THE METHOD OF CARBON NANOTUBES ADDITION IN TO Al - Cu DISSIMILAR FRICTION STIR WELDED JOINT

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Abstract

The method of carbon nanotubes (CNT) addition to a friction stir welded dissimilar joint has been developed. The CNT agglomerates are produced in shape of paper sheets. CNT sheets added to the gap of butt joint during fixture before friction stir welding. Use of CNT sheets provide ability to measure the weight ratio of CNT in welds. Experimental addition of CNT in Al to Cu dissimilar joint for obtaining 7 % CNT in weld was done. XRD study of weld metal shows no formation of carbides as CNT degradation products. SEM study of different weld join parts shows evidence of carbon presence. EDX mapping of carbon in the joint showed that both Al and Cu weld matrix parts have carbon inside.

Keywords: Carbon nanotubes, metal matrix composites, friction stir welding, dissimilar joint

1. INTRODUCTION

Electrical conductivity of dissimilar Al-Cu joints in bus-bars, foil conductors in transformers, connectors, etc. usually made with use of bolts, rivets. Due to behavior under the thermal cyclic load (expanding/contracting) driven by the Joule effect [1] the connection between solid bodies might be lost or became poor and electrical resistance increases. In some cases, energy loses in such joints may be very high even with good connection [2].

Those problems might be solved by welding of Al to Cu, but standard welding approaches of fusion processes (arc, laser) are not possible to use due to difference in physical properties and formation of intermetallic phases between Al and Cu. But solid state welding processes can overcome those limitations and sound weld joint with decreased amount of intermetallics can be obtained by friction stir welding [2,3].

One of possible way to modify the electrical conductivity and mechanical properties of such joints is addition of carbon nanotubes (CNT), nevertheless no methods of addition are proposed yet.

The aim of this work is development of the method for CNT addition to the friction stir welded dissimilar joint, and evaluation of CNT distribution and degradation after welding.

2. EXPERIMENTAL APPROACH

2.1. Materials

Commercially available multi-walled carbon nanotubes were used as a raw material for addition in to the welding joint.

Alloys are: Al - of electro chemical purity, Cu- of electro chemical purity (ETP), chemical composition give in **Table 1** and **2** respectively.

Table 1 Chemical composition of Al-ETP

Element	Fe	Si	Mn	Ti	Al
Concentration, (wt.%)	0.3	0.3	0.025	0.1	Bal.

Table 2 Chemical composition of Cu-ETP

Element	Fe	Ni	S	As	Sn
Concentration, (wt.%)	0.005	0.002	0.004	0.002	0.002
Element	Pb	Zn	O	Sb	Cu
Concentration, (wt.%)	0.005	0.004	0.05	0.002	Bal.

2.2. Methodology

So, called buckypaper was made of purchased CNTs. There are various types of processing for preparation buckypaper described in the literature [4-6]. **Figure 1** shows the prepared buckypaper sample and **Figure 2** - SEM images with different magnification.

