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Preparation and Corrosion Behavior of Bronze -40%w Composite

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Abstract

Bronze -40%w Composites are successfully prepared by compacted mixtures powder into pellets. The green compacts of (bronz– 40wt%W) were sintered for (60- 120 min) at 750, 850, 950°C. Scanning Electron Microscopy (SEM) technique was used for microstructure test of the raw powders, and composites. The results obtained reveal that the densities increased with increasing compaction load, sintering time and temperature. The average of Vickers hardness for composites 60wt% bronze -40wt%W was 91.5. Tin electroplating improves corrosion resistance of the bronze/w, by electroplating with tin solution electrolyte and applying suitable current (0.01A) for 4 hour, coating layers of 45- 60 µm were obtained. Corrosion rate measurements were done for different samples with different conditions (non-coating, coating and scratched coating). The corrosion current of scratched coating sample is higher than unscratched samples, due to cathodic protection of exposed area of composite substrate. Consequently, the corrosion rate of scratched coating sample is higher than unscratched.

Keywords: *Bronze Matrix, Composites, Cu–WC, Corrosion.*

1. Introduction

A considerable interest has been given to metal-metal composites and metal-ceramic composites because of their unique combination of strength, fracture toughness, high hardness, low density, low coefficient of thermal expansion that make them ideal candidates for light weight application [1,2]. Properties of lead, like flexibility, ease in obtaining, corrosion resistance, high density, and low melting point, make it easy to handle and fashion [3]. The combination of high density and good corrosion resistance can be considered as an advantage, which makes lead an excellent material for fishing application, and effective in manufacturing of many types of fishing tackles and angular accessories [4, 5]. Lead is ranked number two in the U.S. government's top 20 hazardous substances propriety list. The U.S. environmental protection agency has listed lead as a toxic chemical and set very restrictive threshold limits for concentrations in air, soil, water and vegetation [6, 7]. However, Lead can be replaced by tungsten because it has higher density and higher melting temperature than lead. Usually adequate mechanical properties and unusual properties are the main reason for fabricating by Powder Metallurgy (PM). Conventional method led to high cost reinforcing phase preparation and poor interface bonding between reinforcement and metal matrix [8]. Copper alloy powder has been selected as a matrix, due to its availability with a low cost, while tungsten (W) powder, which has high density, has been selected as reinforcement to attain a fishing tackle with high density that imitate lead density. The fishing tackles use in sea water should have a good corrosion resistance. After preparation the sample surface electroplating was used to improve corrosion resistance [8]. Milling of elemental Cu, W and graphite mixture was undertaken by many researchers and they have studied the properties of Cu –W composites by mechanical alloying with different conditions [9-15]. The authors have not studied and comparing the structure, densities, hardness, and corrosion of (bronz– 40wt%W) as replacement composites materials of lead in many applications.

2. Experimental

In the present study, the starting materials chosen were bronze powders as matrix (purity 99.9%, purchased from ALDRICH) with a particle size of 325 meshes and tungsten powder (purity 99.9%, purchased from ALDRICH) with average particle sizes 100 meshes. Mixtures of (bronz – 40wt%W) were subjected to ball milling for 2 h at the speed of 100 rpm then compacted into pellets by different loads (5-15Kgf which is equal 156050- 468152 N/M^2(stress) when radius of the sample=

10mm) for 3 min. The green compacts of (bronz–40wt%W) were sintered by tube furnace under protective argon gas atmosphere for different sintering time (60 -120 min) and different sintering temperatures (750°C, 850°C, 950°C), The apparent density, green density and sintered density were taken for the powders and composites by using formula of ρ=m/v and using the gas pycsometer. Tin electroplating to improve corrosion resistance of the bronze/w, by electroplating with tin solution electrolyte and applying suitable current (0.01A) for 4 hour, coating layers of 45- 60 µm were obtained for sample with ($2.5cm^2$) surface area [14]. SEM technique was used for microstructure examination of the raw powders, and composites. The micro-Vickers hardness was measured at 5 points of the samples. The Corrosion Cell was designed for electrochemical measurements using Tafel extrapolation method with AUTOLAB software for corrosion rate determination in 3.5 % NaCl solution as simulated environment to sea water. Corrosion rate measurements were done for different samples with different conditions (non-coating, coating and scratched coating).

