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# QUALITY OF COMPACTION OF BULK NANOCRYSTALLINE $Al_{73}Si_{19}Ni_7mischmetal_1$ ALLOY PRODUCED BY DIFFERENT PRESSURE AT HIGH TEMPERATURE

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**Abstract.** $Al_{73}Si_{19}Ni_7mischmetal_1$ nanocrystalline alloy was produced by different pressure at high temperature. Quality of compaction of samples increases as the pressure increases. The hardness of the bulk nanocrystalline samples is five times higher than that of commercial 4xxx series Al alloy.

## 1. INTRODUCTION

In case of aluminium alloys, many attempts have been made to produce casting alloys, specially rapid solidified alloys. Rapid solidification is a very good method to produce nanocrystalline alloys. Nanocrystalline Al-based alloys containing silicon (Si), rare earth metal (RE) and late transition metal (Ni) combine high tensile strength and good wear resistance [1-3]. Usually, those alloys have nanocrystals embedded in amorphous matrix with average size about 10-30 nm [4]. Therefore, rapid solidification by melt spinning technique leads to better mechanical properties compared to polycrystalline aluminium alloys. This is due to their possible applications in automotive and aerospace industries. However, the form of final product (ribbon) is inconvenient for structural use. That is why a lot of work has been done to obtain nanocrystalline alloys in bulk form. One of the process is consolidation under high pressure of ball milled ribbons.

The aim of this work was to manufacture high strength bulk nanocrystalline alloys from Al-Si-Ni-Mm system. Replacement of RE by mischmetal (Mm) reduces the cost of investigated materials, as Mm is an order of magnitude cheaper than pure rare earth elements.

## 2. EXPERIMENTAL

Composition of mischmetal (Mm), in at.%, was: Ce-50.3, La-43.5, Pr-5.9, and Nd-0.3. Bulk nanostructured $Al_{73}Si_{19}Ni_7Mm_1$ alloys were produced by ball milling of nanocrystalline ribbons followed by high pressure hot compaction. Nanocrystalline ribbons of the investigated alloys were produced directly by melt-spinning method. The temperature of hot compaction has been chosen from differential scanning calorimetry (DSC) result and was 200 °C. Several values of pressure in the range from 2 GPa to 7.7 GPa applied for 5 min were used to check the influence of this parameter on the porosity and the mechanical properties of the bulk samples. Scanning electron microscopy (SEM) was used to investigate the quality of compaction of the samples. The microstructure of the samples was analysed by X-ray diffrac-

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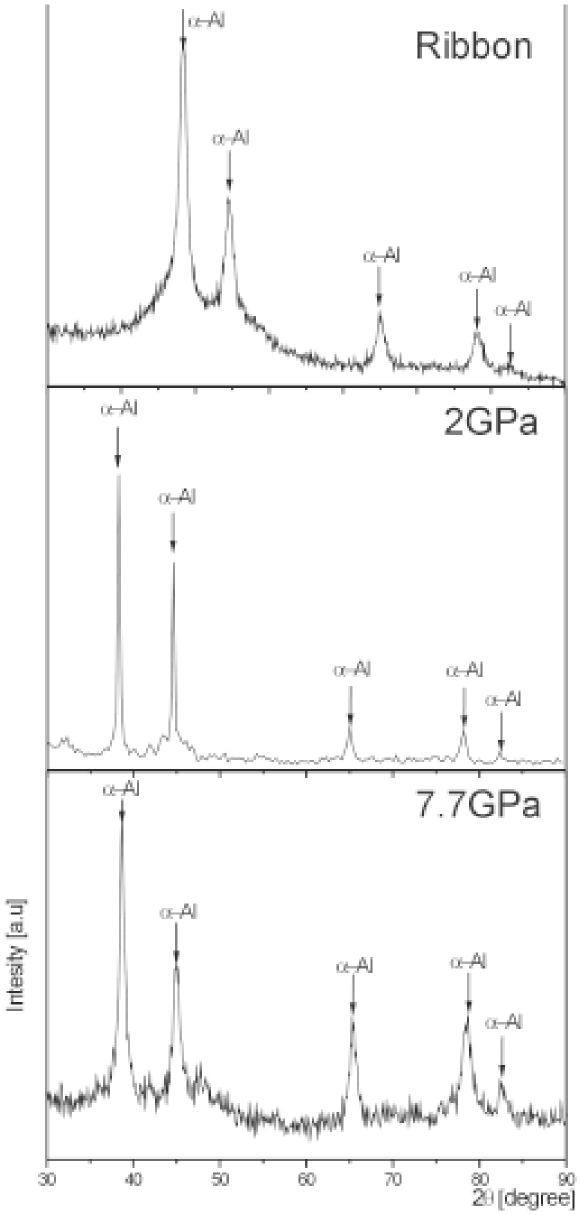


