Characterization of a Ni Base Alloy Obtained by Mechanical Alloying Followed by SPS

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The present work deals with the morphological and structural evolution of ternary Ni-Co-Cr alloys during mechanical alloying (MA). Comparative analyses of two routes of sintering were considered. Sintering processes were conventional sintering (CS) and spark plasma sintering (SPS). Raw materials were elemental cobalt, chromium and nickel pure powders supplied by Sigma-Aldrich. Compositions studied were Ni50Co45Cr5, Ni50Co40Cr10, Ni50Co35Cr15 (at. %). MA was performed using a high energy SPEX 8000 ball mill. Powders mixtures were milled for 0, 5, 10, 15 and 20 h. The ball to powder weight ratio was about 5:1. All runs were done under argon atmosphere to avoid oxidation. Microstructural characterization was performed by XRD and SEM. The Fig. 1 shows the morphology of mixture Ni50Co35Cr15 milled from 0 to 20h. In Fig. 1(a-e) is observed that as the milling time is increasing the particle surface is more spherical, and the size distribution is more homogeneous. Fig. 1(f-j) show cross section microstructures of milled powders. For lower milling times a quasi-lamellar structure is observed, which is typical in the early stages of MA [1]. With further milling, a more uniform microstructure was observed, Fig. 1(i-j). General microanalyses by EDS show that the chemical composition of all systems is homogeneous after longer milling times; the oxidation during the milling process is very low. Fig. 2 presents the XRD patterns from ternary Ni50Co45Cr5 alloys after MA and sintering process. Fig 2a shows the

XRD patterns from milled mixtures. Elemental characteristic peaks are shortening and broadening as the milling time increases. Is observed a shift of main characteristic reflections, which is due to the solid solution formation. Fig. 2(b-c) show the XRD patterns of consolidated samples after CS and SPS respectively. Ni solid solution is observed in both samples. A sharp and high intensity peaks are observed. CS present the presence of small reflections which were identifies as oxides. Powders also show an heterogeneous micro strain while in the sintered bulks is most common to find homogeneous deformation [2]. Fig. 3 shows the representative microstructure in some Ni50Co35Cr15 consolidated samples after milling and sintering processes. Fig. 3(a-b) show the representatives microstructures obtained with CS, notice the porosity, and the void among particles, denoting not full densification. Samples consolidated by SPS, Fig. 3(c-d), show a full consolidation and a more homogeneous microstructure. During SEM observations, a dark grey phase (chromium rich) was observed in samples milled for the shorter milling times.

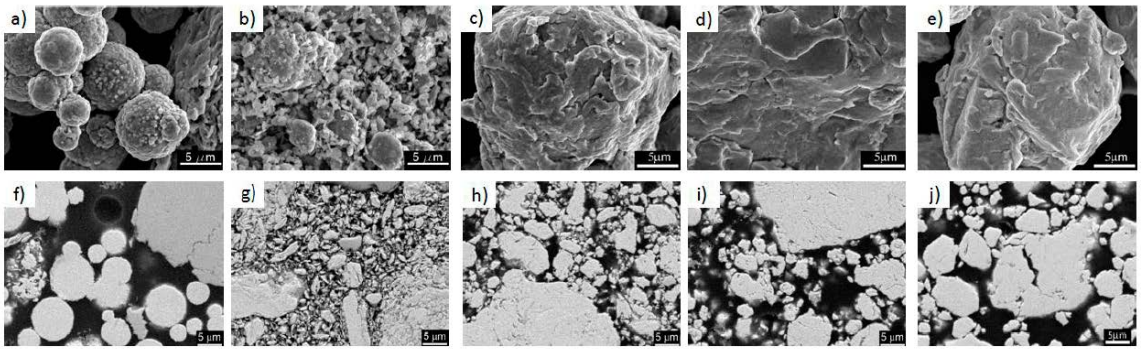

FIG. 1. Powders milled Morphology of $Ni_{50}Co_{35}Cr_{15}$: a) 0h, b)5h, c)10h, d)15h, e)20h 1000X and microstructure: f)0h, g)5h, h)10h, i)15h, j)20h 3000X

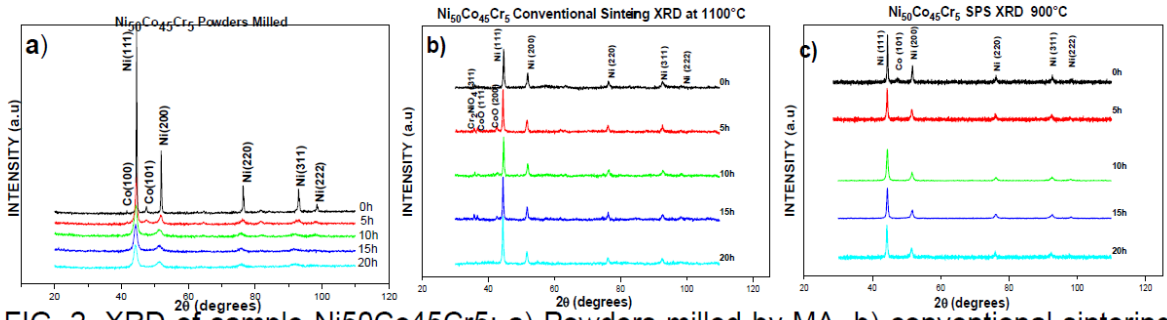

FIG. 2. XRD of sample Ni50Co45Cr5: a) Powders milled by MA, b) conventional sintering and c) plasma sintering

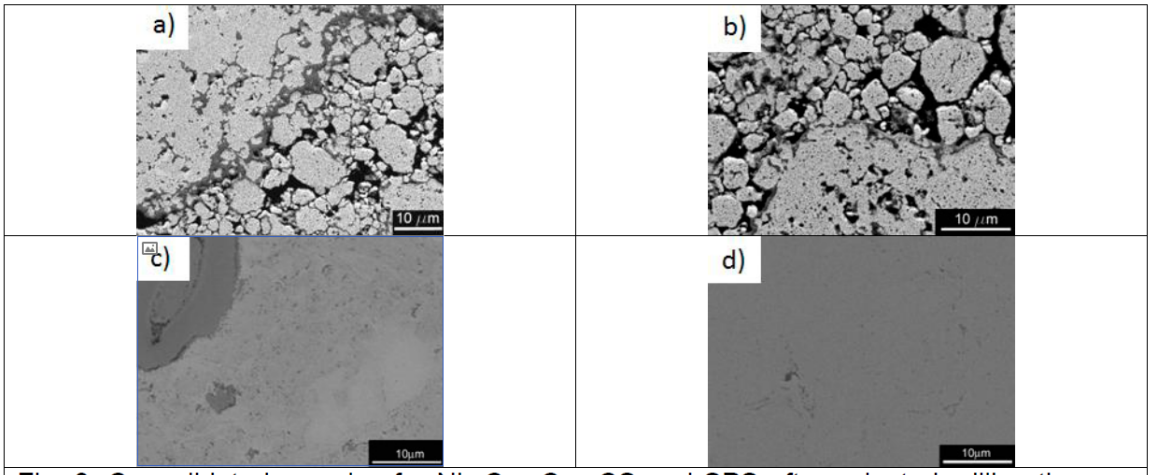

Fig. 3. Consolidated samples for $Ni_{50}Co_{35}Cr_{15}$ CS and SPS after selected milling times. a) 5h CS, b) 20 h CS, c) 5h SPS, d) 20 h SPS