3. Results and Discussion

3.1. SEM and EDX Analysis

SEM micrographs of of bronze alloy powders, as in Fig. 1, show a spherical shape with different sizes.

The SEM image of the reinforcement powder (W) is shown in Fig. 3.2 the shape is clear polygonal with different sizes that are difficult to measure it due its irregularity. Powder characterization is necessary for future repetition and understanding the results.

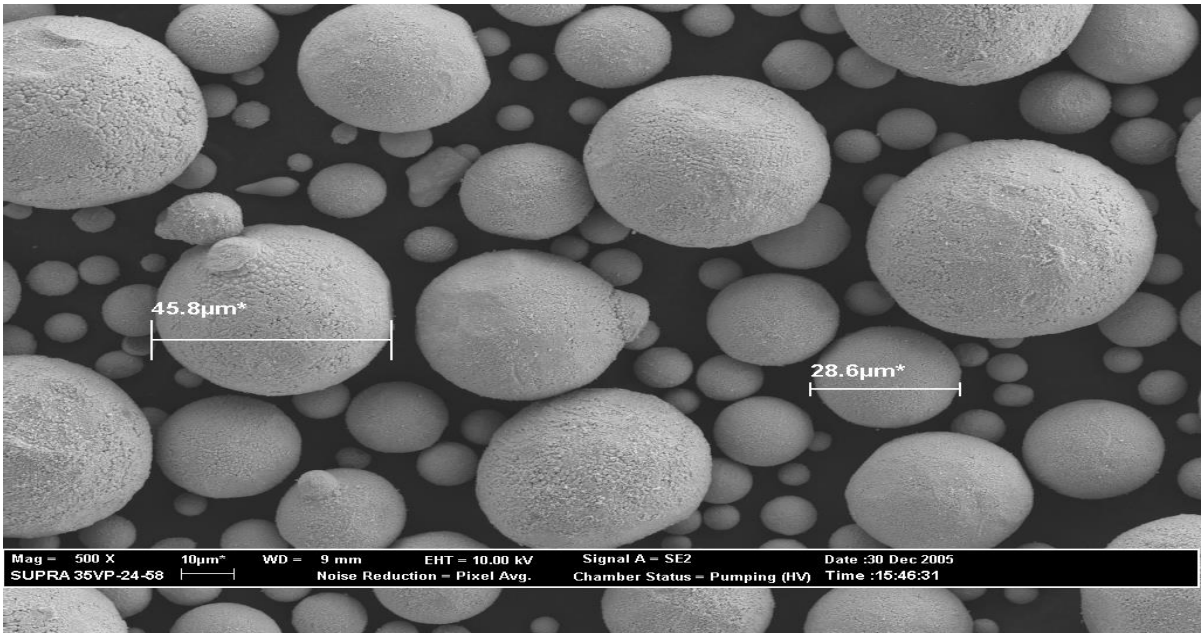

Figure 3.1. SEM micrograph of (a) bronze alloy powders, 500x

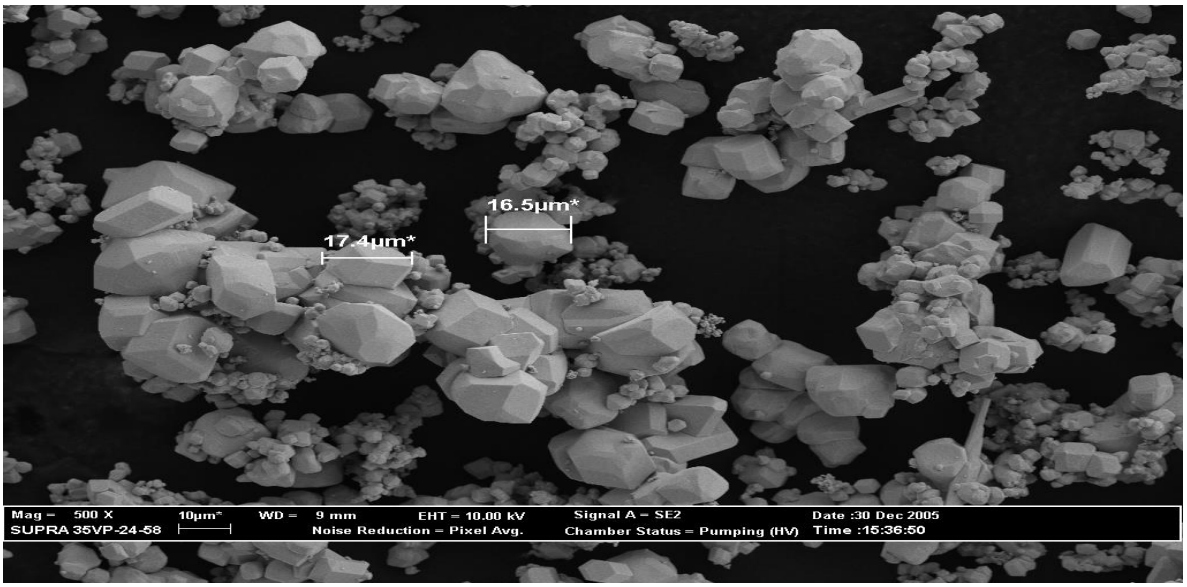

Figure 3.2. SEM micrographs of W powders, 500 X.

The matrixes of bronze alloy has been analyzed using EDX (Energy Dispersive X-ray) technique to determine and confirm its chemical compositions as show in Fig. 3.3 After select the point in the matrixes as show in Fig. 3.4. A uniform dispersion of reinforcement (W) powder in the metal matrix offers improvement in density and the mechanical properties of resultant composites as show in Fig. 3.4