**Fig. 1.** XRD patterns of melt spun ribbon (a), bulk sample compacted at 2 GPa (b) and at 7.7 GPa (c).

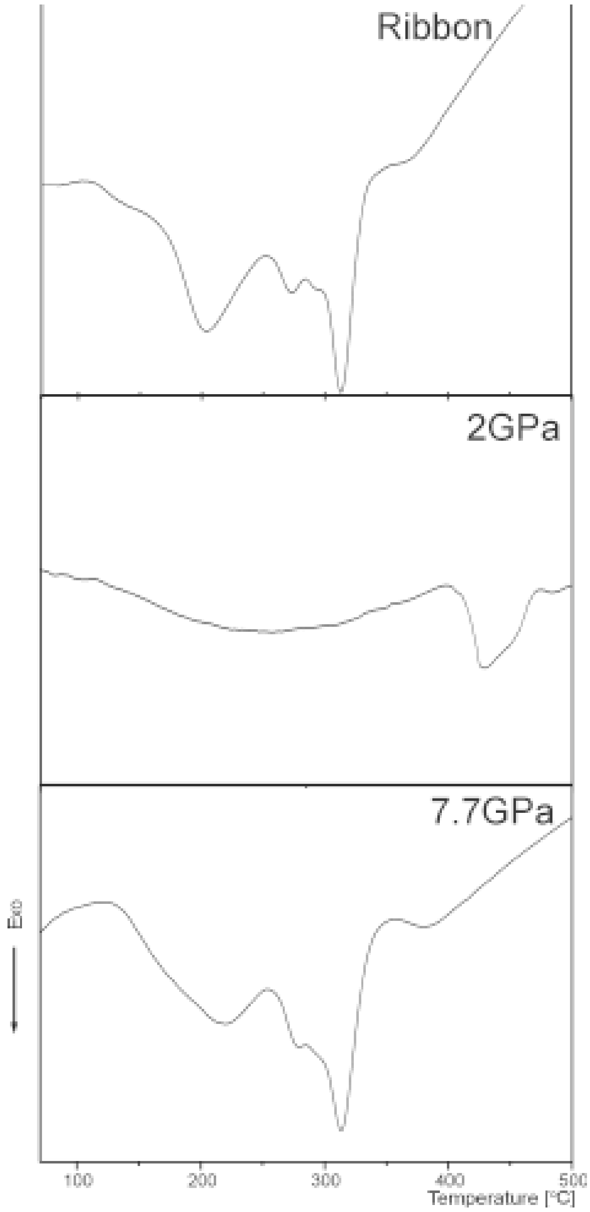


**Fig. 2.** DSC traces of the melt spun ribbon (a), bulk sample compacted at 2 GPa (b) and at 7.7 GPa (c).

tion technique (XRD). Mechanical properties were carried out in terms of Vicker's hardness with a load of 1 kG.

## 3. RESULTS

Fig. 1a presents the XRD pattern of melt spun ribbon. We can see only α-Al peaks on the amorphous halo. Fig. 2 shows DSC scan for the ribbon (a) and bulk sample compacted at 7.7 GPa (c) with two overlapping exothermic peaks. The process of crystallisation for the sample compacted at 2 GPa has been changed from two overlapping peaks to one (Fig. 2b). The temperature up to which the nanostructure is preserved in the melt spun ribbon is about 200 °C. The temperature for high pressure hot compaction were chosen from the DSC curve of the ribbon as 200 °C.

