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Copper laminated composites reinforced with Al_2O_3 nanoparticles by suspension method and hot pressing

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Abstract. Laminated composite of copper with alumina nanoparticle reinforcements has application such as electrical industries. Electrical junctions should have high electrical, thermal conductivity with good mechanical strength. In this research the layers interface of pure copper were reinforced by alumina nanoparticles. For the production of the composite, first alumina nanoparticles were dispersed on Cu layers by suspension method and then the layers were hot pressed at 950°C under 20 MPa pressure. After composite making, the microstructure, the tensile and impact of these composite were studied. The results showed that by increasing amount of alumina nanoparticles up to 0. 5 wt %, tensile and impact strength were increased and for the composites with more than 0.5 wt % because of agglomeration of nanoparticles, these properties were decreased.

1. Introduction

Metal laminated composites are a type of metal matrix composites, consisting of layers metals which they have good of mechanical properties such as high specific strength and stiffness. These kind of materials can be a good choice in transportation industries [1, 2]. There are several methods for the production of metal laminated composites. These can be classified according to the metal state: solid state, liquid state and vapour state processes are thus generally distinguished [2-8]. In the metal laminated composites, the interface of layers affects the properties of them and can be improved by strengthen of reinforcements ceramics. Hence, the whole properties of the composite can be changed by production method, interfaces strength and reinforcement.

In the present work copper-alumina nanoparticles laminated composites were successfully fabricated using alumina suspension method and hot pressed [9-10] and then the effect of amount alumina nanoparticles was studied on tensile and impact strength of the composites

2. Materials and Processing

High purity α-Al_2O_3 nanoparticles (20 nm) were used as starting materials. Slurries with different amount of Al_2O_3 (0-0.1 wt%), 50 cc distilled water and sulphuric acid as a *surfactant* were mixed by a magnetic mixer for 20 min. Rectangular pure copper sheets with 10×6×1 mm^3 in size were cut and cleaned with acetone to remove pollutions. Then the copper sheets were immersed into the slurries to deposit alumina nanoparticles on them. This process was repeated to achieve the required alumina content and distribution. Subsequently, the sheets were gently removed from the slurry and dried at100°C for 1 h. Finally, the three layers laminated composites were fabricated at 950 °C and 20 MPa pressure for 5 minutes by pressing method.

3. Experimental

The microstructure of the deposited copper sheets with nanoparticles was studied by a Scanning Electron Microscopy. Also the samples were then cut from the laminated composites using cutter to study microstructure, tensile strength and impact behaviour. After sectioning, the composites were hot-mounted and subsequent polishing of the metallographic specimens. Once the required metallographic finish was obtained, observations were made on unetched samples using a SEM. The tensile tests on the composites were conducted using a Universal testing machine (Instron Model 4206). The room-temperature tensile tests were carried out at a crosshead speed of 1 mm/min. Also, the tensile fracture surfaces of composites samples were investigated by SEM. The interfacial bonding strength of layer was analyzed by impact test.

4. Results and discussions

The results and discussion on this study are presented in this section. First, the microstructure of the copper sheets deposited with alumina nanoparticles before and after pressing is illustrated and discussed. Then, tensile and impact behaviour of the laminated composites were compared. Final, tensile fracture results of the composites are discussed.

4.1 Microstructure

The microstructures of the copper layers surfaces after deposited with alumina nanoparticles are shown in figure 1 and figure 2. The micrograph results showed that distribution and agglomeration of alumina on the copper sheets surfaces depend on wt %t of alumina and surfactant in solution. In higher concentration of alumina in solution causes large size agglomeration. In solution up to 0.05 wt% alumina the nanoparticles were well distributed with small size agglomeration. It should be noted that the initial concentration of particles [11] affects the distribution alumina to the whole laminated composite.

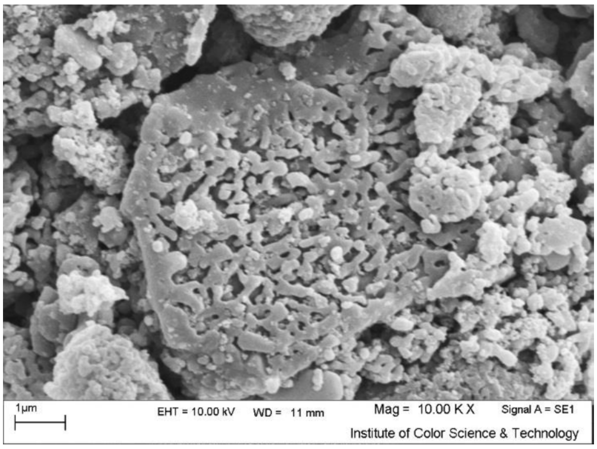

Figure 1. SEM micrograph for 0.1w% alumina agglomerated on copper sheet.