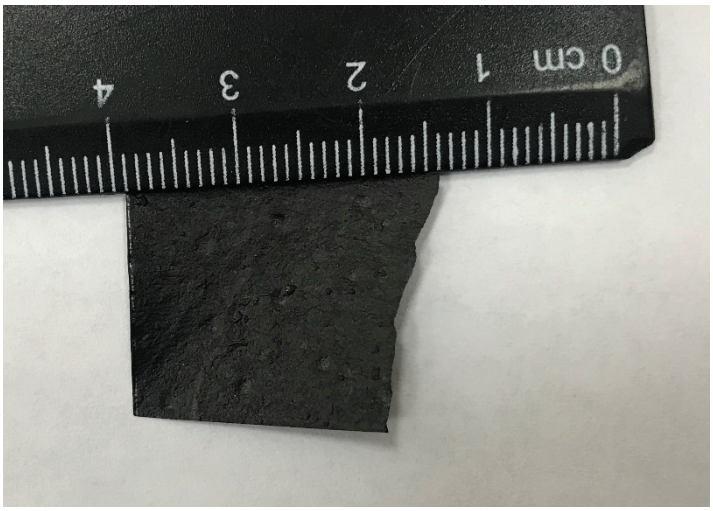

Figure 1 Sample of buckypaper

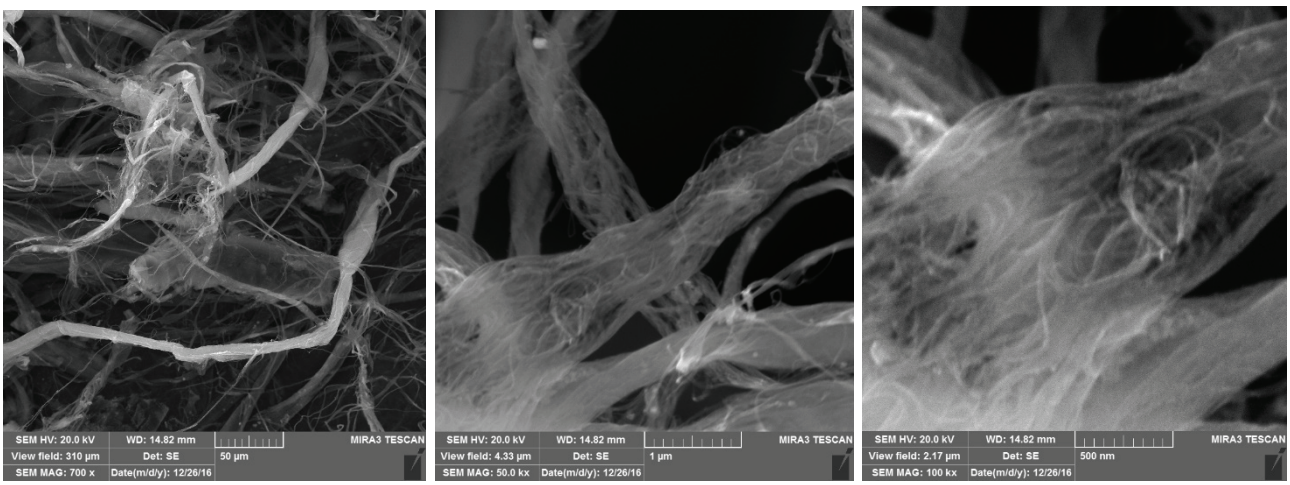

Figure 2 SEM images of prepared buckypaper

Friction stir welding parameters were found with a several tryouts of Cu to Al butt welding. Parameters are given in **Table 3** it is important to notice that during welding the tool has offset to aluminium side with respect to good welding practice [7]. Buckypaper was sliced to 3 mm wide strips and placed in the butt joint between 3 mm thick Al and Cu sheets without visible gap.

Mass of the added CNT buckypaper was measured and it is corresponded to 7 % of CNT in weld metal.

XRD of polished upper surface was evaluated (**Figure 4**) as well as SEM of stir zone with EDX mapping in cross section (**Figures 5 - 9**).

Table 3 Friction stir welding parameters

Rotation speed, rpm	Travel speed, mm/min	Force/Impulse Force, kN	Tool probe offset to Al side, mm
1200	100	7	2.0

