



Study The Properties of Sintered Al-Composites Matrix Reinforced With Nano-Al Oxide And/Or Carbon Nano Tubes

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Abstract

The present work is concerned with studying the synthesis and characterization of hybrid aluminum bronze matrix strengthened with nano-aluminum oxide particles ($n\text{-Al}_2\text{O}_3$), and carbon nano tubes (CNTs). The selected matrix composite was successfully incorporated with different weighted percentages of CNTs (i.e. 1.0 and 2.0 wt.%) and/or $n\text{-Al}_2\text{O}_3$ (i.e. 1.0 and 2.0 wt.%) by sintering process. From the microstructure analysis, $n\text{-Al}_2\text{O}_3$ particles was dispersed uniformly and holding over the surface of aluminum bronze. Furthermore, some agglomeration was found due to reinforced CNTs into aluminum bronze matrix. From hardness tests, it was found that incorporated $n\text{-Al}_2\text{O}_3$ and CNTs into matrix increased the hardness of composites to be equal 230 HV, which is around 2.3 times higher than that of an aluminum bronze matrix. Moreover, the wear loss of CNTs - Al_2O_3 /aluminum bronze composites diminished because of the impact of homogeneous circulation of CNTs in aluminum bronze and low corrosion coefficient of uncovered CNTs on the well-used surface. Notable from the results, the electrical resistivity of the hybrid composites are lower than the matrix. Hopefully, the findings are expected to provide profound knowledge and further reference towards the studied composites of the miniaturised electronic package.

Indexing terms/Keywords: CNTs; Nano Al_2O_3 ; Electrical Resistivity; Hardness; Wear; Composites.

Subject Classification: Matherial science Classification; Composite materials Classification.

Type (Method/Approach): Characterization of aluminum bronze matrix composite strengthened with different wt. % (0–2) of CNTs and $n\text{-Al}_2\text{O}_3$ particles were studied. Furthermore, the microstructure, microhardness, wear, density and electric resistivity were investigated.

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1. Introduction

In recent years, metal matrix composites (MMCs) reinforced with nano-particles are being developed worldwide, due to their promising properties appropriate for a large number of functional and applications. Composites of nano crystalline copper network and a couple percent of finely scattered nanoparticles of alumina demonstrate grand warm soundness of miniaturized scale structure and mix of high quality and conductivity over a broad assortment of temperatures. For the practical invigorating, the second stage particles (dispersoid) must be thermo powerfully consistent, fine with general estimations of 5.0–50.0 nm, homogeneously appropriated inside the network grains to reinforce material by an appealing direct association of the particles with moving disengagements [1-2]. The dispersoids can give significant quality to the composite even at high temperatures, where other strengthening frameworks (e.g. precipitation or icy working solidifying) quickly lose their sufficiency [3]. These various properties are great with organization in high-temperature warm or electrical transports, microwave tubes, switches, breakers, and resistance welding anodes. Aluminum bronze is considered as very useful in different applications of industries due to its good tough and ductile at all temperatures and retain their strength well at elevated temperatures. The joining of clay particles can significantly improve the high-temperature mechanical properties, oxidation and wear resistance, without genuine disintegrating of warm and electrical conductivity of the copper matrix. Therefore, various nano-sized oxides have been used as dispersion into composites. In view of the more affordable researches, Al₂O₃ particles have been used as reinforced element in the matrix [4–16].

Extensive investigations have been directed in carbon nano tubes (CNTs) fortified polymer matrix composites with a surprising upgrade in mechanical properties contrasted with those of solid materials. Nonetheless, constrained examination has been finished in planning, auxiliary, physical and mechanical properties of metal–CNT nano composites. Poor wetting conductor powerless inter facial clinging to lattice materials, agglomeration among themselves with Van-der-Waals power, in homogeneous dispersion of CNTs in the grids and corrupted thermal security at high handling temperature are the prime disadvantages to use CNTs as fortifications of metal grid composites. For example, Kuzumaki et al. reported almost no change in the tractable quality of CNT strengthened Al nano composites arranged by routine powder blending, hot-squeezing took after by hot expulsion due to in homogeneous scattering of CNTs in the metal grid [17]. Additionally, CNTs as fortifications of metal matrix composites have accounted for poor efficiency due to agglomeration among themselves with Van-der-Waals power, poor wetting conduct or powerless inter facial attaching to grid materials and corrupted warm dependability at high sintering temperature [18–21]. It was reported that the increase in weight% of nano CuO particles improved the mechanical properties of sintered hybrid aluminum matrix [18]. In addition, a hybrid composite of copper metal matrix reinforced with TiC and graphite particles through microwave processing has been developed [22]. Vencl et al. [23] illustrated that Cu–2.5 wt.% Al composite exhibited the best wear resistance, 2.5 times higher than that of Cu–5 wt.% Al₂O₃ composite. Also, high hardness and nano-sized Al₂O₃ particles improved wear resistance of Cu–2.5 wt.% Al composite. On the other hand, it was reported that adding carbon nanotubes into copper matrix composites reduced the wear rate, the friction coefficient, and the plastic deformation [24].