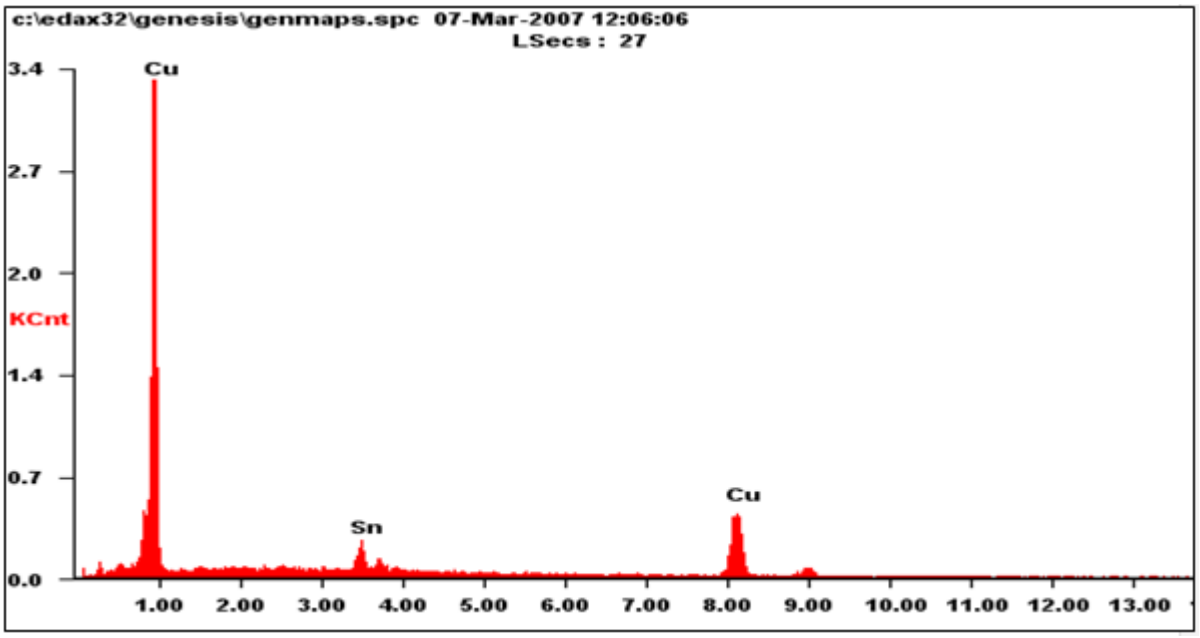

Figure 3.3. EDX microanalysis of matrix.

