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MECHANICAL AND STRUCTURAL CHARACTERIZATION OF GRAPHITE COATED SILVER NANOPARTICLES-REINFORCED ALUMINUM

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Abstract. Pure aluminum with graphite coated silver nanoparticles (~ 10 nm) composites were prepared by mechanical milling, cold compacted, sintered and hot extruded. Transmission electron micrographs and energy dispersive spectroscopy showed that nanoparticles were homogeneously dispersed into the aluminum matrix and did not coalesce, grow or dissolve on it because of their graphite coating. Within the range 0-2 silver nanoparticles weight percentage, mechanical properties such as Yield strength (σ_y), maximum strength (σ_{max}) and micro hardness (VHN) were improved, compared to the as annealed aluminum properties.

1. INTRODUCTION

Even current use of aluminum and its alloys in industrial applications is wide because of their low density and good workability, it is limited due to their low yield strength. Improving aluminum strength for aerospace and aeronautics applications has lead to study and develop aluminum matrix composites. Aluminum composites with excellent mechanical properties at both room and medium (473K) temperatures [1,2] have been prepared. Common dispersing particles are carbides, nitrides and oxides and processes are held in both solid and liquid phases [3,4].

Powder metallurgy (PM) offers a good and versatile process to produce aluminum composites in solid state. In particular, mechanical milling (MM) is and outstanding way due to the high homogeneity particles dispersion and relatively low costs it presents [5,6]. Even some recent studies have been made [8-12], they include coarse particles [8,9] or conclude that nanoparticles can be dissolved into the aluminum matrix by heating or applying high deformations [10-12].

The present work studies the incorporation of a new kind of silver nanoparticles in an aluminum matrix by mechanical milling, followed by cold pressing, pressure-less sintering and hot extruding. These nanoparticles are graphite-coated silver particles.

2. EXPERIMENTAL PROCEDURE

Composites were prepared from pure aluminum (99.5%, -325 mesh) and graphite coated silver Nanoparticles, here forward Ag-C NP (Nanotechnologies, Inc.). Compositions were made with 0, 0.25…. 1.75, 2 silver nanoparticles (disper-

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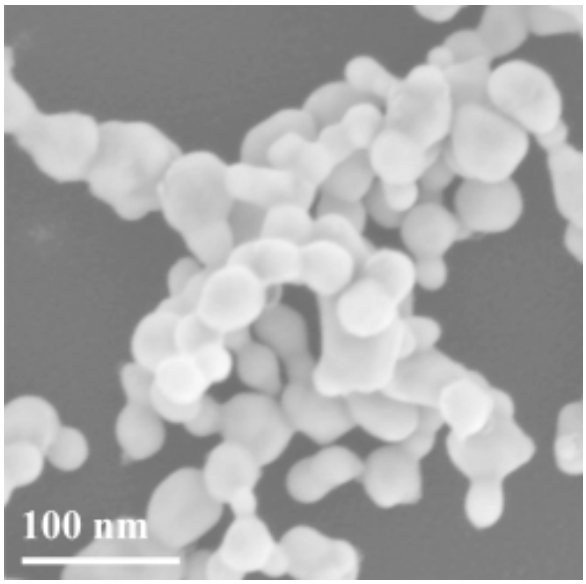

Fig. 1. SEM image from the as-received Ag-C NP.

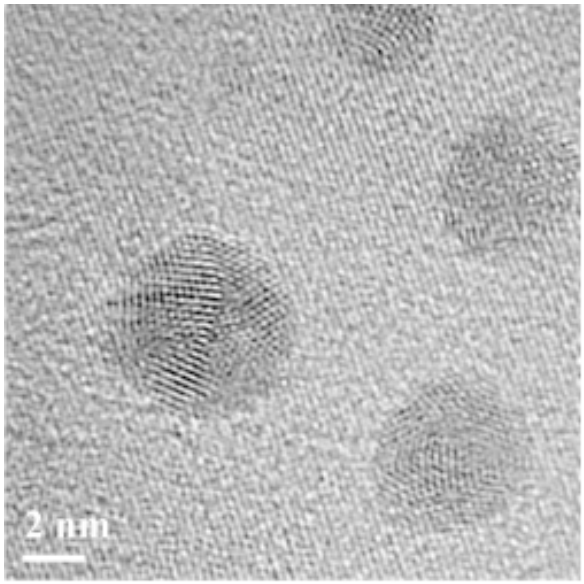

Fig. 2. HRTEM image from Ag-C NP in aluminum matrix.