In the light of the survey, although a lot of research has been done on synthesis and characterization of different ceramic particles or CNTs fortified aluminum bronze framework composites. However, to the best of our knowledge, aluminum bronze matrix composites reinforced by nanoparticles (2.0 wt. % n-Al₂O₃), nanotubes (2.0 wt.% CNTs) or (1.0 wt. % CNTs + 1.0 wt.% n-Al₂O₃) have not yet studied. Hence, the present work aims to study characterization of aluminum bronze matrix composite strengthened with different wt. % (0–2) of CNTs and n-Al₂O₃ particles. Furthermore, the microstructure, microhardness, wear, density and electric resistivity of the examined nanocomposites were investigated.

2. Materials and Methods

As received n-Al₂O₃ particles were 99.99% in purity, 50 nm in normal size. CNTs 95% in purity, 30 nm in normal distance across, and 30 μm in normal length, created by nanotech Egypt. Pure copper powder with a normal molecule size of 70 μm purity 99.8%, and Al, powder of 99.98% with average particle size of 100 μm



created by Alpha Chemika, were chosen as the beginning materials of matrix of the composites. Four samples were prepared, Aluminum bronze (89 wt.% Cu - 11 wt.% Al) matrix, Aluminum bronze – 2.0 wt.% CNTs, Aluminum bronze – 2.0 wt.% n-Al₂O₃, and Aluminum bronze – 1.0 wt. % CNTs + 1.0 wt.% n-Al₂O₃. The initial powders of the grid compound, the support and 2.0 wt% acetone as a binder were mixed for 90 min at 300 rpm in a stainless steel blending container with stainless steel bars with 10 mm measurement and 50 mm length, giving a rod to-powder weight proportion of 3:1. Then, the blend was placed in dryer for 60 min. at 80 °C to evacuate the acetone. The blended powder was filled into a cylindrical die with distance across (8.0 mm), 5.0 mm height, and uni-pivotally pressed at pressure of 800 MPa. The prepared green compacts were sintered in vacuum furnace at a temperature of 900 °C for one hour with 10 °C/min heating rate. The presence and distribution of the reinforced nanoparticles were studied using scanning electron microscope (SEM). The SEM used in this study was SEM-JEOL JSM5800-LV. An energy dispersive spectrometry (EDS) was used to determine chemical composition of the studied composites. Vickers hardness tester (Lecco Vickers hardness analyzer, Model: LV 700, USA) was measured using 1.0 kg for 15 s. The average hardness of at least six readings of different indentations was taken for each specimen. Rough wear tests were conducted for composites using a pin-on-plate method under typical heaps of 2, 4 and 6 N, at steady sliding velocity 1.5 m/s. In these tests, every example is ground up to review 1200 emery paper to guarantee that the wear surface is in finished contact with the grating counter-face. Round samples having contact region of 12.57 mm² are stacked against a circle, which pivoted at 250 rpm. The plate conveyed a rough SiC paper of 400 Grit. The sliding separation was kept consistent at 200 m for every sample. During sliding, the abrasive wear rate of the pins was defined as the weight loss suffered per unit sliding distance. An electronic equalization having a determination of 0.0001 gm. was used to gauge the weight reduction. The pins were cleaned in acetone and dried preceding weight measurement. The relative dampness was measured yet not controlled and was in the scope of 60% amid these tests. Electrical resistivity was discovered utilizing smaller scale ohm Meter of motwane make (Demonstrate LR-2045). The Motwane LR 2045 is computerized smaller scale ohm meter equipped for measuring low resistance.

3. Results and Discussion

3.1 Microstructure

The microstructural of CNTs and n- Al₂O₃ particles strengthened in Aluminum bronze matrix composites were examined using SEM, as shown in Figs. 1-4. Besides, the constituents of nanocomposites were identified using the EDS analysis. It is clear that the diverse microstructures are created by the composites relating to the sort of supports of n- Al₂O₃ and CNTs. The composite demonstrates a split free and all around cleaned surface. This split free surface might be credited to the best possible circulation of weight amid compaction and legitimate cleaning of the test [25]. Additionally, it was observed uniform dispersion and holding of n- Al₂O₃ particles over the surface of Aluminum bronze, as seen in Fig. 2. Moreover, EDS analysis was carried out for n- Al₂O₃ fortified Aluminum bronze matrix composite to probe the composition of the attached nanoparticles. For 2 wt. % n-Al₂O₃ fortified Aluminum bronze matrix, it reveals the presence of Al, O and Cu. The oxygen pinnacle is because of the nearness of n- Al₂O₃ which include by 2% weight in the specimen. In addition, the SEM and EDS of CNTs strengthened in Aluminum bronze composite are revealed in Fig.3. It is noted that the scattering of CNTs into Aluminum bronze matrix was normal and some agglomeration was found. This can be credited to the correct ball processing of powder. Additionally, it was found that CNTs was broken into pieces when they are ball processed for a drawn out time with high vitality balling [26]. Besides, CNTs have no breaks on its surface because of the best possible day, age of ball processing, weight proportions of ball and powder. EDS investigations of the 1.0 wt.% CNTs and 1 wt.% n- Al₂O₃ fortified aluminum bronze matrix composite are presented in plainly the tops for the upper, oxygen, aluminum and carbon, as observed in Fig. 4. The EDS investigation confirms that CNTs and n- Al₂O₃ particles are existing inside the composites.