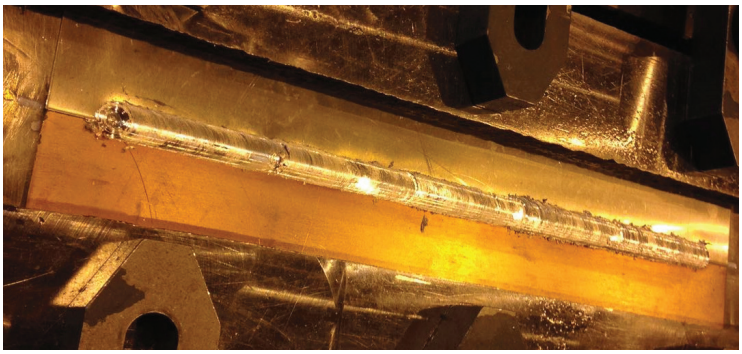

Figure 3 Overview of the joint

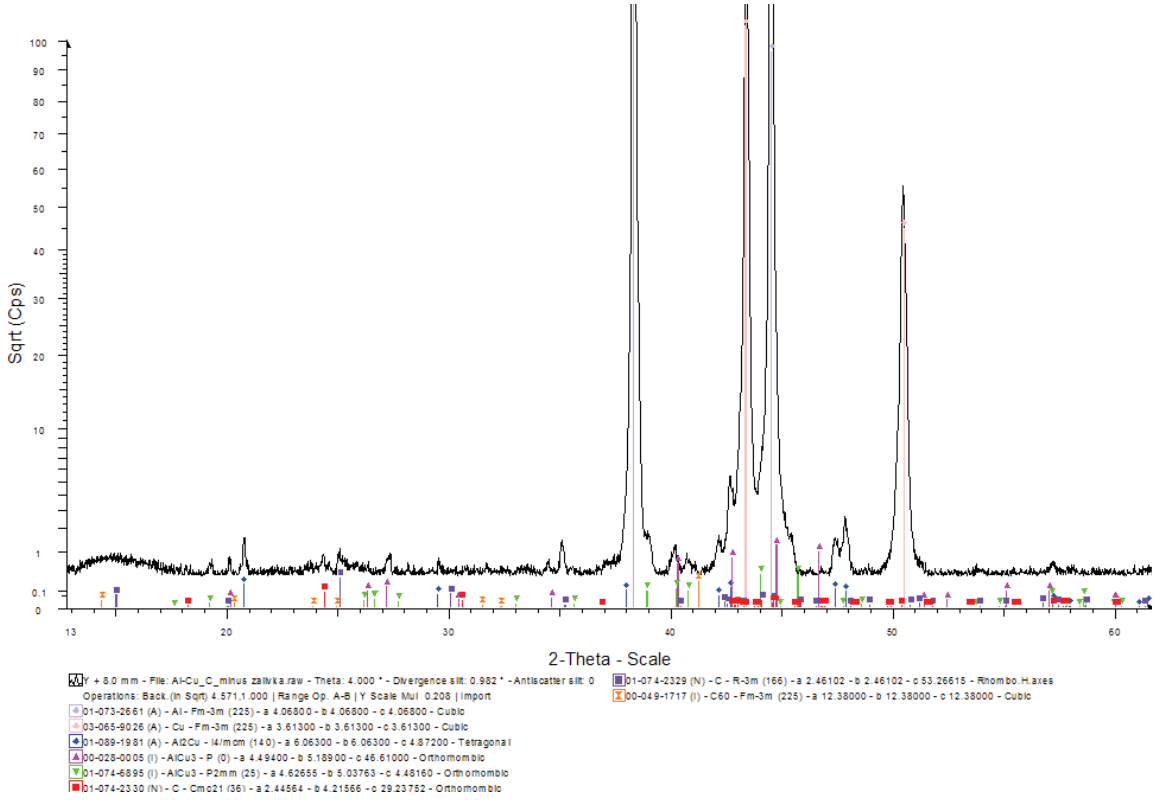

Figure 4 XRD patterns

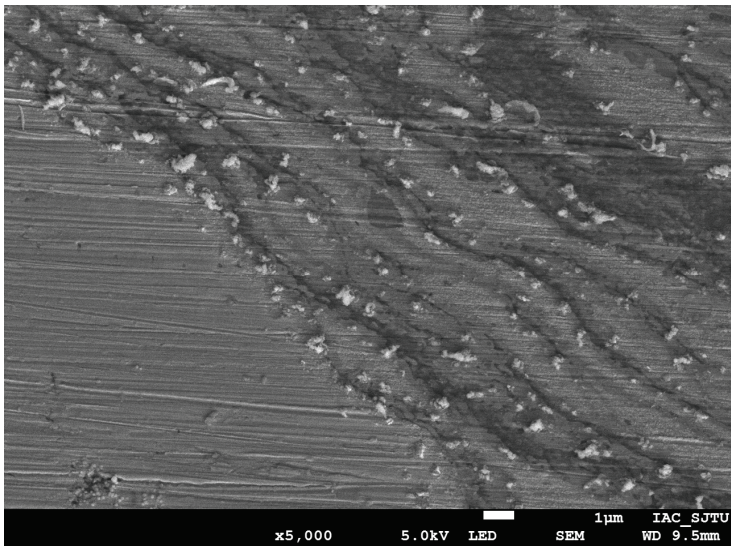

Figure 5 SEM image of stir zone near boundary with copper

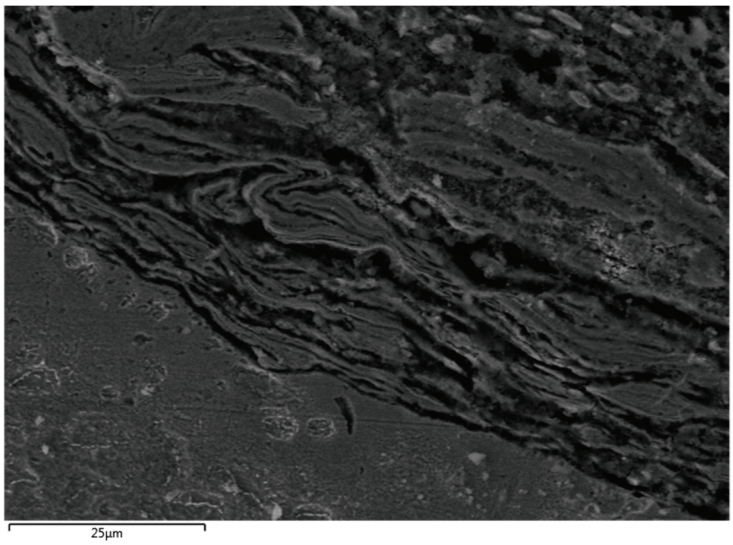

Figure 6 SEM image of stir zone near boundary with copper

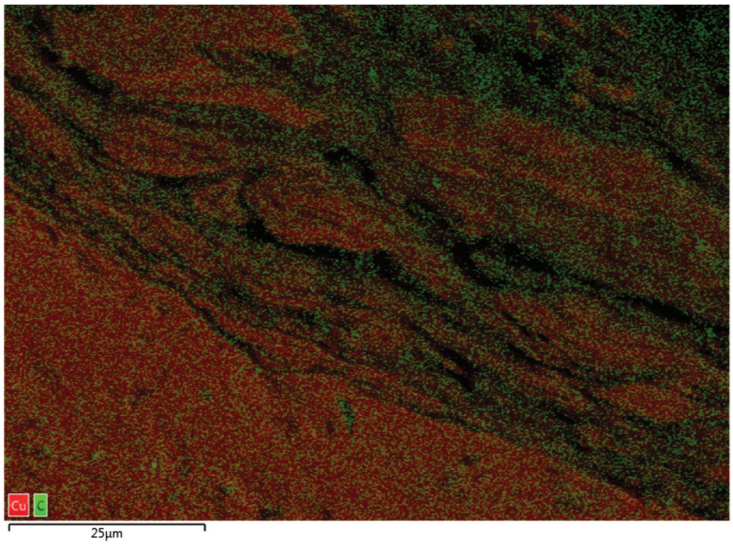

Figure 7 EDX mapping of copper and carbon in stir zone near boundary with copper

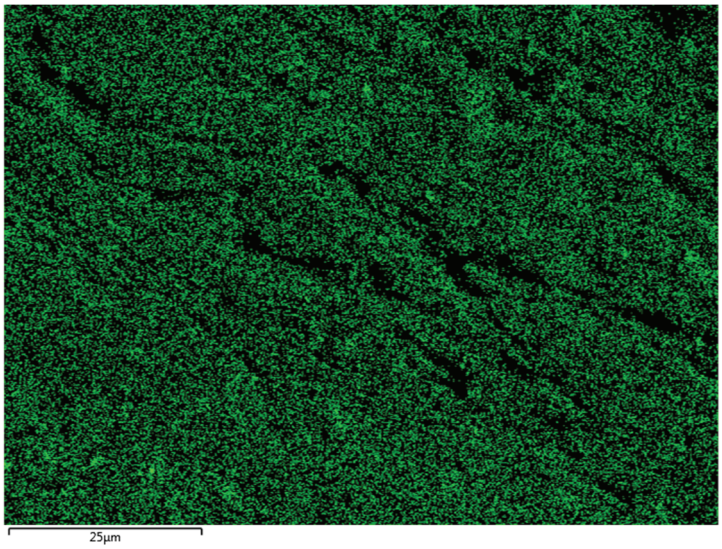

Figure 8 EDX mapping of carbon in stir zone near boundary with copper

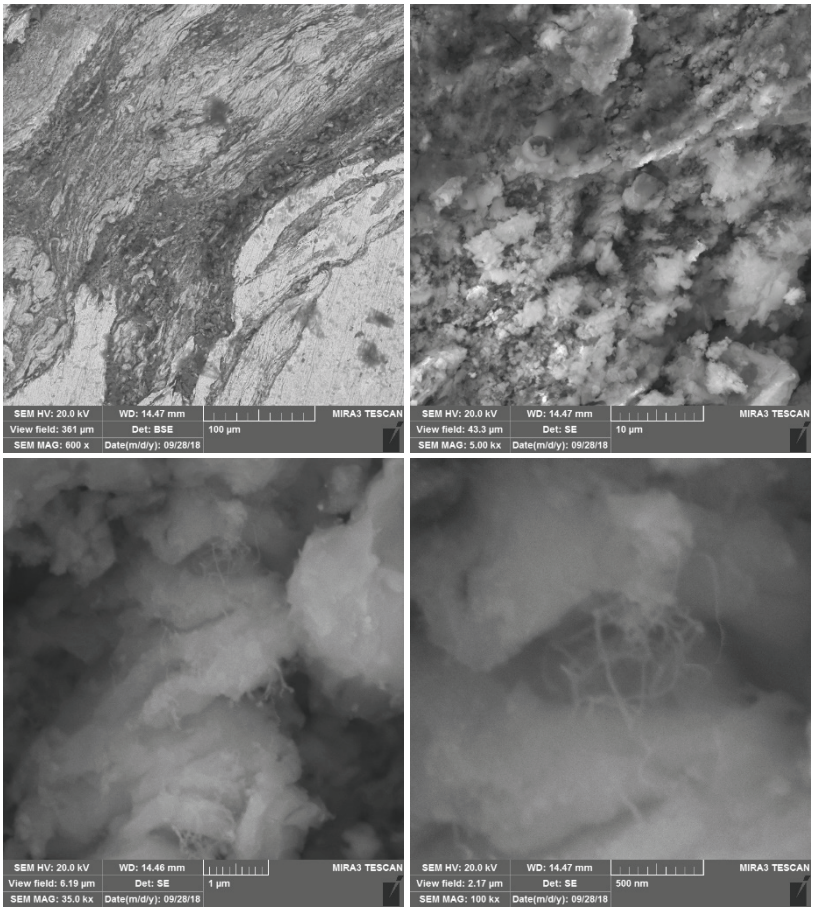

Figure 9 SEM image of stir zone between material clusters

3. RESULTS AND DISCUSSION

