ni and Cu using a technique PSPP (Plasma Skull Push-Pull) using the fusion equipment Discovery All the EDG equipment the same process was validated by De Araújo et al (2009) in the LMF manufacturing of Ni-Ti and Cu-al systems.

Ti-Ni-Cu solubilization served to homogenize, and thereby obtain the best transformation curves needed for DSC studies. Therefore, gross melting alloys Ti-Ni-Cu, passed through a heat treatment of 800 °C for 15 minutes in an electric furnace TITAN Platiniun Quartz of EDG equipment.

3. RESULTS AND DISCUSSION

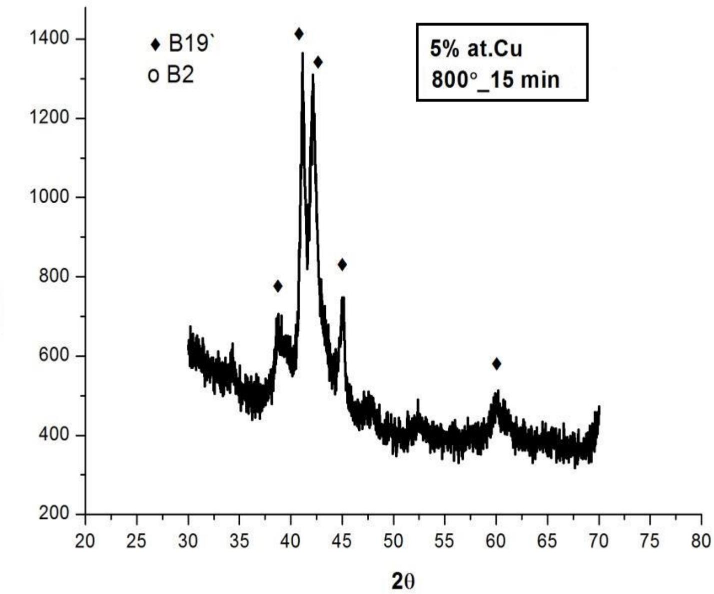
Fig. 1 shows the product of mergers of Ti-Ni-Cu alloys by PSPP. In order to characterize the product and process of mergers, ten (10) ingots varying the concentration of copper (5, 6, and 7 at.% Cu) in the nickel substitution was produced. The casting was conducted within the internal volume aluminum molds in the form of prismatic bar (prismatic bar with dimensions 3.2 cm long, 2.5 cm wide and 0.5 thick).



a) b)

Figure 1. Fusion Products Ti-Ni50-x Cux-a) prismatic bar with dimensions 3.2 cm long, 2.5 cm wide and 0.5 cm thick b) strip of prismatic bars.

To analyze the structure of forming alloys with XRD experiments were performed and the results obtained are shown in Figure 2. Figure 2 shows the difatogramas alloys with different concentrations of Cu. It was observed that the ambient temperature (Tamb) the Ti-Ni-Cu alloys showed the presence of phase structure B19 "(monoclinic).



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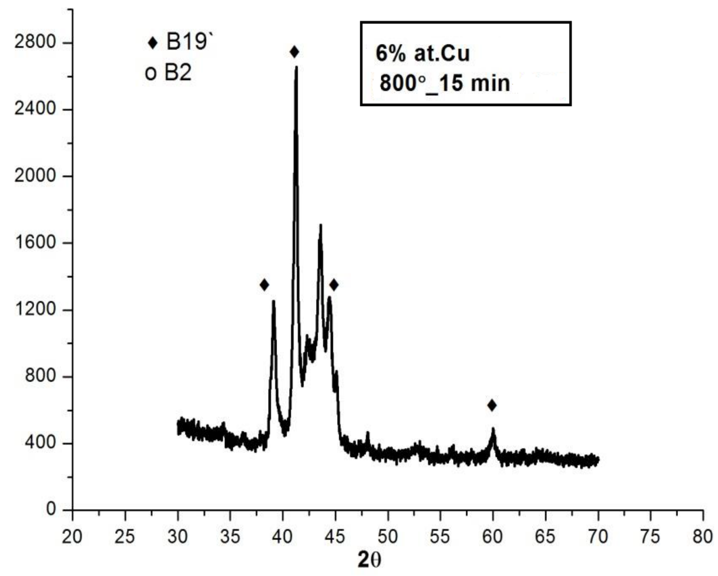