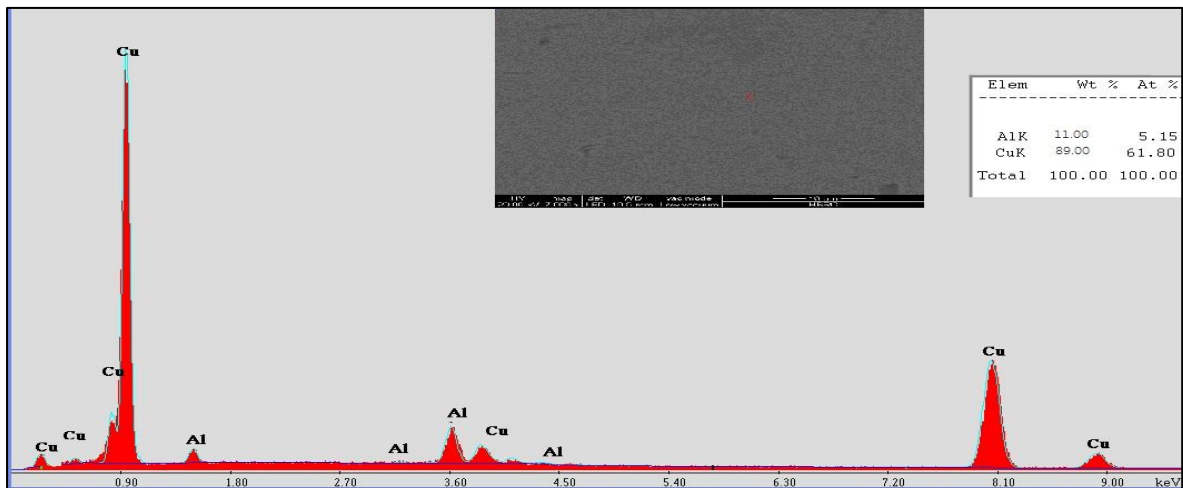


Fig. 1 SEM of aluminum-bronze matrix composite and EDS analysis.

3.2 Microhardness

The microhardness of the n- Al_2O_3 particles and CNTs incorporated in Aluminum bronze matrix composites measured by Vickers micro hardness tester, as exhibited in Fig. 5. As cleared, the hardness increases with blending the matrix by n- Al_2O_3 particles or CNTs. In addition, when n- Al_2O_3 together with CNTs are incorporated, the hardness of composites will be equal 230 HV, which is around 2.3 times higher than that of an Aluminum bronze matrix without existing n- Al_2O_3 particles or CNTs, as obtained in Table 1. According to previous investigation, when the CNTs/metal or CNTs/ceramic nanocomposites are manufactured by the atomic level process, the synthetic holding framed between the CNTs and the matrix particles gives homogeneous conveyance of CNTs and also high interfacial quality [27]. Subsequently, it is confirmed that such significant improvement of hardness is resulting from the high interfacial quality of CNTs and n- Al_2O_3 particles/aluminum bronze interface, the homogeneous dissemination of CNTs and n- Al_2O_3 particles inside the aluminum bronze matrix and accomplished high relative densities. In this manner, it can be demonstrated that the mechanical properties of CNTs and n- Al_2O_3 strengthened in nano composites are normal when the outside load can be shared by homogeneously circulated CNTs and n- Al_2O_3 through the heap exchange from matrix to CNTs and n- Al_2O_3 particles by sound interfacial quality of n- Al_2O_3 /matrix and CNTs/matrix.