Analysis of XRD patterns shows evidence of Cu_xAl_y - intermetallic phase formation but no carbides are found as any other possible chemicals with carbon (**Figure 5**). So due to temperature and stir processes during welding intermetallics formation was stated in several papers [2,7]. As well as carbides, carbonates and many

other carbon containing chemicals are stated to be the CNT degradation products [8-11]. At that point, no CNT degradation during friction stir welding of Al to Cu was found using XRD.

SEM mapping analysis of carbon distribution near Cu boundary (**Figures 7, 8**) is evidence that CNT distributed both in Al and Cu metal matrix. Nevertheless, it is well seen that carbon distributed not evenly. The reason for that might be the metal flow during stir process. With the same reason Al and Cu metal forms a sort of material clusters of complex shape. It is well seen form **Figures 5 - 7** that metals also distributed not evenly. Analysis of SEM images of boundary between clusters with high magnification (**Figure 9**) shows CNT in metal matrix.

4. CONCLUSION

Method for the addition of carbon nanotubes to friction stir welded joint has been developed. Carbon nanotubes were found in stir zone of weld metal between clusters of Cu and Al. No evidence of CNT degradation during friction stir welding was found. Distribution of CNT in both copper and aluminium matrix of weld metal has achieved.

ACKNOWLEDGEMENTS

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