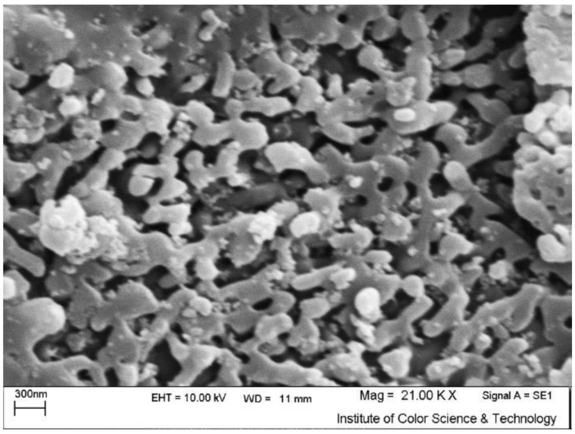

Figure 2. SEM micrograph for 0.1w% alumina copper sheet.

4.2. Tensile and impact behaviour

The results obtained from tensile test are given in figure 3 and figure4. Figure 4 shows representative stress-strain curves of three composites with different wt% alumina in comparison to the unreinforced aluminium. All curves show an increase in strength and the composite with 0.05wt % show higher strength, which is higher than that of matrix at a given strains. It can be concluded that a proper amount of alumina and well distribution in the interfaces leads to significantly higher bonding strength of interfaces which it will be improved fracture strength of the laminated composites.

It can be seen from figure. 5, that the tensile fracture strength was increased with the amount of wt% of alumina from 0 w% to 0.1w%. The delaminating at the interface was no found up to 0.05 wt%. Inhibition of delamination prevents neck formation in the laminated composite. This is mainly due to the well distribution of nanoparticles in the interface which was high enough for Cu sheets to bond significantly. In contrast, the fracture strength of the composite with 0.1wt% of alumina is deceased, due to the agglomeration of alumina during deposition and composite making processes. The fracture surfaces were observed by SEM showed the dimples in figure 5 and figure 6. Hence copper layers in the laminated composites fractured in a rather ductile manner in all composites, but a different manner from that of the monolithic copper and the degree of brittleness was increased. Also the effect of interface strength on the tensile behaviour of the laminated composited were confirmed by others researchers [3, 12-16].

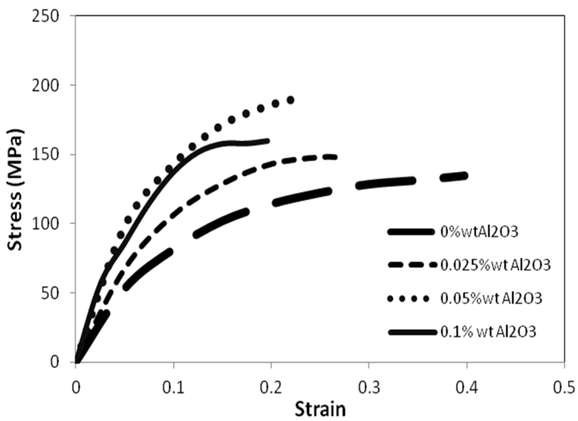

Figure 3. Stress-strain of the composites with different concentration of alumina.

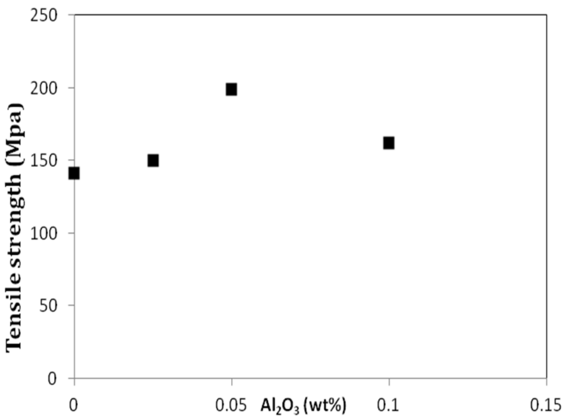

Figure 4. Tensile strength of the composites for different alumina concentration.