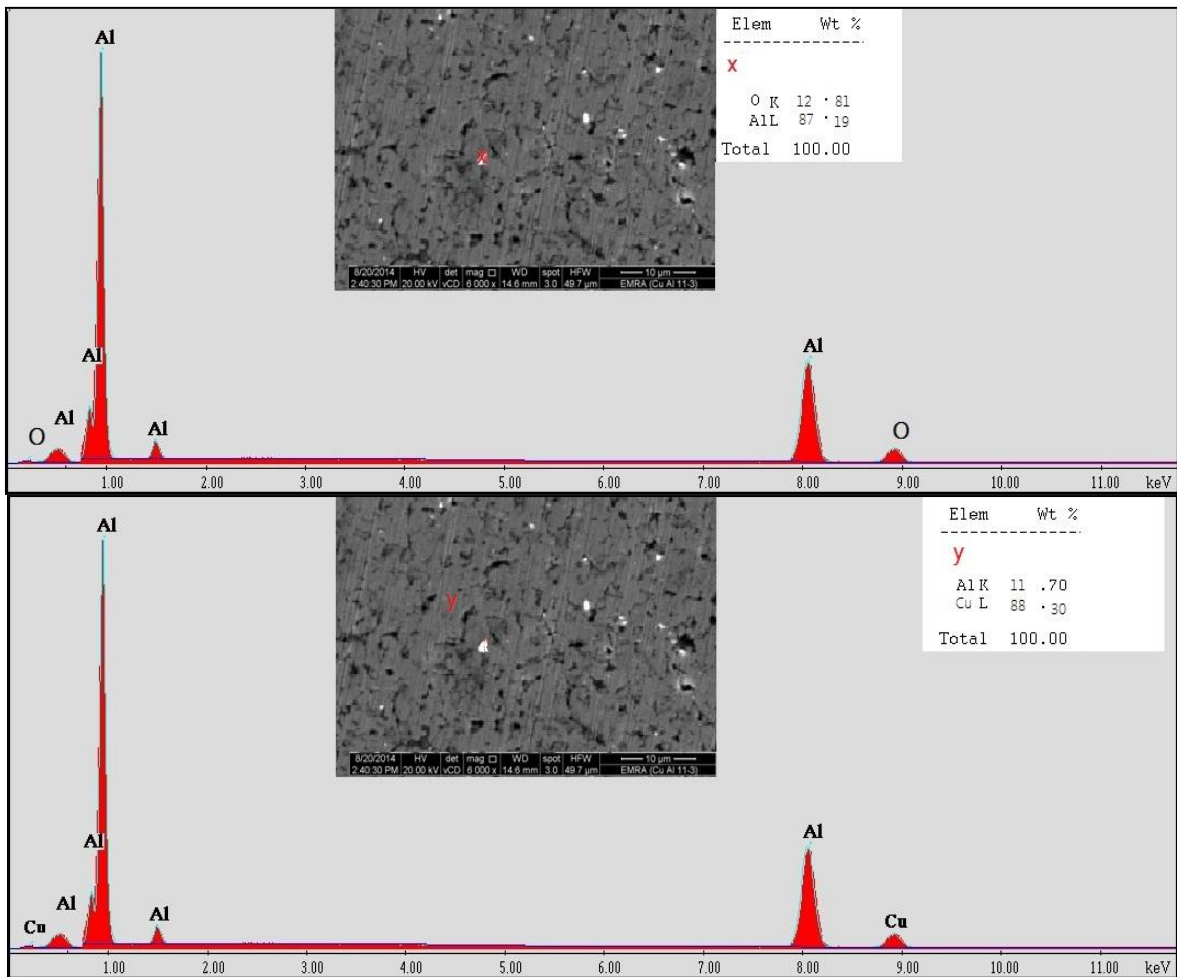


Fig. 2 SEM and EDS of aluminum bronze- 2 wt.%Al₂O₃ composite.