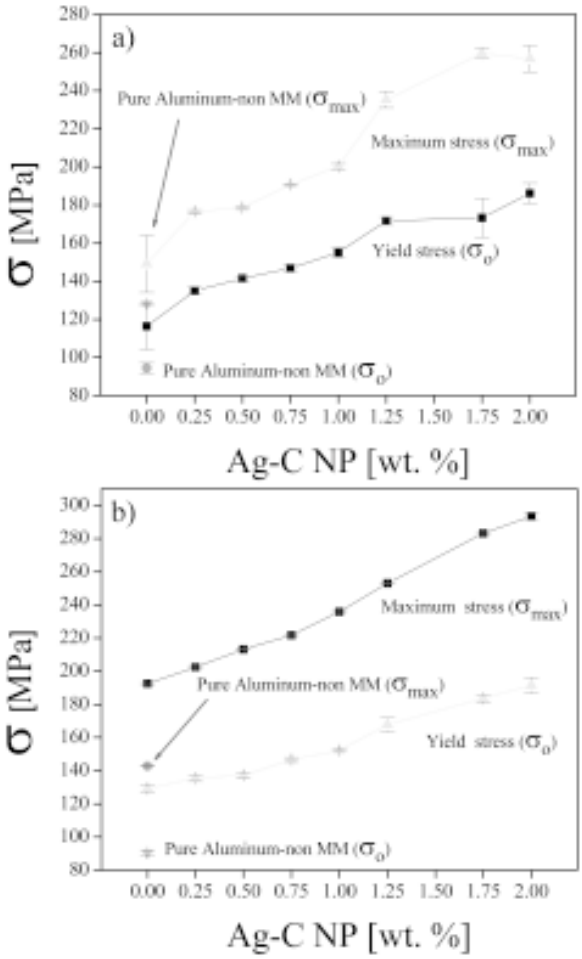

Fig. 3. Yield strength and maximum strength as a function of Ag-C NP for both, tensile (a), and compressive (b) tests.

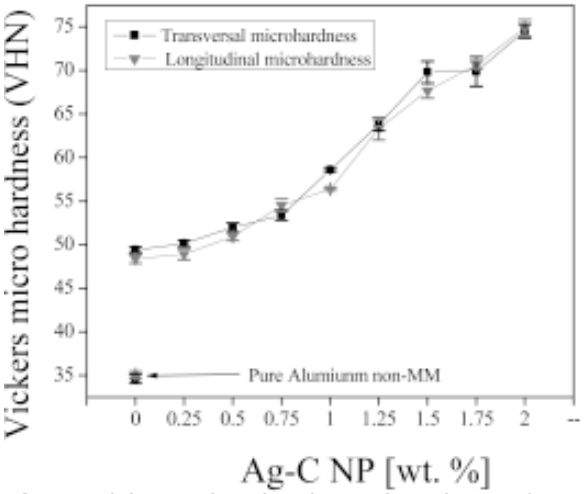

Fig. 4. Vickers micro hardness (VHN) as a function of Ag-C NP weight percentage.

soids) weight percentage. 50 g of raw material were mixed and then milled in a high energy Simoloyer mill during 2 h under argon atmosphere with a 20:1 ball to powder weight ratio.

Compacted rods (40 mm diameter) were made by pressing the processed powder at ~ 950 MPa. These rods were hot sintered at 823K during 3 h (50 K/min heating rate ramp up) and then hot extruded (823K) to obtain a 10 mm diameter rod.

Samples were mechanically characterized in Instron testing equipment at 0.030 mm/s displacement and at room temperature. Structural analysis was performed by scanning electron microscopy

(SEM) and transmission electron microscopy (TEM). Vickers micro hardness (VHN) was also evaluated.