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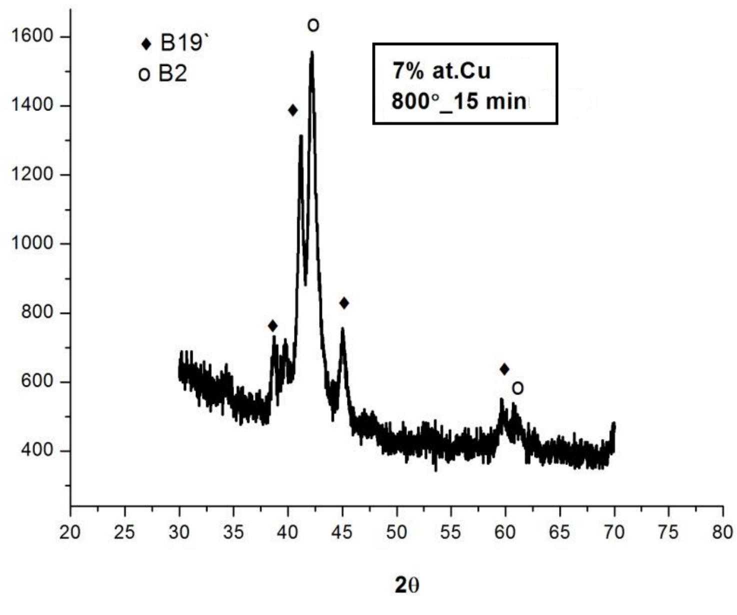

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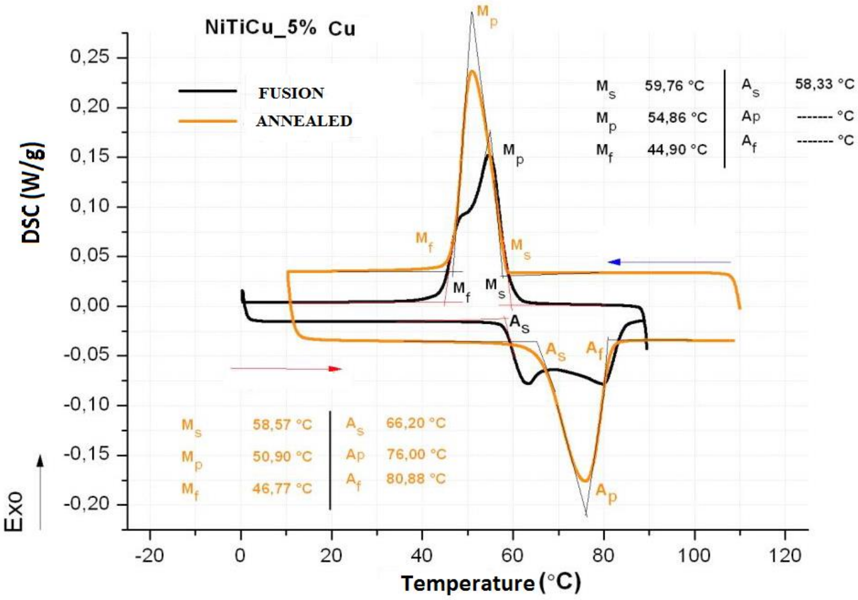
Figure 2. XRD of the Ti--Ni50-x Cux alloys produced by PSPP, the atomic compositions of copper: a) 5%, b) 6% and c) 7%.