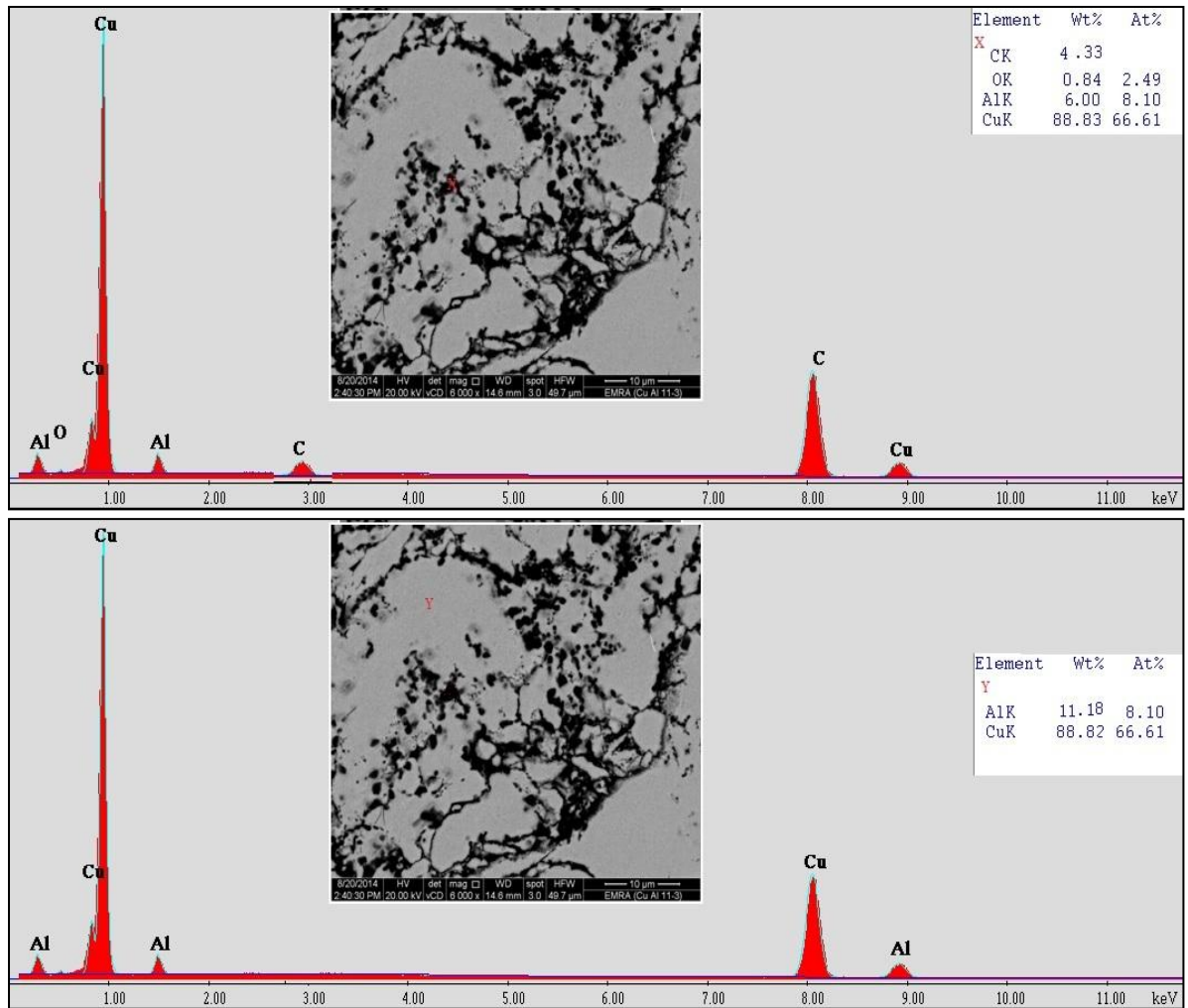


Fig. 3 SEM and EDS of aluminum bronze-2 wt.% CNTs composite.

Table 1 Microhardness values of the examined specimens.

Composite	Hv
Aluminium Bronze	100
Aluminium Bronze-2% CNTs	170
Aluminium Bronze-2%n- Al ₂ O ₃	200
Aluminium Bronze-1%n- Al ₂ O ₃ +1% CNTs	230

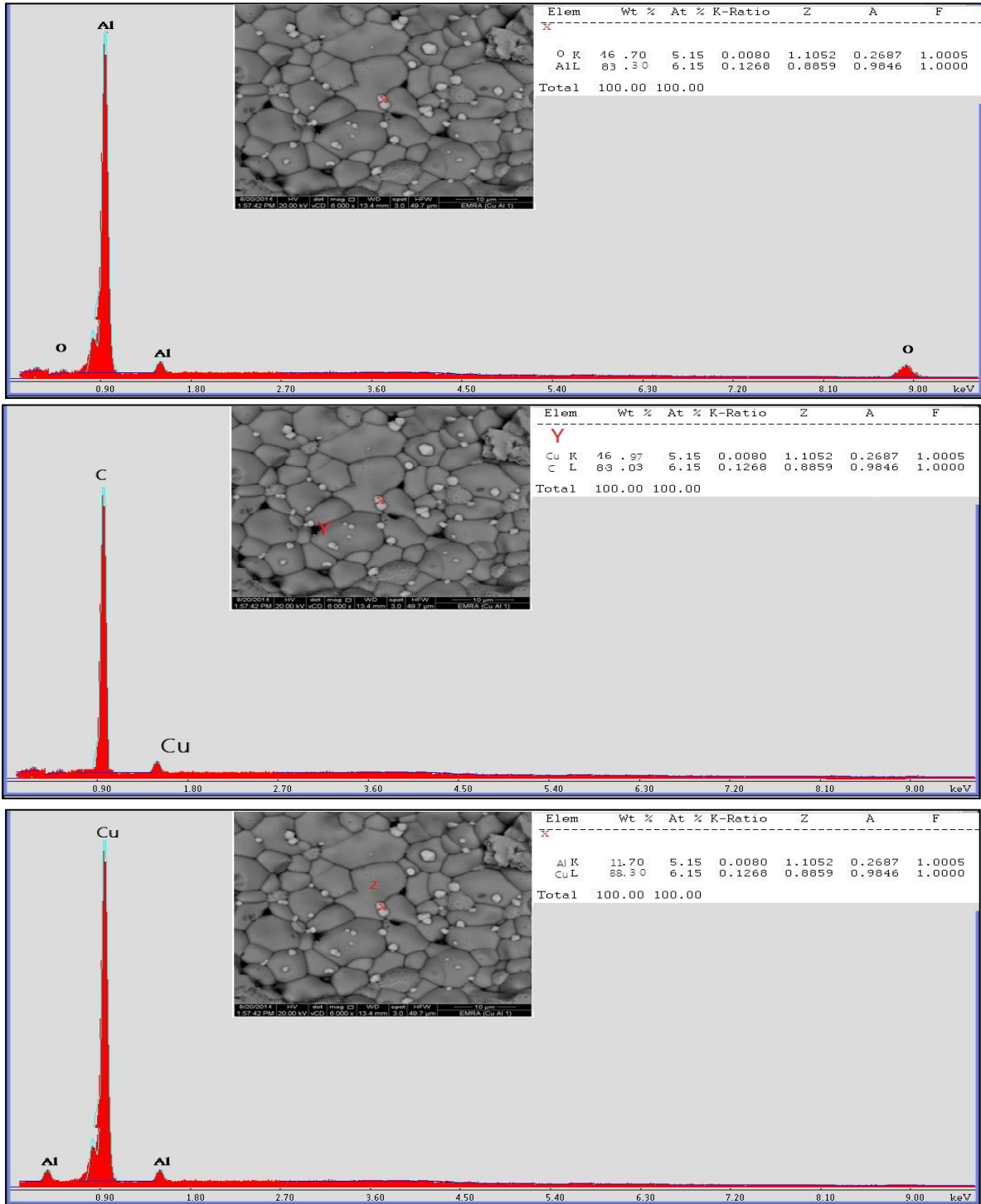


Fig. 4 SEM and EDS of aluminum bronze- 1 wt.%Al₂O₃-1 wt.%CNTs composite.