3. RESULTS

Fig. 1 shows a SEM micrograph only from the Ag-C NP in the as-received condition. For the Ag-C NP 1% weight-percent composite, HRTEM image (Fig. 2) shows the nano-size of the particles and the gray contrast that surrounds the silver nanoparticles, which correspond to carbon. TEM micrographs show that silver nanoparticles did not coalesce or grow and graphite shell was preserved.

Mechanical properties were improved within the studied compositions. Fig. 3 shows how yield stress and maximum stress are improved as Ag-C NP is increased up to 2% weight content.

Also, Vickers micro hardness was increased (Fig. 4). Both transversal and longitudinal measurements are similar for each composition, so we can consider composites are isotropic. Micro hardness was improved up to 110% compared to the micro hardness for 0% silver nanoparticles composite with no MM.

4. DISCUSSION

Silver nanoparticles remained graphite coated during all process. This is the key point for studied composites, silver nanoparticles are not dissolved into aluminum matrix during process. It is known from experimental and theoretical analyses that the maximum effect for strengthening is reached if dispersoids size is smaller than 50 nm and distance between them is within the 100-500 nm range [13].

The strengthening improvement by dispersed nanoparticles can be explained by some mechanisms, as the well known Orowan's [14] or different as Hirsch mechanism [15].

Even in some composites the mechanical properties improving is due to the formation of a disordered interface boundary between matrix and nanoparticles [16], in our study it is not that way since we can not see that interface, as Fig. 2 shows.

5. CONCLUSIONS

Mechanical properties of the aluminum matrix have been improved. There is a direct correlation between mechanical properties and Ag-C NP within studied compositions.

Ag-C NP size and shell preservation has allowed improvements. This work opens the possibility to study new composites based on aluminum alloy matrix.

Further research is needed to determine what the strengthening mechanism is and how to control it.

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REFERENCES

[1] J.M. Torralba, F. Velasco, C.E. Acosta, I. Vergara and D. Cáceres // *Composites A* **33** (2002) 427.
[2] M. Gupta and T.S. Srivatsan // *Mater. Lett.* **51** (2001) 255.
[3] S. Harris // *J. Mater. Sci. Technol.* **4** (1998) 231.
[4] P.K. Rohatgi, R. Asthana and S. Das // *Int. Met. Rev.* **31** (1986) 115.
[5] J.G. Cabańas-Moreno, R. Martínez-Sánchez, H.A. Calderón, H. Balmori and R.M. Umemoto // *Mater. Sci Forum* **225-227** (1996) 435.
[6] D. Oleszak, V.K. Portnoy and H. Matyja // *J. Metas. Nanocryst. Mater.* **2-6** (1999) 345.
[7] R. Martínez-Sánchez, S. Díaz de la Torre, F. Espinosa-Magańa, L. Bejar-Gómez and J.G. Cabañas-Moreno // *J. Metas. Nanocryst. Mater.* **10** (2001) 487.
[8] J.Y. Chang and A. Shan // *Mater. Sci. Eng*. **347** (2003) 165.
[9] M.V. Markushev and M.Y. Murashkin // *Mater. Sci. Eng.* **367** (2004) 234.
[10] I. Gutierrez-Urrutia, M.A. Muñoz-Morris and D.G. Morris // *Mater. Sci. Eng. A* **394** (2005) 399.
[11] C. Xu, M. Furukawa, Z. Horita and T.G. Langdon // *Acta Mater.* **51** (2003) 6139.
[12] B.B. Straumal, B. Baretzky, A.A. Mazilkin, F. Phillipp, O.A. Kogtenkova, M.N. Volkov and R.Z. Valiev // *Acta Mater.* **52** (2004) 4469.
[13] M. Besterci // *International Journal of Materials and Product Technology* **15** (2000) 356.

[14] R.George, K.T. Kashyap, R. Rahul and S. Yamdagni // *Scripta Materialia.* **53** (2005) 1159.

[15] T. Hatano // *Phys. Rev. B.* **vol 74** (2006) 205414.

[16] T.H. Courtney, *Mechanical behavior of materials* (New York: McGraw-Hill, 1990).