Synthesis of Al-based CNT Composite by Spark Plasma Sintering

Chander Prakash[1*], **Sunpreet Singh**[1]
[1]School of Mechanical Engineering, Lovely Professional University, Phagwara, Punjab, India

Abstract

In the present research work, an attempt has been made to utilize the potential of spark plasma sintering technique to develop Al-CNT composite. The alloying of Al and MWCNT was carried out using ball mill and sintering was carried out using SPS technique. Morphology, mechanical properties was investigated by FE-SEM and nano-indentation technique. From the SEM, micrograph, the relative density of the synthesized composite was obtained in the range of 85-95 %. The results showed that Al-CNT possessed elastic modulus of 65 GPa and tensile strength 215 MPa).

Introduction

In recent years, the demand of aluminum (Al) alloys for the automotive, aerospace, other industrial applications. However, Al and its alloys are susceptible to excessive wear rate in metal-on-metal, which causes failure of the component [1-6]. This phenomenon limits the utility of these materials. The alloy factor has been admitted to testing the Al alloy to improve the mechanical properties. Spark plasma sintering (SPS), a potential strategy for metal-processed alloyed metal consolidation, has arisen [7-11]. The present paper aims to develop A-CNT composites produced via the SPS process.

Materials and Methods

The high purity (~99.9 percent) powder (PP) particles such as Al, and MWCNT were produced. In Wt% of Ag and MWCNT, the PP was mixed as: 95:5. Next, the ultrasound was ultrasonically treated with deionized water and combined for 1 hour with ultrasound. The powder blend is then homogenized by the magnetic punching unit. The homogenized mixture was dried before solidification and consolidation was performed using spark plasm sintering method (SPS-5000) at 400 K sintering temperature and 40 MPa pressure at the heating speed of 50 k / min (holding time 5 min) was applied under vacuum environment. Fig.1 shows the mechanism for the same.

There was a sturdy lightweight with a thickness with approx. 20 mm or 4 cm. FE-SEM (JEOL 7600F) fitted with EDS and XRD techniques described the as fabricated nano-composite. The elastic modulus has been calculated using the Oliver-Pharr process by nanoindentation (Hyistron TI-950 indentation system). The tnsile strength was determined by ASTM standard.

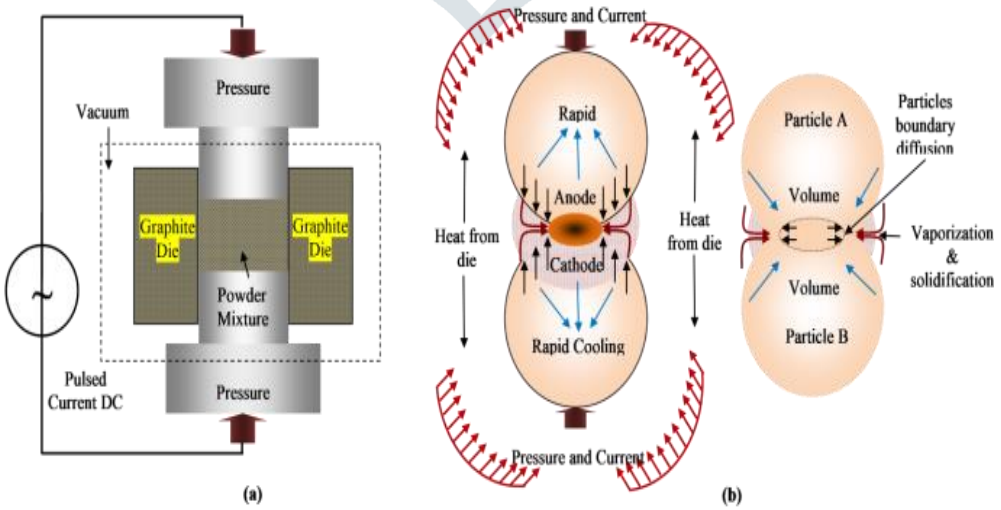

Fig.1. Sintering mechanism of powder particles via SPS technique

Results and Discussions

Fig. 2 shows the image of as-synthesized Al-CNT composite. Highly dense structure was observed. The SEM micrograph clearly showed that in Al-matrix, the CNTs and SiC particles were distributed homogenously. The CNTs appeared in bright agglomerate form, while SiC is dark form. As a consequence, CNT accumulation increases the distribution within the matrix of the agglomerates of the CNT.

