Production of Nanodiamond Reinforced Al Composites by Mechanical Alloying

H. KAFTELEN, M. L. ÖVEÇOĞLU

Department of Metallurgical and Materials Engineering, Istanbul Technical University, Maslak, Istanbul, 34469, Turkey

e-mail: kaftelen@itu.edu.tr

1. SUMMARY

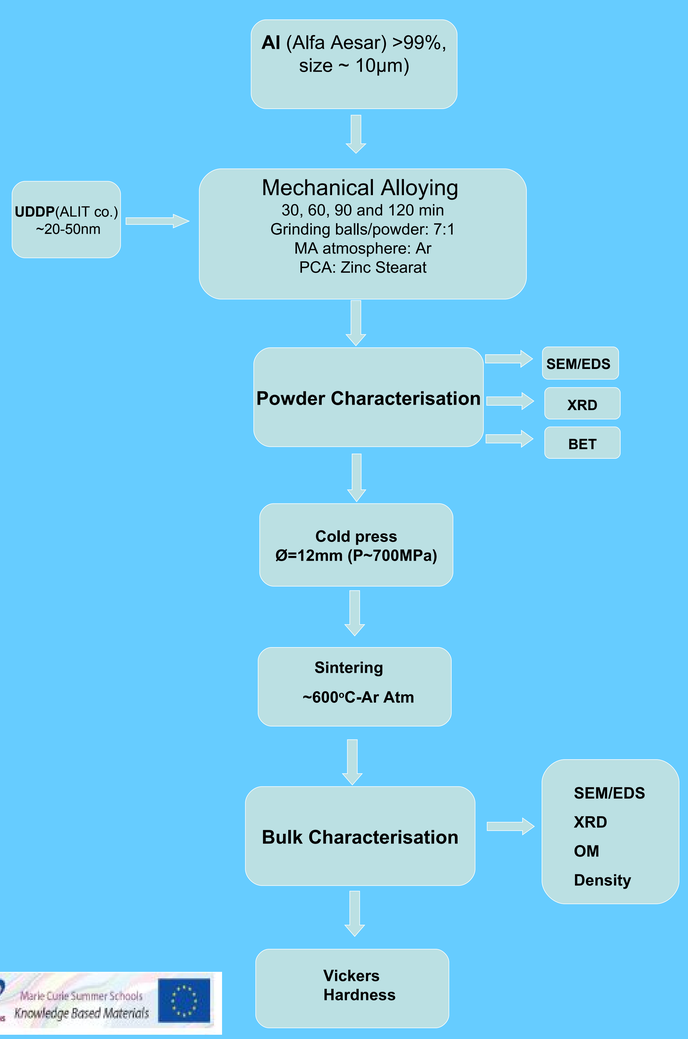
Nanodiamond powders were used as a reinforcement material in aluminum matrix to improve physical and mechanical properties of composites. Composite powders of aluminium matrix reinforced with ultra dispersed nano-diamond particles were produced by high energy ball milling (8000D Spex mixer mill)under Ar atmosphere for four different mechanical alloying(MA) times, i.e. 30, 60, 90 and 120 min. The MA'ed composite powders were later consolidated and sintered under protective atmosphere at 650 °C. The microstructures of both sintered and MAed powders were investigated using SEM/EDS, XRD analysis. XRD results showed that Al4C3 phases are occasionally formed and its intensity increases with increasing the amount of nano-diamond.

2. INTRODUCTION & BACKGROUND

Mechanical alloying is a process in which initial constituent powders are repeatedly fractured and cold welded by the continuous impacting action of a milling medium. Eventually composite powder particles, whose composition corresponds to the percentages of the respective constituents in the original charge, are formed. The resulting composite powders are characteristically dense, cohesive and homogeneous [1]. In the last ten years, diamond nanopowders have aroused considerable interest among those engaged in both fundamental and applied investigations. Nanodiamond, also called nanocrystalline diamond powder, or ultra dispersed diamond is considered a promising material for various applications, including abrasives for the semiconductor and optical industries, extra durable and hard coatings, additives to lubricants for engines and moving gears, polymer reinforcements, protein adsorbents, and even medicinal drugs [2-4]. The purpose of this work is to characterise the physical and microstructural properties of nano-diamond reinforced composites produced by ball milling.