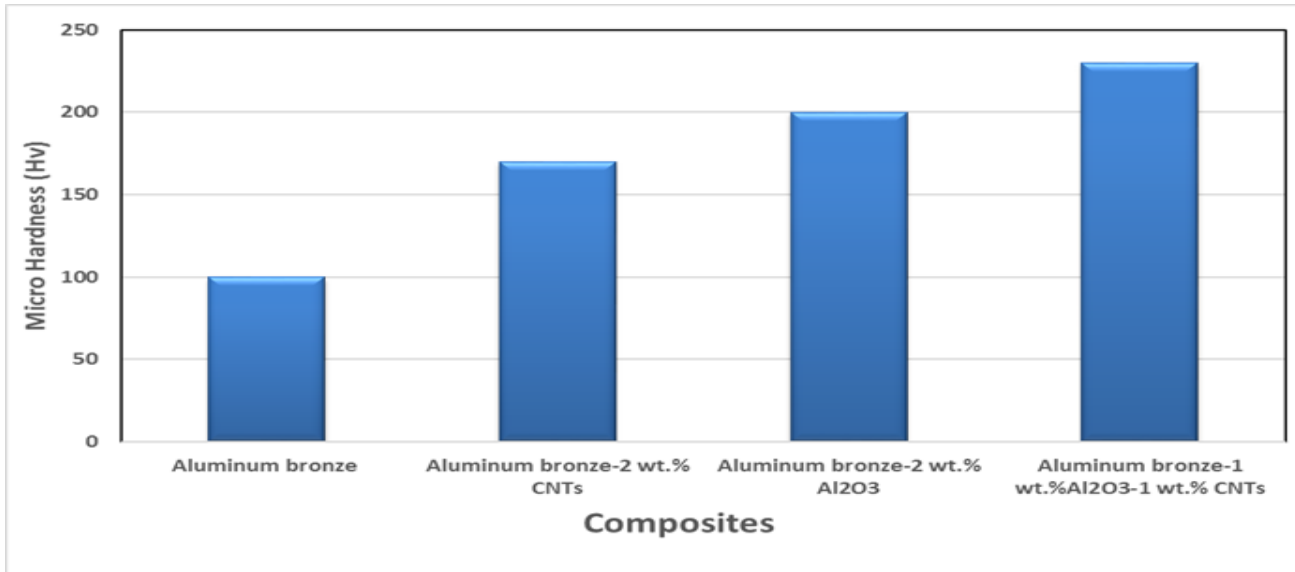


Fig. 5 Hardness of composites and aluminum bronze matrix.

3.3 Wear

Fig. 6 illustrates the wear loss of aluminum bronze, n- Al₂O₃/aluminum bronze, CNTs/aluminum bronze composites, and CNTs + n- Al₂O₃/aluminum bronze composites assessed by pin-on-disk wear test. Under dry sliding wear condition, the wear loss of CNTs + n- Al₂O₃/aluminum bronze composite is decreased to one-third compared with those of aluminum bronze matrix. Consequently, this composite shows three circumstances higher wear resistance by an expansion of CNTs+ n- Al₂O₃. It was reported that CNTs presented to the well-used surface amid wear process can go about as a greasing up carbon film inferable from its low wear coefficient [10]. Hence, the wear loss of CNTs + Al₂O₃/aluminum bronze composites is surprisingly diminished because of the impact of homogeneous circulation of CNTs in aluminum bronze and low corrosion coefficient of uncovered CNTs on the well-used surface. The hardness and wear resistance of the cross composites were better than that of the network material. Similarly, it was reported that the hardness of the composites containing SiC and Al₂O₃ was higher than that of the composites with SiC and Gr because of the consolidated sticking impact of SiC and Al₂O₃ and the higher hardness of Al₂O₃ to that of the Gr [26].

