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JOINING HEATSINK COMPOSITE MATERIALS TO CERAMICS*

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The special kind of MMCs (carbon fibre or tungsten particle reinforced copper matrix composites) with a low coefficient of thermal expansion, a high thermal conductivity and thermal stability, can be used successfully in many industrial areas as e.g. heatsink in electronic packaging, electric contacts with high dimensional stability, substrates for high – power semiconductors with similar thermal expansion as silicon or ceramics.

In order to make full use of the advantages of this kind of materials, it is necessary to joint it to ceramics. This paper presents the results of investigations concerning the soldering of carbon fibre – copper and tungsten particle – copper composites to Al_2O_3 ceramics using Sn-Pb-Ag and Au-Sn fillers. The morphology and the nature of the interface layer after bonding process between the composite, filler material and ceramic were examined by microstructure investigations – analysing the linear and surface distributions of the elements. The analysis the surface and linear distribution of elements in the composite to alumina ceramics joints has shown that the nature of this interface is rather diffusion type.

1. INTRODUCTION

The special kind of MMCs (carbon fibre or tungsten particle reinforced copper matrix composites) with a low coefficient of thermal expansion, a high thermal conductivity and thermal stability, can be used successfully in many industrial areas as e.g. heatsink in electronic packaging, electric contacts with high dimensional stability, substrates for high – power semiconductors with similar thermal expansion as silicon or ceramics. Usually, the materials of the

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heatsink are composites like AlSiC, CuMo or pure copper. The appropriate heatsink are characterised: a good thermal conductivity, a coefficient of thermal expansion as closest as possible from ceramics, a good ability for machining and a good ability for the plating.

A point of considerable importance is the possibility of joining the composites with metals or their alloys. The major problem here is to choose the appropriate joining technique, such that ensures the formation of a high quality joint resistant to the service conditions, avoids the degradation of the composite microstructure, in particular of the interface layer between the matrix and the reinforcement, and, still, is not expensive [1].

This paper presents the results of investigations concerning the soldering of carbon fibre – copper and tungsten particle – copper composites to Al_2O_3 ceramics using Sn-Pb-Ag and Au-Sn fillers. The morphology and the nature of the interface layer after bonding process between the composite, filler material and ceramic were examined by microstructure investigations – analysing the linear and surface distributions of the elements. The analysis the surface and linear distribution of elements in the composite to alumina ceramics joints has shown that the nature of this interface is rather diffusion type.

2. EXPERIMENTAL PROCEDURE

Materials

The materials used for the experiments were:

- Cu/C_f composites containing 40 vol.% of C_f. These composites were manufactured by powder processing route (BRITE-EURAM III project no. BE-3876). The value of thermal conductivity of $Cu\text{-}C_f$ material is 150 W/mK and value of coefficient of thermal expansion 6.7×10^{-6}/K [2-3].
- Cu/W composites containing 62 vol.% of tungsten particles. These composites were manufactured by powder metallurgy technique (IEMT, Poland). The value of thermal conductivity of Cu/W material is 230 W/mK and coefficient of thermal expansion 9.2×10^{-6}/K.
- Al_2O_3 ceramics coating by Au by thick film technology technique (thickness of metallization 10 μm).

The Fig.1 shows the microstructure of Cu/C_f and Cu/W composites.

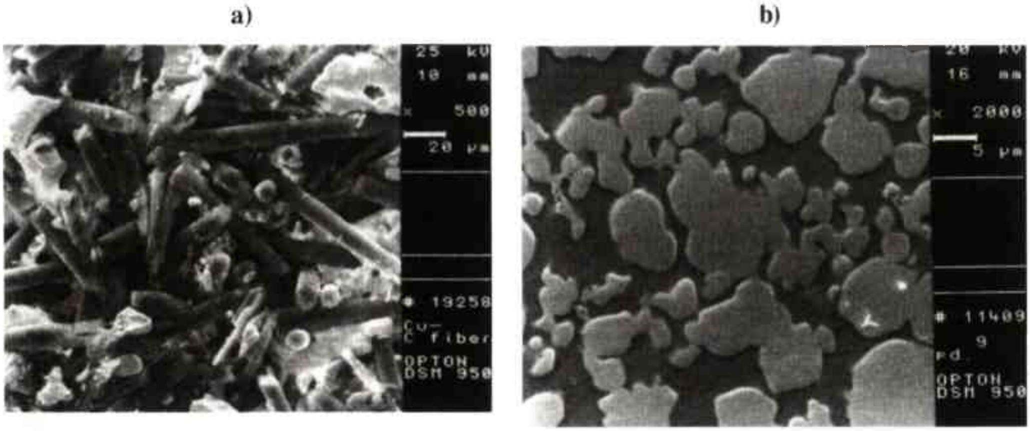

Fig.1. The microstructure of Cu/C_f (a) and Cu/W (b) composites.