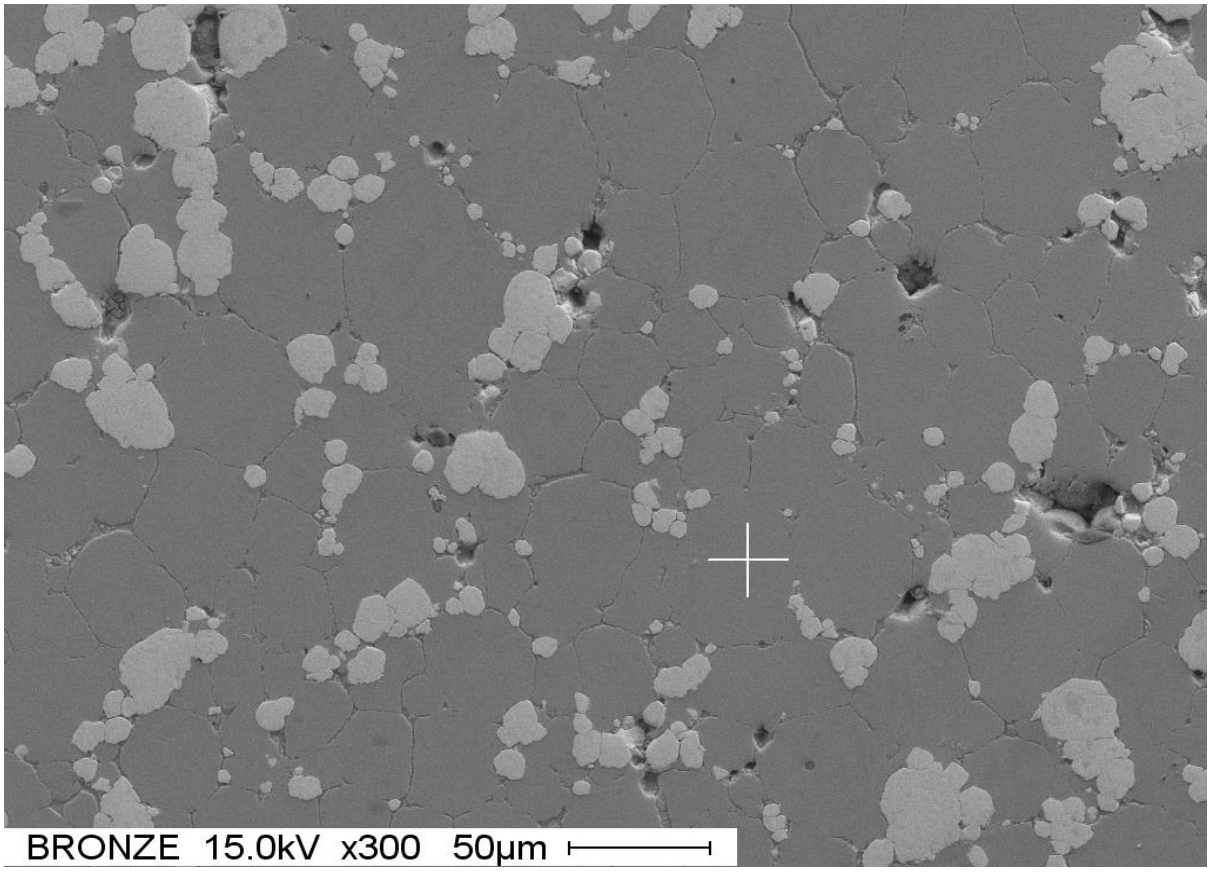

Figure 3.4. SEM micrograph shows the matrix

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The reinforcement tungsten (w) has been analyzed using EDX (Energy Dispersive X-ray) technique to