The observation in figure 7 is that the total strain to failure results for the composite indicates that the tensile deformation is decreasing with increasing amount of reinforcement. These results have been interpreted in terms of the effect of wt% of alumina on the failure of laminated composites; this trend is attributed to the greater probability for delamination during deformation. Interfacial delamination is increased with increasing agglomeration in higher wt% of alumina. Also the impact test results were showed the same fracture behaviour of tensile test (figure 8).

The fracture surfaces were observed by SEM showed the dimples. Hence copper layers in the laminated composites fractured in a rather ductile manner in all composites, but a different manner from that of the monolithic copper. The delamination at the interface was no found up to 0.05 wt. %. Also the impact test results were showed the same fracture behavior of metal laminated composites [17-18].

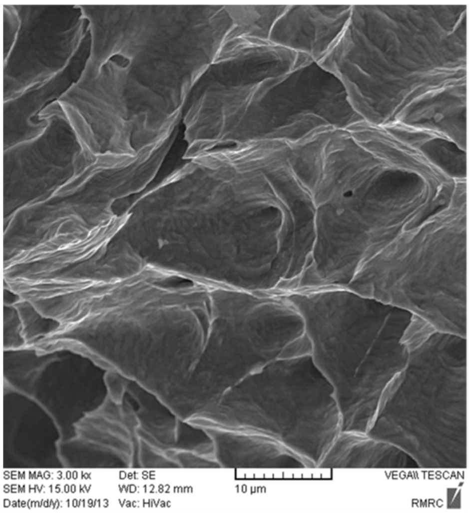

Figure 5. SEM micrograph of tensile fracture surface for the composite with 0.025 wt%alumina.

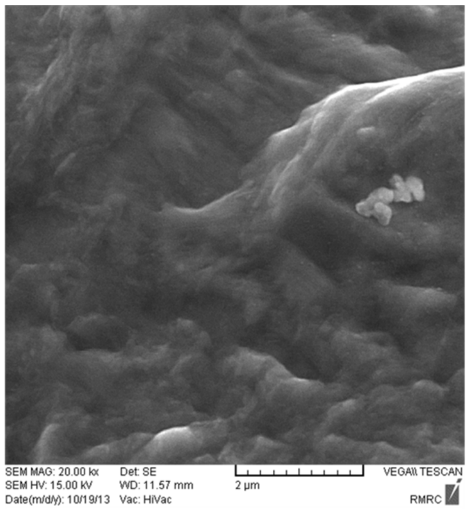

Figure 6. SEM micrograph of tensile fracture surface for the composite 0.05 wt% alumina.

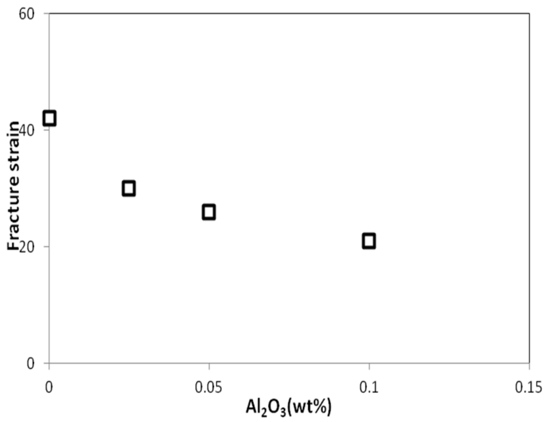

Figure 7. Tensile fracture strain of the composites for different alumina concentration.

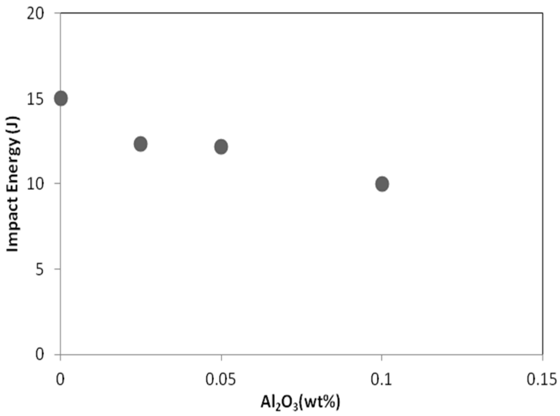

Figure 8. Impact energy versus alumina concentration in the laminated composites**.**

5. Conclusions

The tensile and impact behavior of the laminated composites was affected by amount of wt% of alumina nanoparticles. The ultimate tensile strength of the composites were increased up to 0.05 wt % reinforcement and in higher concentration, because of agglomeration of the nanoparticleac the strength was decreased.

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