3. EXPERIMENTAL METHODS

Processing routes used for the production of the composite materials



4. RESULTS & DISCUSSIONS

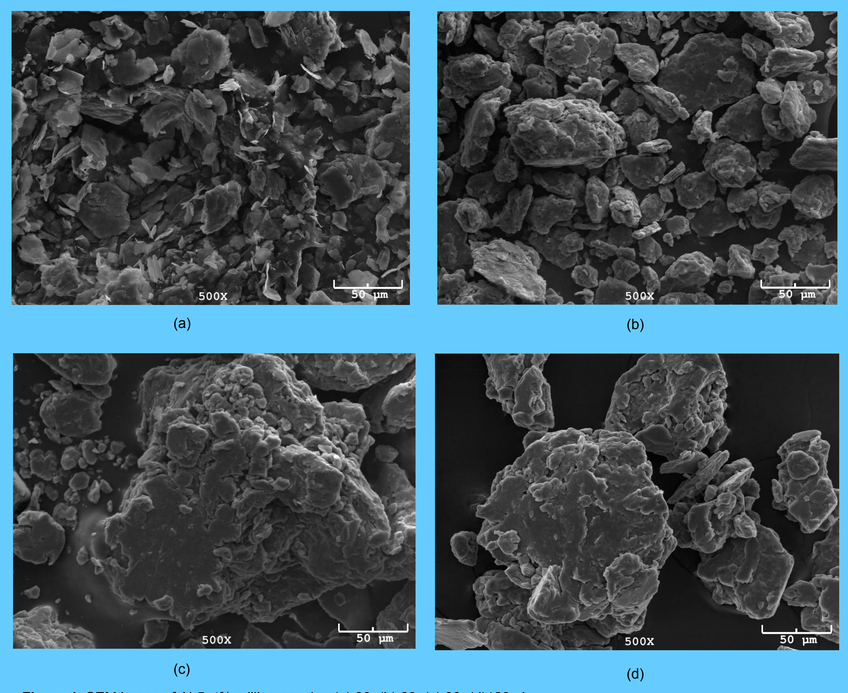


Figure 1. SEM image of Al-5wt% milling powders(a) 30, (b) 60, (c) 90, (d)120min

The morphology of 5 wt% diamond reinforced Al composite powders after 30, 60, 90 and 120 min milling time is given in Figure 1. Steady state morphology was observed at 120 min mechanical alloying time.

Compositions	Milling time (min)		
	30	90	120
	Surface Area (m^2/g)		
Al-UDDP (1 wt %)	5.25	1.468	1.330
Al-UDDP (5 wt %)	9.772	1.488	1.112
Al-UDDP (10 wt %)	18.57	2.813	2.009

Table 1. Surface areas of nanodiamond reinforced Al-UDDP composites

The specific surface area of both as-received and milled powders was measured by nitrogen adsorption at liquid nitrogen temperature using Autosorb 1C apparatus from Quantachrome, see Table 1. Prior to analysis, the milled samples were outgassed in helium for 24h at 150 °C. The sorption isotherms (quantity of argon adsorbed onto the sample surface at various pressures) were measured at 77 K and analysed using the Barret, Joyner and Halenda (BJH) method [5].

After milling, powder compressibility decrease due to the particle cold working, the obtaining finer microstructure increases mechanical properties. The mechanically alloyed powders of low tap densities show flake morphology, while the others show equiaxial morphology. The laminar morphology of the shorter time powders mechanically milled means poorer powder packing, as shown in Figure 2.

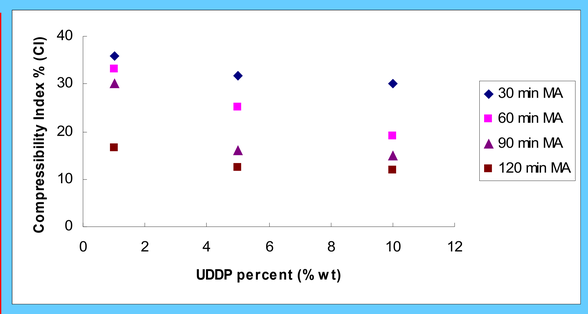


Figure 2. Variation of compressibility of milled powders depends on nano-diamond weight percent