determine and confirm its chemical composition, as shown in Fig. 3.5. After select the point in the reinforcement of composite as shown in Fig. 3.6.

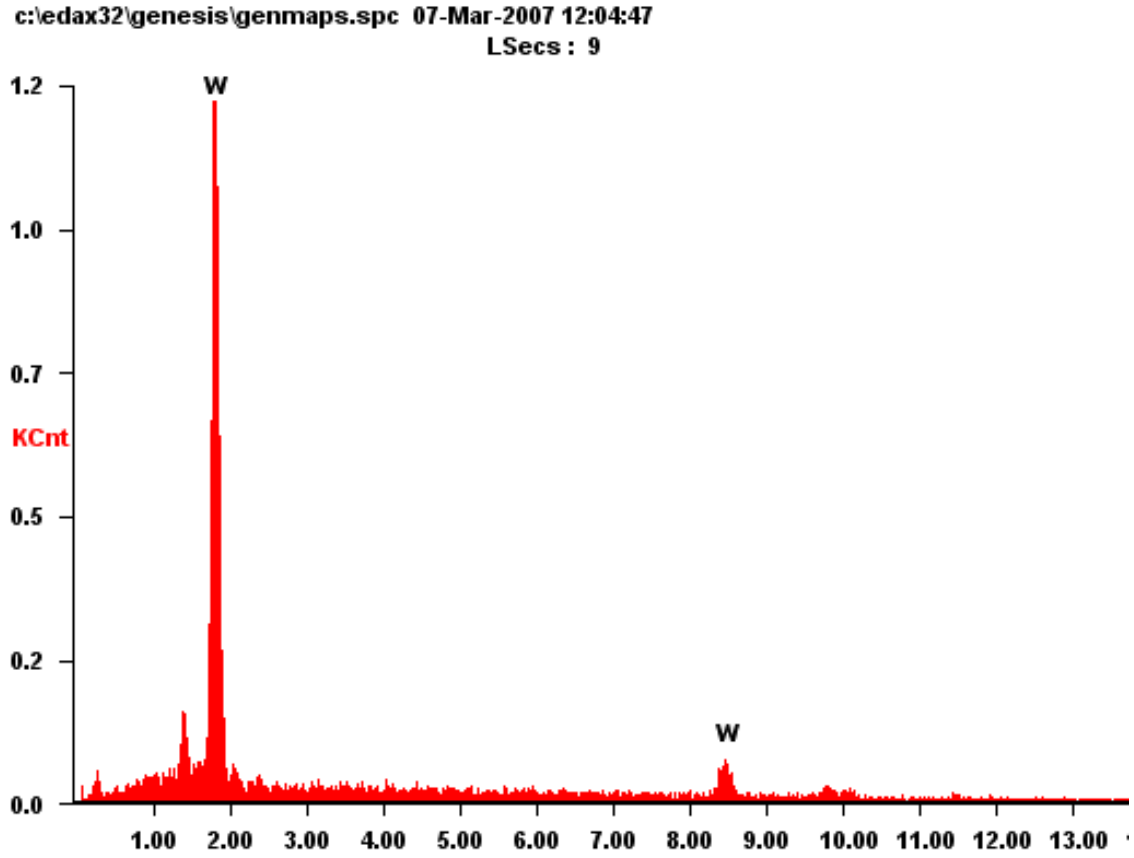

Figure 3.5. EDX microanalysis of reinforcement.