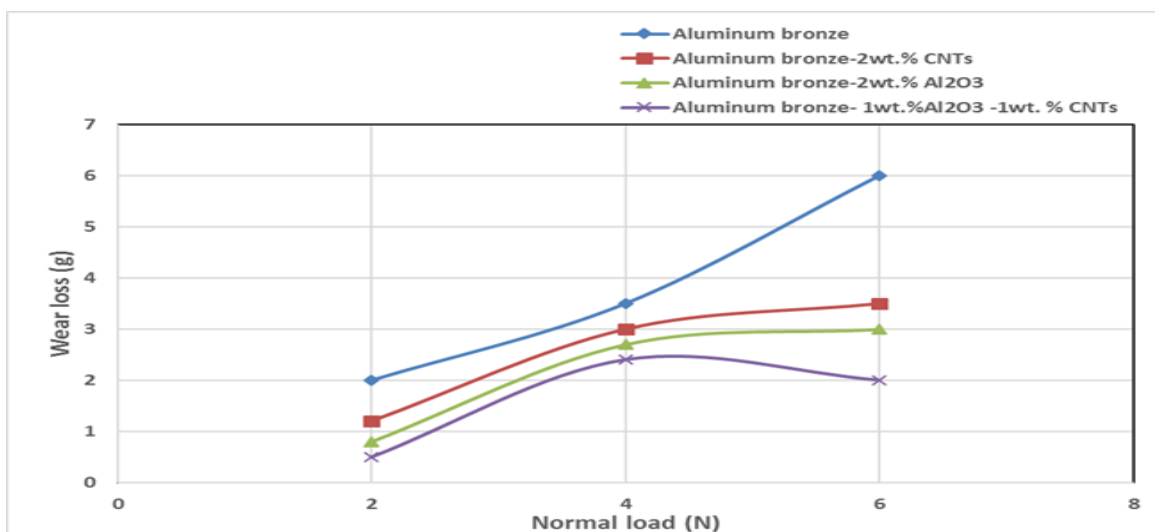


Fig. 6 Wear loss in (g) of the aluminum bronze and composites.



3.4 Density

The experimental and theoretical densities values of the composites containing different support rates are shown in Fig.7. It can be seen that the experimental and theoretical density values are nearer to each other for the separate composites, as shown in Table 2. Additionally, it was observed that the density of aluminum bronze matrix - CNTs or n- Al₂O₃ particles, and hybrid composites are higher than that of the base matrix. Obviously, the density of aluminum bronze - 2.0 wt.% CNTs has the higher density compared with the others examined composites. This increase in density of the aluminum bronze - 2.0 wt. % CNTs composite resulted from the higher density of CNTs than that of the Aluminum bronze. The density of the Aluminum bronze matrix increased by around 8.62% as the CNTs content was added to the matrix. The theoretical density of composite was calculated by the following equation:

$$\rho_c = V_p \rho_p + V_m \rho_m$$

Where ρ_c , ρ_m and ρ_p are density of composite, matrix and particles, respectively. V_p and V_m are the volume portion of particles and matrix, respectively.

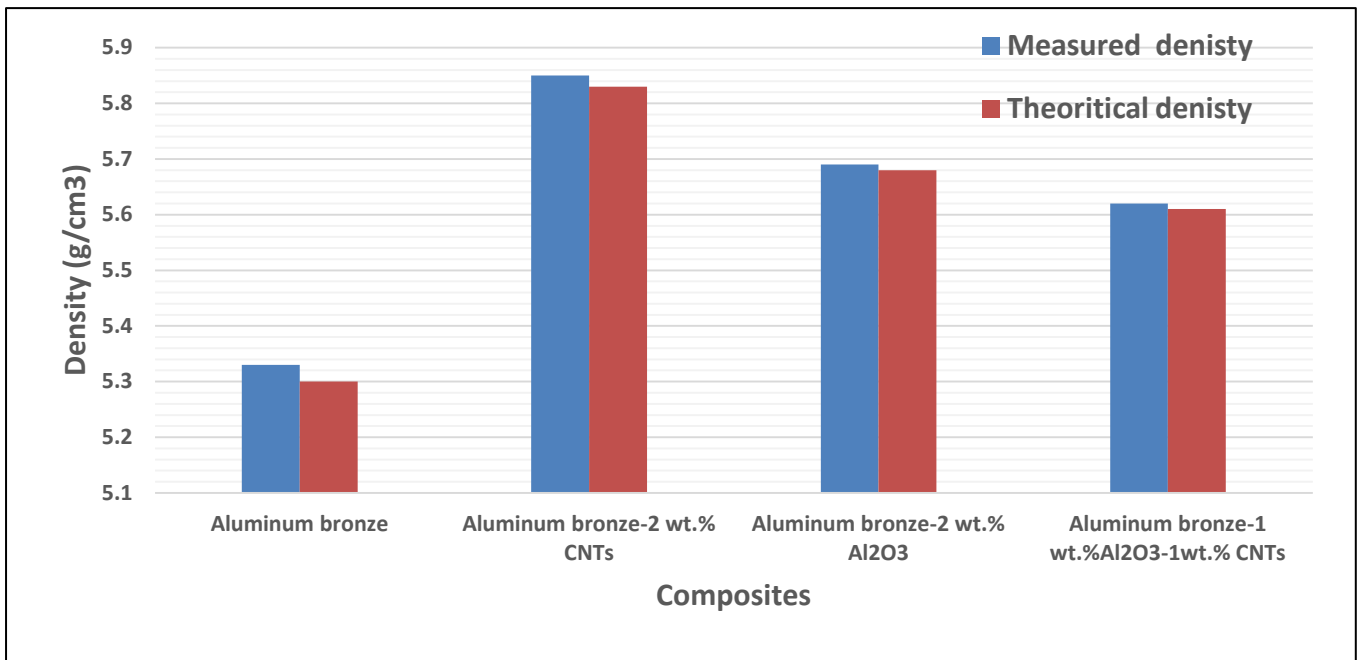


Fig. 7 Experimental and theoretical densities of aluminum bronze and composites.