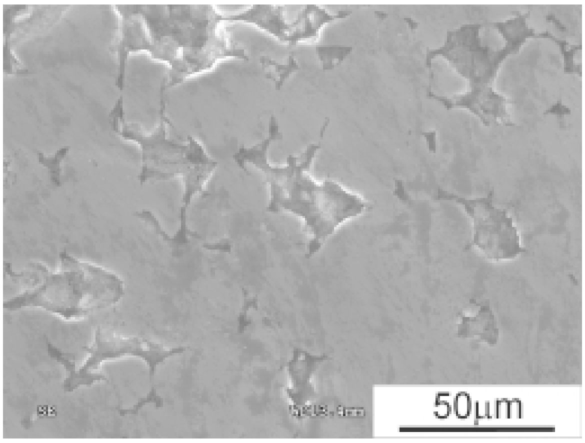


**Fig. 3.** SEM micrograph of the surface of the bulk sample compacted at 2 GPa and 200 °C.

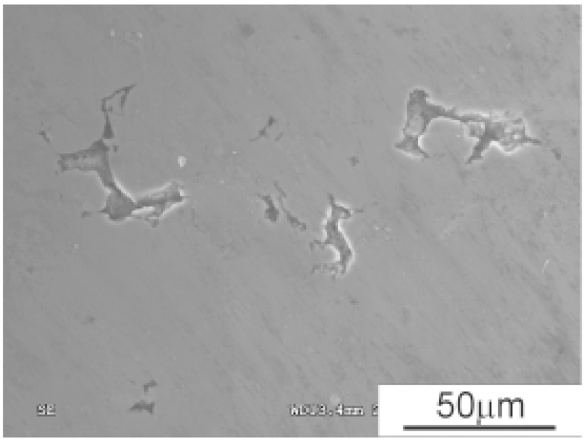


**Fig. 4.** SEM micrograph of the surface of the bulk sample compacted at 4 GPa and 200 °C.

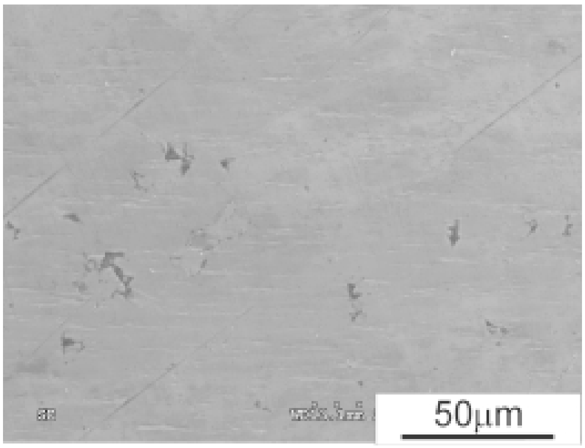


**Fig. 5.** SEM micrograph of the surface of the bulk sample compacted at 6 GPa and 200 °C.

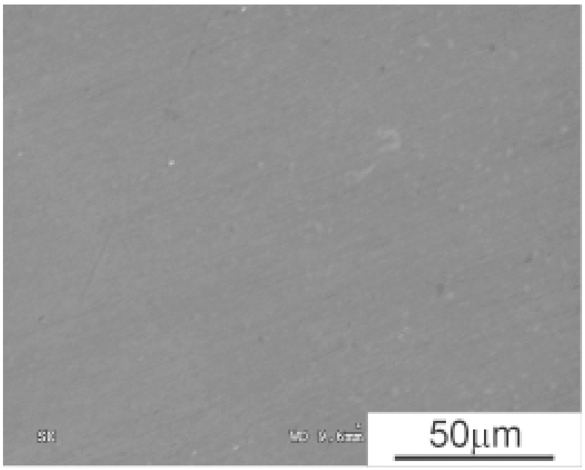


**Fig. 6.** SEM micrograph of the surface of the bulk sample compacted at 7.7 GPa and 200 °C.

Figs. 1b and 1c show XRD patterns of the bulk nanostructured material. On this figure we can see also only $\alpha$-Al peaks on the residual amorphous "halo" for the bulk sample compacted at 7.7 GPa. For the sample compacted at 2 GPa the peaks of $\alpha$-Al are sharper and we can not detect amorphous "halo" on it. The calculated grain size from XRD patterns using Scherrer formula was in the range from 40 to 60 nm. Figs. 3-6 show SEM images of the different bulk nanostructured samples. We can observe that the quality of compaction increases with increasing of the pressure from 2 GPa to 7.7 GPa. The sample which was compacted applying 2 GPa is not homogeneous. We can observe pores and the particles of the powder are not well compacted. Bulk material pressed at 4 GPa also have some pores. On the surface of the sample compacted at 6 GPa we can still observe residual pores. The sample pressed at 7.7 GPa is well compacted without pores. As we can see the optimal pressure is 7.7 GPa in this alloy. The hardness of the alloy was about 300 *HV* for all samples pressed at different pressure. This value is almost the same compare to alloys obtained by Inoue from pure elements [5]. The hardness is 5 times higher than that of the commercial polycrystalline 4xxx series alloy.

## 4. CONCLUSIONS

The main conclusions derived from this work are:

1. Quality of compaction of samples increases as the pressure increases. The number of the

pores and their size decreases with increasing pressure.
2. Samples manufactured at 7.7 GPa and 200 °C exhibit smooth surface free of pores.
3. The hardness of the bulk nanocrystalline samples is five times higher than that of commercial 4xxx series Al alloy.

## ACKNOWLEDGEMENTS

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