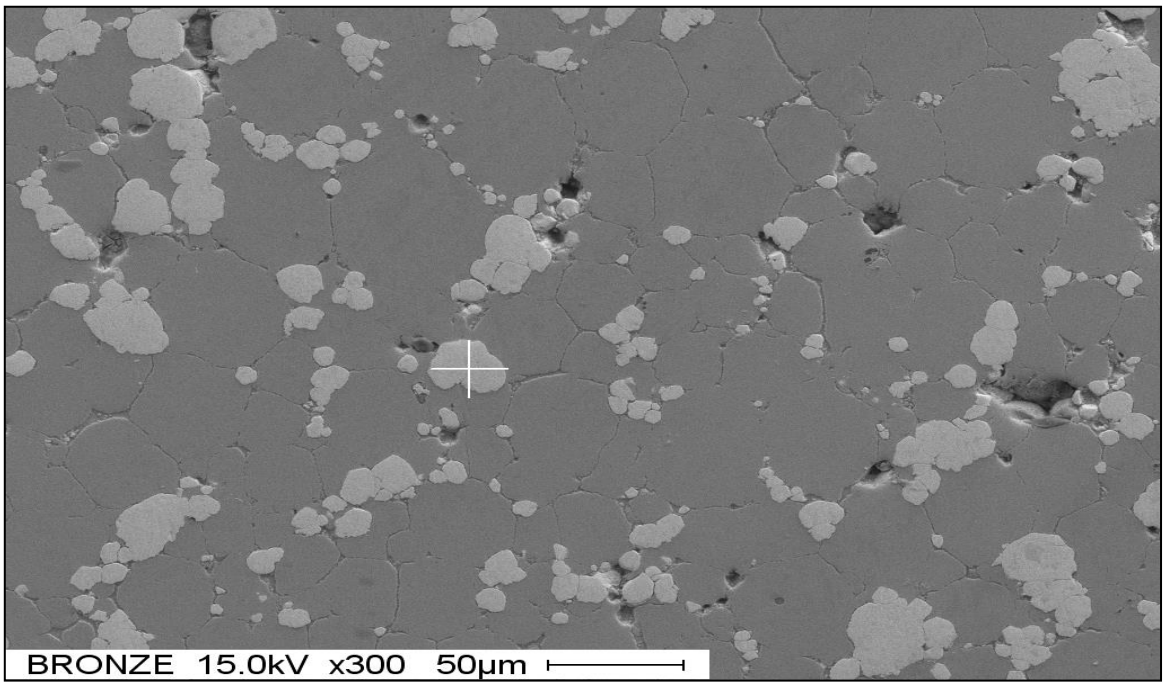

Figure 3.6. SEM micrograph shows the reinforcement

3.2. Density and Hardness Measurements

The aim of the present work is to replace the lead by bronze-w composites which have height density, good corrosion resistant and low cost. There for the follow of density improvement is required during powder technology process. The sintered densities were measured according the formula of ρ=m/v to calculated the sintered density; where:

P = density, m = mass of sample, v = volume

$v = \pi r^2 Xd$, r= radius of the die cavity = 0.65 cm,

d = thickness.

Apparent density is one of the fundamental properties of a powder, which affects processing parameters such as the design of compaction mould and the magnitude of the press motions required to compact. The average apparent density of bronze/tungsten powder was 5.90 cm^3 due to bronze has spherical shape as show in Fig.1. The green density as function of compacting load showed an increase with increasing the compacting load [17]. Table 3.1 illustrates the compressibility of the composite powder

Table 3.1: Compressibility of composite powder

Sample No.	The Type of composite	Load (Kgf)	The height of sample (cm)	$v = \pi r^2 Xd$ cm^3	Weight (g)	Green Density (g/cm^3)
4	60wt%bronze 40wt%w	5,000	0.35	0.464	4.41	9..83
5	60wt%bronze 40wt%w	10,000	0.33	0.438	4.44	10.1
6	60wt%bronze 40wt%w	15,000	0.31	0.411	4.42	10.75