Table 2 Experimental and theoretical densities of the examined composites.

Composite	Experimental density	Theoretical density
Aluminium Bronze	5.382351846	5.27
Aluminium Bronze-2% CNTs	5.724374853	5.71
Aluminium Bronze-2%n- Al₂O₃	5.691200755	5.58
Aluminium Bronze-1%n- Al₂O₃+1% CNTs	5.659537317	5.54



3.5 Electrical Resistivity

Fig. 8 shows the variation of electrical resistivity with different composites. It was observed that the average electrical resistivity of the aluminum bronze 2 wt.% CNTs composite decreases about 25% compared with the matrix. This shows that the addition of conducting CNTs in good conducting matrix phase severely affect the electrical resistivity. From results, it is clear that CNTs are homogeneously dispersed in aluminum bronze matrix. However, the addition of ion-conducting n- Al_2O_3 particles in good conducting matrix phase does not severely affect the electrical resistivity. Notable from the results, the electrical resistivity of the hybrid composite is lower than the matrix.

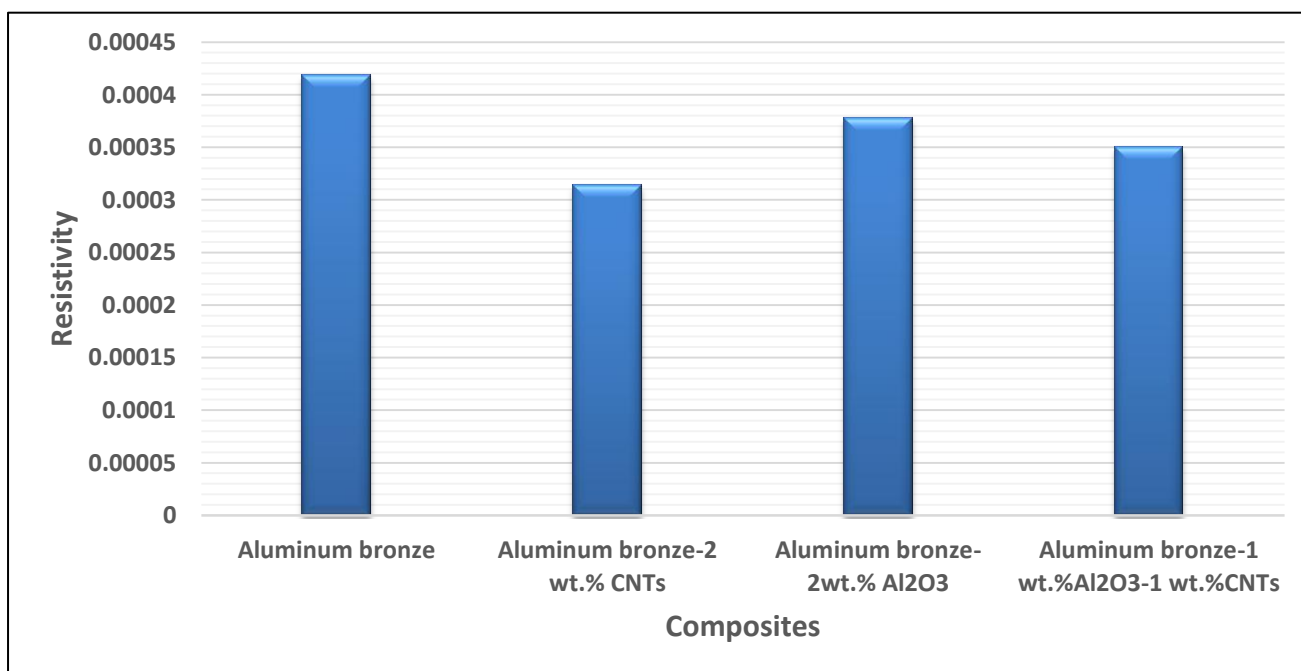


Fig. 8 Electrical resistivity of aluminum bronze and composites

4. Conclusions

In this study, the effect of reinforcing n- Al_2O_3 NPs and/or CNTs on the microstructure characterization, microhardness, wear, density and electrical resistivity of in Al bronze matrix was studied. The results are summarized as follows:

- (1) Hybrid Al bronze matrix reinforced with CNTs and n- Al_2O_3 particles were prepared successfully using sintering process.
- (2) The characterization of n- Al_2O_3 particles and CNTs dispersed in Al bronze matrix composites were studied using SEM with EDS analysis. The result indicated the presence of CNTs and n- Al_2O_3 particles in the Al bronze matrix composites.
- (3) Inclusion of CNTs and/or n- Al_2O_3 in the metal matrix composites improved the microstructure and the properties of the composite material.
- (4) The hardness and wear resistance of manufactured CNTs + n- Al_2O_3 /aluminum bronze composite were significantly the highest compared with the others composites.
- (5) It has observed that the density of the matrix increased by around 8.62% as the CNTs was reinforced. In addition, results showed that the typical electrical resistivity of the aluminum bronze CNTs composites increased around 25%.



Conflicts of Interest

The authors declare that they have no conflicts of interest.

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