In Ni-Ti binary alloys equiatômicas addition to the formation of B2 and B19` structures coexist another phase which precedes the martensite phase identified as R, the orthorhombic structure. This intermediate layer is formed from precipitates, and cause changes in the structure of the alloy, resulting in two stages of processing. The formation of precipitates in the alloy depends on the solidification process and compositions of the Ni-Ti binary. Compositions above 50% at. Ni Ni-Ti alloys can form precipitates varied. Another important aspect that was observed was the lack phase R in the results of XRD patterns of all Ti-Ni-Cu alloys under study. According Saburi (1998) the increase of Cu in Ni-Ti alloy inhibits the formation of precipitates in the B2 matrix, thereby suppressing R phase.

Fig.3 shows the DSC curves of the $Ti_{50}Ni_{50-x}Cu_x$ (x = 5, 6 e 7 at.Cu%) alloy during heating and cooling processes from Fig.2 DSC curves of $Ti_{50}Ni_{50-x}Cu_x$ (x = 5, 6 e 7 at.Cu%) alloy and alloy annealed at 800 ºC for 15 minutes. DSC phase transformation peaks are visible on the curve of alloy, indicating that alloys are crystalline. After annealing the ribbon at 800 ºC for 15min, there is only one-stage transformation peak during heating and cooling in the DSC curve that can be attributed to reversible Martensitic Transformation. The corresponding transformation temperatures are as follows: M_s=17 ºC, M_f =7 ºC, A_s=14.3 ºC and A_f =33 ºC. The transformation hysteresis between reversible MT of the annealed ribbon is defined as the difference between peak temperatures of austenite (A_p) and martensite (M_p).



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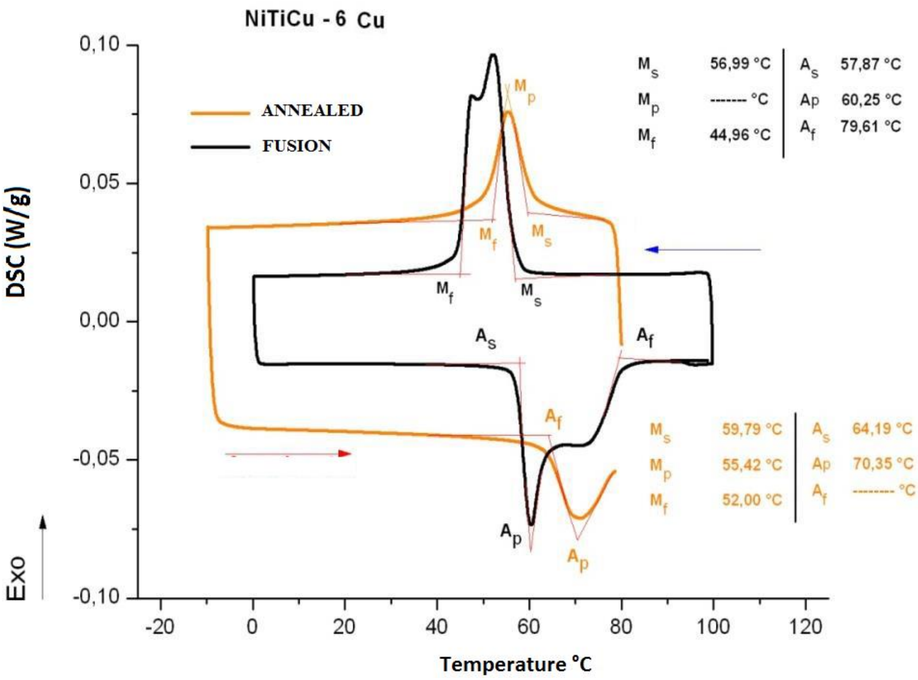