The green density increase with increasing the compacting load due to decrease the volume of the sample with increasing the load, the formula ρ=m/v was used to determined the density. From Table 3.1 high the green density of 60wt%bronze -40wt%w due to the bronze compatibility and apparent density, compatibility depended on the type of the powder and the particle size of powder. From the Table 3.1 the Vary pressures between 5,000-15,000 (Kgf) were applied, by suitable pressure 10,000 (Kgf) good shapes after ejecting samples from the die were produced. The hardness was calculated from the diagonal length of the indentation optically determined for each indentation. The average of Vickers hardness for composites 60wt% bronze -40wt%W was 91.5. Fires samples bronze-w was sintered for 60 and 120 minute at 850 °C under protective atmosphere of argon gas. 10 ton was applied; sintered densities with 120 minute were higher than sintered densities with 60 minute, due to 2 hour sintering time enough to occur good densification (form and growth necks). The sintered density increase with increasing the sintering temperature but at high sintering temperature the samples particles was faced distortion and agglomeration because the matrix reach the pointe, as shown in Figure 3.7.

Figure 3.7: Samples bronze-w

A) before Sintering with a diameter of 10 mm

B) after Sintering temperature of 1000 °C (Distorted sample)

3.3. Corrosion Rate Measurements

SEM coating examination shows that the coating had uniform layer, due to clear regularity and shows good coating adhesion with substrate as shown in Figure 3.8 and the coating thickness varies between 30 µm and 58 µm.

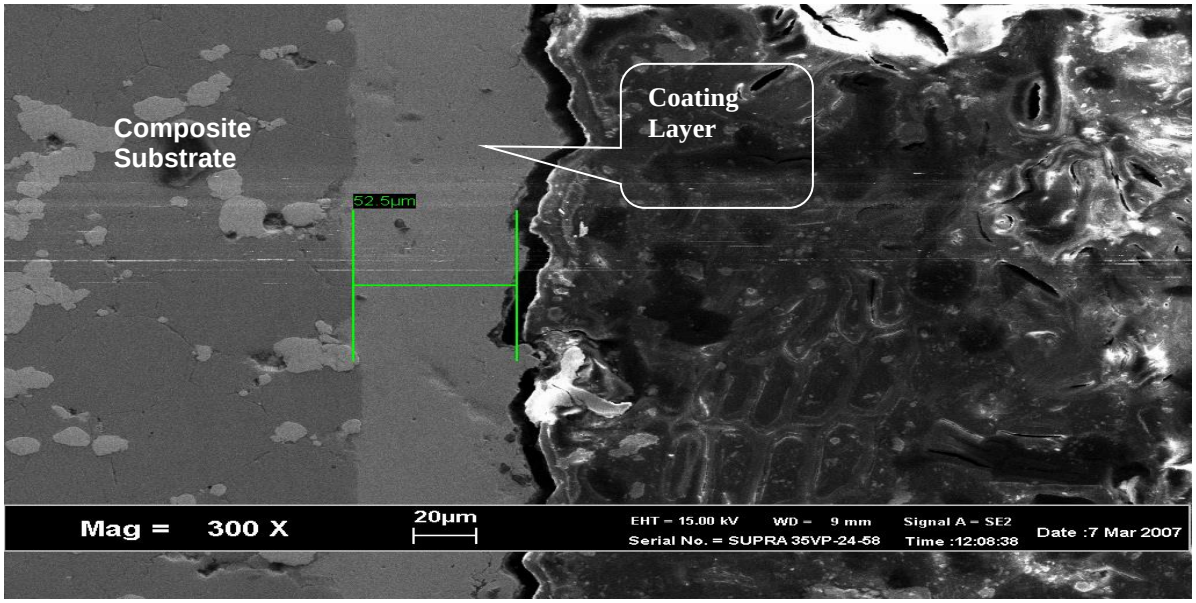

Figure 3.8: SEM micrograph shows the tin coating of thickness reveals good adhesion with the substrate (bronze-40%w)