Joining the heatsink materials

The Cu/C_f and Cu/W composites were joined with gold coated alumina ceramics using vacuum brazing technique (Fig.2) [4].

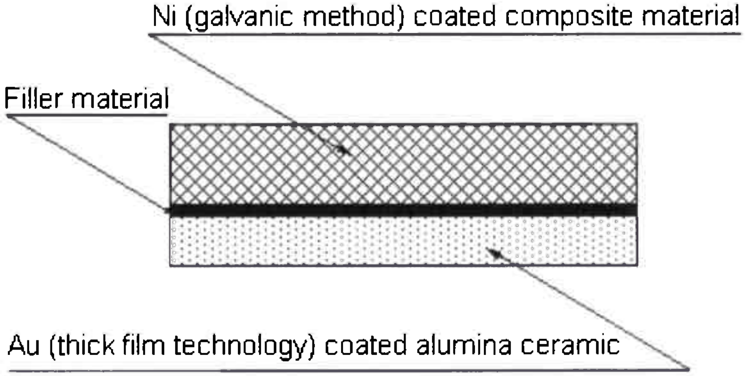

Fig.2. The scheme of the sample.

For improving the wettability this kind of heatsink materials by filler material, the Ni, Pb-Sn alloy or Sn coated Cu/C_f and Cu/W composites were used to the experiments (Fig.3).