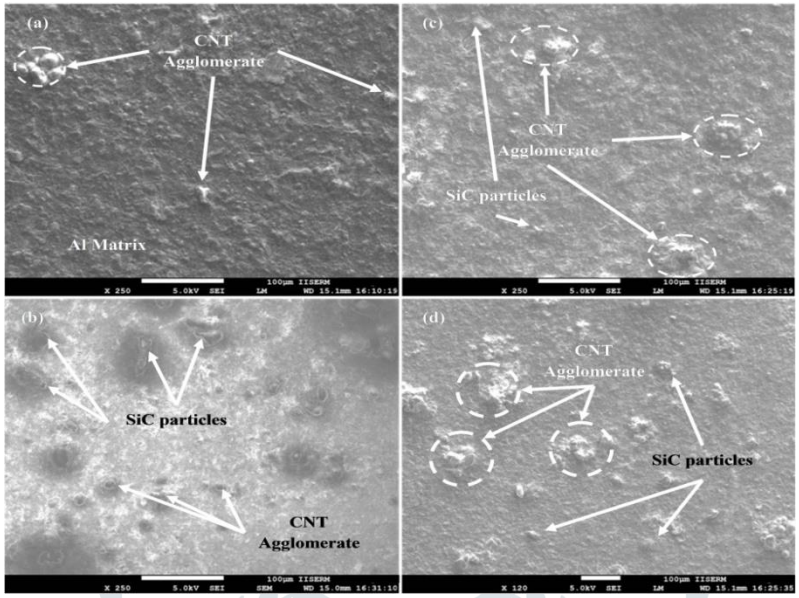

Fig. 2. Al-based composites

Illustration 2 (a), (b), (c), and (d) show the Al-5 percent CNT SEM micrograph, Al-1 percent CNTs-10 percent SiC, Al-3 percent CNTs-10 percent SiC, and Al-5 percent CNTs-10 percent SiC, respectively. The SEM micrograph clearly showed that in Al-matrix, the CNTs and SiC particles were distributed homogenously. The CNTs suit the region and are in agglomerate shapes, while SiC fits the black areas. The CNTs correlate. As a consequence the CNT accumulation increases the distribution within the matrix of agglomerates of CNTs. The microstructure of the CNTs is integrated into the grain matrix interface with a variety of locations. It was found in previous studies that the CNTs were more than 93 percent agglomerates and seem to have similar trends in this sample. The white dot appears on the CNTs. The sintered compact hybrid transverse cross-sectional microstructure of the Al-CNTs-SiCp. The SiC particles microstructure is reinforced with CNTs by means of the Al grain matrix interface. The SiC particles suit the distorted black forms and are evenly distributed in the matrix. There has been a lack of interaction between SiCp and the Al-Si matrix. In previous studies, the nature of grain growth and the presence of CNTs is confirmed after plasma sintering in the interface on the grain frontier. The SPS process will succeed in overwhelming grain output because of the quick heating and pressure applied.

Conclusions

All in all, the findings indicate that the spark plasma sintering technique has excellent potential to develop Al-based metal matrix composite.

References

1) Deuis, R.L., Subramanian, C. and Yellup, J.M., 1997. Dry sliding wear of aluminium composites—a review. Composites Science and Technology, 57(4), pp.415-435.
2) Canakci, A., Varol, T. and Ozsahin, S., 2013. Prediction of effect of volume fraction, compact pressure and milling time on properties of Al-Al 2 O 3 MMCs using neural networks. Metals and Materials International, 19(3), pp.519-526.
3) Canakci, A., Varol, T. and Ertok, S., 2012. The effect of mechanical alloying on Al2O3 distribution and properties of Al2O3 particle reinforced Al-MMCs.

4) Nassar, A.E. and Nassar, E.E., 2017. Properties of aluminum matrix Nano composites prepared by powder metallurgy processing. Journal of king saud university-Engineering sciences, 29(3), pp.295-299.
5) Sannino, A.P. and Rack, H.J., 1995. Dry sliding wear of discontinuously reinforced aluminum composites: review and discussion. Wear, 189(1-2), pp.1-19.
6) Madeira, S., Miranda, G., Carneiro, V.H., Soares, D., Silva, F.S. and Carvalho, O., 2016. The effect of SiCp size on high temperature damping capacity and dynamic Young's modulus of hot-pressed AlSi–SiCp MMCs. Materials & Design, 93, pp.409-417.
7) Prakash, C., Singh, S., Farina, I., Fraternali, F., & Feo, L. (2018). Physical-mechanical characterization of biodegradable Mg-3Si-HA composites. PSU Research Review.
8) Singh, B. P., Singh, R., Mehta, J. S., & Prakash, C. (2017, August). Fabrication of biodegradable low elastic porous Mg-Zn-Mn-HA alloy by spark plasma sintering for orthopaedic applications. In IOP Conference Series: Materials Science and Engineering (Vol. 225, No. 1, p. 012050). IOP Publishing.
9) Singh, R., Singh, B. P., Gupta, A., & Prakash, C. (2017, August). Fabrication and characterization of Ti-Nb-HA alloy by mechanical alloying and spark plasma sintering for hard tissue replacements. In IOP Conference Series: Materials Science and Engineering (Vol. 225, No. 1, p. 012051). IOP Publishing.
10) Bhushan, B., Singh, A., Singh, R., Mehta, J. S., Gupta, A., & Prakash, C. (2018). Fabrication and Characterization of a New Range of β-type Ti-Nb-Ta-Zr-xHaP (x= 0, 10) Alloy by Mechanical Alloying and Spark Plasma Sintering for Biomedical Applications. Materials Today: Proceedings, 5(14), 27749-27756.