By using AUTOLAB software corrosion rate was easily obtained. With polarization scan rate of 0.0005 V/second, density of sample 8.4 g/ cm^3 and surface area 1.453 g/ cm^3. Figures (3.9) show the obtained results of different type of samples composition and conditions (un-scratched coating, scratched coating, and un-coated samples) with Tin (Sn), in 3.5 % NaCl solution at room temperature (25 ^oC),

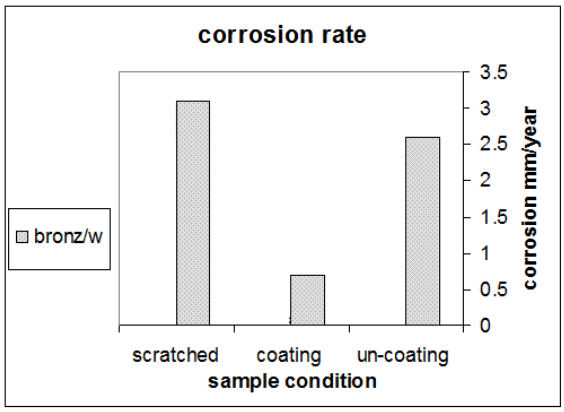

Figure 3.9: Corrosion rate for two composite with different condition

The corrosion behavior of a coated part (coating-substrate system) is determined by the corrosion resistance of the coating material in 3.5 % NaCl solution at room temperature medium. The coatings may be have two type defects: pores, damaged by scratches or other wear mechanisms, and other defects after electroplating process, the types of defects allow the corrosive medium to contact the substrate material [18]. That is why a coated sample was scratched with sharp tool to obtain scratched coating samples with scratch length of 10 mm, and 1 mm width. According to electrochemical series of metals, the coating metal which is Tin (Sn), is less noble than the substrate material, which is considered as Copper alloy, (the substrate material is composite material contains of 40 wt% of W reinforcement matrix of (bronze) [19]. It is an example of a corrosion cell, which is provided by an imperfect (scratched) coating of Tin (Sn) on composite samples immersed in 3.5 % NaCl solution. The current generated passes from the copper to the tin by the path of lowest resistance and returns to the copper through the solution by the passage of ions. The tin dissolves and is called the anode; whilst the copper is called the cathode. The corrosion current density of the scratched samples is more than un-scratched coating samples [20]. The corrosion current of scratched coating sample is higher than unscratched samples, due to cathodic protection of exposed area of composite substrate. Consequently, the corrosion rate of scratched coating sample is higher than unscratched.

4. Conclusion

Work has been done to prepare non lead heavy weight composites for fishing tackles application. Composites of bronze with reinforcement of 40 wt%w were produced. Proper powder mixing lead to homogenous tungsten distribution and two hours sintering time at 850 ^oC was suitable time to improve the density and hardens. Slight improvement in density when sintering temperature increased from 850-900^oC was observed. However sintering at 1000 ^oC was found detrimental on the final shape due to distortion by melting. Tin electroplating to improve corrosion resistance of the bronze/w, Thickness of coating layers that obtained were 45- 60 µm by electroplating with electrolyte(tin solution) by applied suitable current (0.01A) for 4 hour. The Corrosion Cell was designed for electrochemical measurements using Tafel extrapolation method with AUTOLAB software for corrosion rate determination in 3.5 % NaCl solution as simulated environment to sea water. Corrosion rate measurements were done for different samples with different conditions (non-coating, coating and scratched coating). The corrosion current of scratched coating sample is higher than unscratched samples, due to cathodic protection of exposed area of composite substrate. Consequently, the corrosion rate of scratched coating sample is higher than unscratched.

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