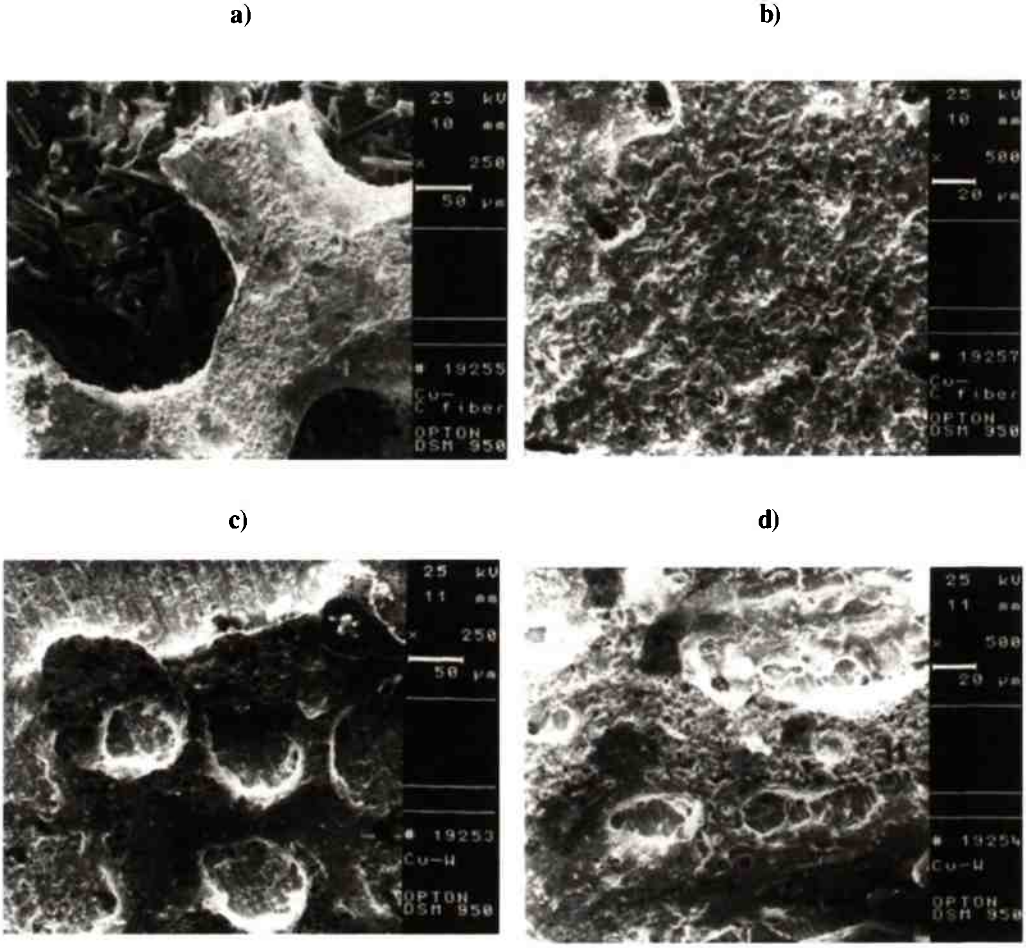

Fig.3. The wettability by AuSn20 filler material: a) uncoated Cu/C_f composites, b) Ni coated Cu/C_f composites, c) uncoated Cu/W composites, d) Ni coated Cu/W composites.

For the experiments the special vacuum brazing patterns, which: precise setting of the samples, uniformly temperature distribution, low pressure and easy removal of samples after joining process protected, were designed and produced (Fig.4).

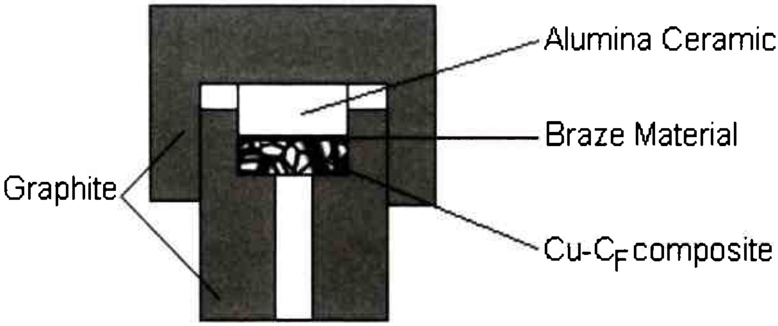

Fig. 4. Scheme of vacuum brazing pattern.

After the tentative experiments, the following filler materials were used to the joining processes:

A - 60Sn3.5Ag36.5Pb - melting point - 178-180°C,
B - 62.5Sn1.4Ag36.1Pb - melting point - 178-180°C,
C - AuSn20 - melting point - 280°C,
D - 5Sn3Ag92Pb - melting point - 300°C.

For there filler materials different brazing time (3.5 and 10 min) and different brazing temperature (A, B - 205-230°C, C - 220-350°C, D - 340-370°C) were examined. The schematic illustrations of the vacuum brazing process, Au coated Al_2O_3 ceramic to Ni coated composites using 60Sn3.5Ag36.5Pb filler material are show in Fig.5.

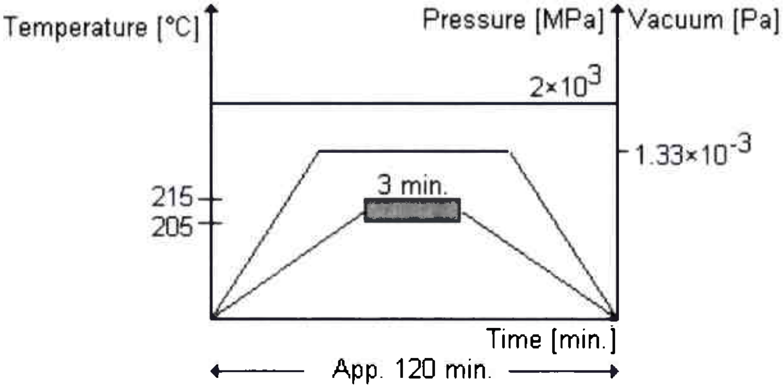

Fig.5. The schematic illustrations of the vacuum brazing process Au coated Al_2O_3 ceramic to the coated composite.

3. RESULTS AND DISCUSSION

The best results for the 60Sn3.5Ag36.5Pb filler material were achieved. The average shear strength (for 15 samples) of the joints was good - about 25 MPa. Fig.6 shows obtained joints – without any deformations.