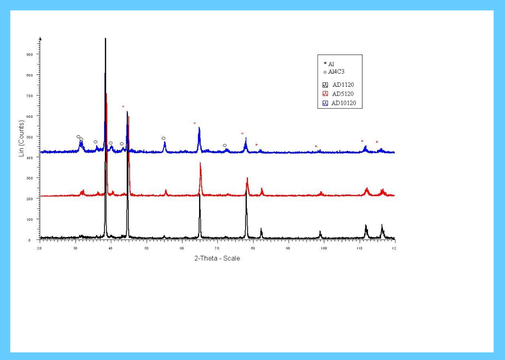


Figure 3. XRD results of sintered samples

Figure 3 shows the XRD results of sintered samples.

In the nano-diamond composites, Al_4C_3 phases are occasionally formed and its intensity increases with increasing the amount of nano-diamond.

5 w/o nanodiamond reinforced composite SEM morphology was given in Figure 4.

EDS analysis showed that the carbon concentration at point a is about 47 wt %, while at point b no carbon was observed, see Figure 4.

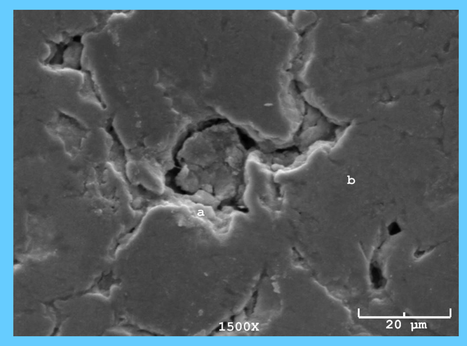


Figure 4. SEM images of 5w/o UDDP reinforced composites

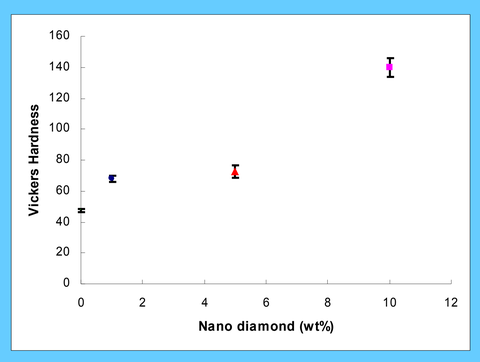


Figure 5. Vickers Hardness of sintered samples

Sample	HV	S.Dev
Al	47.6	±1.069
Al+1% UDDP	68.1	± 2.136
Al+5% UDDP	72.8	± 4.612
Al+10% UDDP	130	± 6.24

In this study micro hardness measurements of were carried out using Schimadzu™ hardness instrument at a load of 25 mg. In order to avoid displacement of particles under the indenter powders were molded in a rigid resin. From each set of samples, 20 impressions were taken per sample to obtain mean micro hardness values. The mean hardness and the standard deviation for each sample were calculated as an error-band representation in Figure 5. The hardness value of 10 wt%UDDP reinforced Al composites was obtained ~130HV while non-reinforced value is ~48 HV.

5. CONCLUSIONS

- Compressibility of milled powders decreases with milling time increases which may be explained by depends on nano-diamond weight percent
- 130 HV -hardness value of 10 wt%UDDP reinforced Al composites was obtained while non-reinforced value is ~48 HV.
- Surface area of composite powders increases with increasing the amount of reinforcement. Unexpectedly, surface areas of powders decreases when the milling time increases.
- XRD results showed that Al_4C_3 phases are occasionally formed and its intensity increases with increasing the amount of nano-diamond.

6. REFERENCES

1. T. E. Volh, U. S. Patent No:3 877, 930 issued 15 Apr. (1975)
2. V. Y. Dalmatov, Russ. Chem. Rev. 70(2001) 607
3. G. Post, et. al., Russ. J. Appl. Chem 75(5)(2002) 755
4. G. P. Bogetyvera, M. A. Morinich, V. L. Gvyazdovskaya Diamond Related Materials 9(2000) 2002
5. E. P. Barett, L. G. Joyner, P. P. Halenda J. Amer. Chem. Soc. 73 (1951) 373

Marie Curie Summer Schools Knowledge Based Materials

www.pmlab.itu.edu.tr