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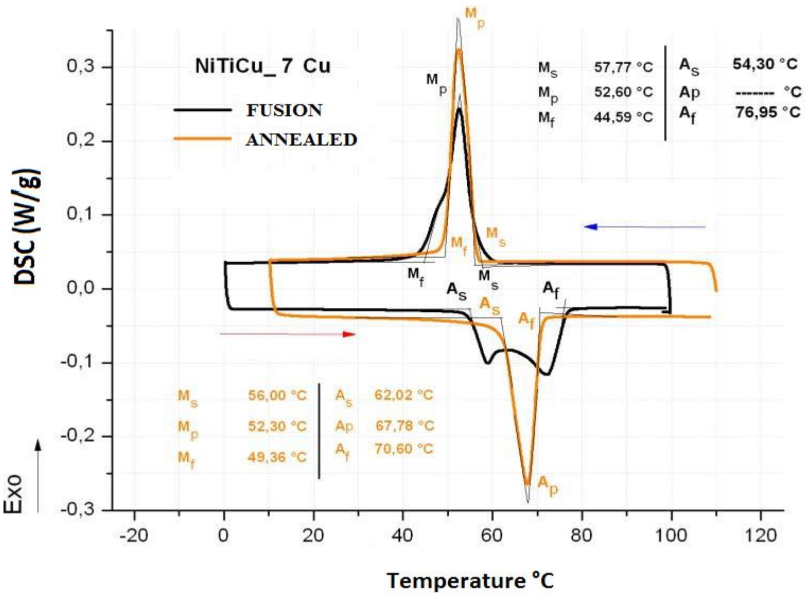

c)

Fig.3 DSC Ti-Ni-Cu alloys melting and solubilized with Cu concentrations: a) 5% atCu; b) 6% and c) 7% atCu.

The DSC curves of gross alloys have double peaks, assigned will heterogeneous. Homogenize the system, there was a heat treatment of solubilization at 800ºC for 15 minutes, this procedure is reported in the literature (WALNUT, 1995). The solidification of these alloys occurs, in general, conditions out of balance, the cooling and solidification occur so rapidly that there is not enough time for the diffusion alloy reaches equilibrium composition, so that the resulting composition does not is homogeneous throughout the ingot, therefore, the solubilization was carried out to obtain homogeneous alloy (NOGUEIRA, 1995).

The results indicate that the addition of Cu affects very little the Ms transformation temperatures, which shows that the highest value is around 7 ° C (Ms of the alloy with 3 at.% For the reference Ni-Ti). However, for the values, it has up to 15 ° C change (from the alloy with 7% at.Cu reference to Ni-Ti). Figure 4 shows the behavior of Ms transformation temperatures and of the Ti-Ni-Cu alloys produced by PSPP.

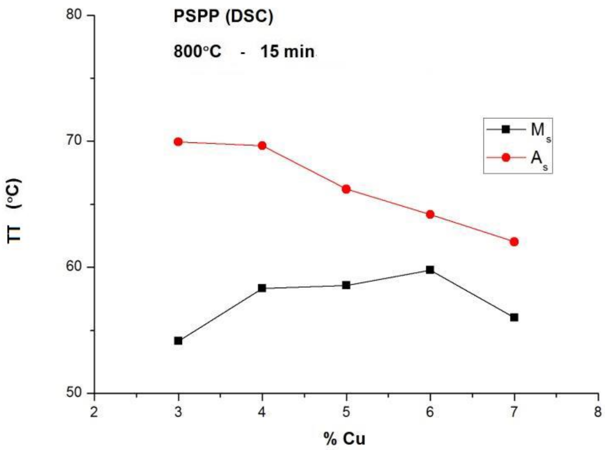

Figure 4. Cu content in the Ti-Ni-Cu solubilized in relation transformation temperature (Ms – Martensite, As - Austenite).

4. CONCLUSION

1. The increase of Cu in the alloy causes significant changes in the temperatures of transformation, causing reduction of the processing temperatures;
2. In curves of Ti-Ni-Cu alloy phase transformations presented after solubilization was obtained as a single stage processing B2 - B19 ';
3. The elimination phase occurred in all R alloys Ni-Ti-Cu.

ACKNOWLEDGEMENTS

Acknowledgements to the Program of Graduate Studies in Sciences and Materials Engineering UFCG, and the Higher Education Personnel Improvement Coordination (CAPES).

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