Fig.6. The obtained (Ni coated Cu-C_f composite to Au coated Al_2O_3) joints.

A thorough analysis of the microstructure of the composites before and after the joining process has shown that the distribution of the reinforcing phase in the vicinity of the joint does not differ from that observed in the matrix [5]. The typical microstructure of Cu/C_f and Cu/W composites to gold metallized ceramic joint are show in Fig.7-8.

The analysis the surface and linear distribution of the elements in the Cu/W and Cu/C_f to gold coated Al_2O_3 ceramics has shown that the nature of these interfaces is rather diffusion type.

The Fig.9-10 give evidence for the above statement.

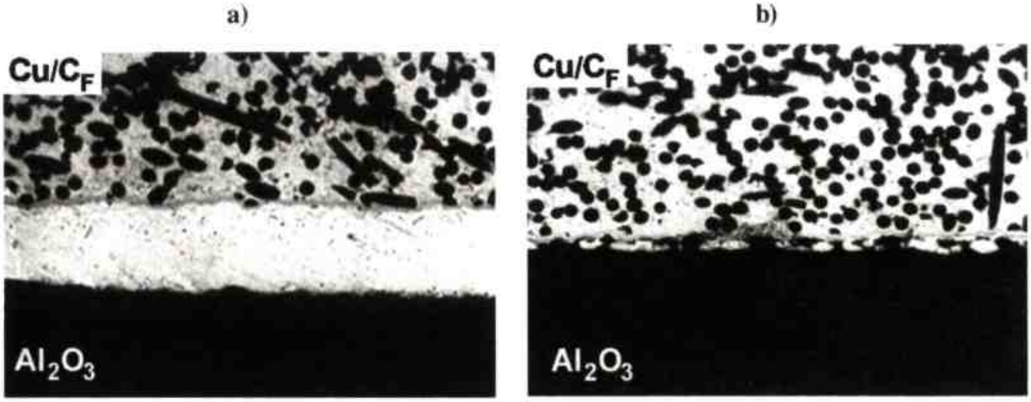

Fig.7. The microstructure of Cu/C_f - Al_2O_3 joints obtained using: a) AuSn20 filler material (x250), b) 60Sn3.5Ag36.5Pb filler material (x100).

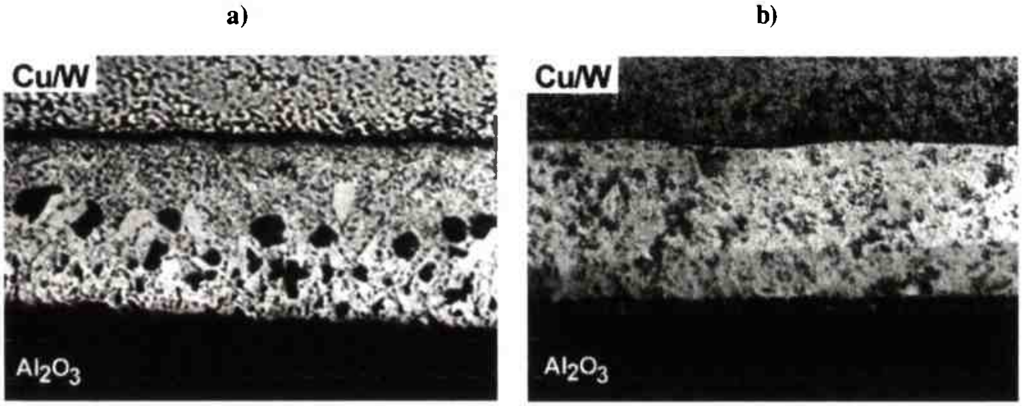

Fig.8. The microstructure of Cu/W - Al_2O_3 joints obtained using: a) 60Sn3.5Ag36.5Pb filler material (x250), b) AuSn20 filler material (x100).

4. SUMMARY

On the basis of the above results, we can state, that:

- the average (for 15 samples) shear strength of the joints was good - about 25 MPa;
- the obtained joints were without any deformations;
- the investigation of microstructure of obtained joints shows the continuous, uniform structure and good wettability of composite materials by filler;
- the analysis the surface and linear distribution of the elements in the Cu/C_f and Cu/W to gold coated Al_2O_3 ceramics has shown that the nature of these interfaces is rather diffusion type.

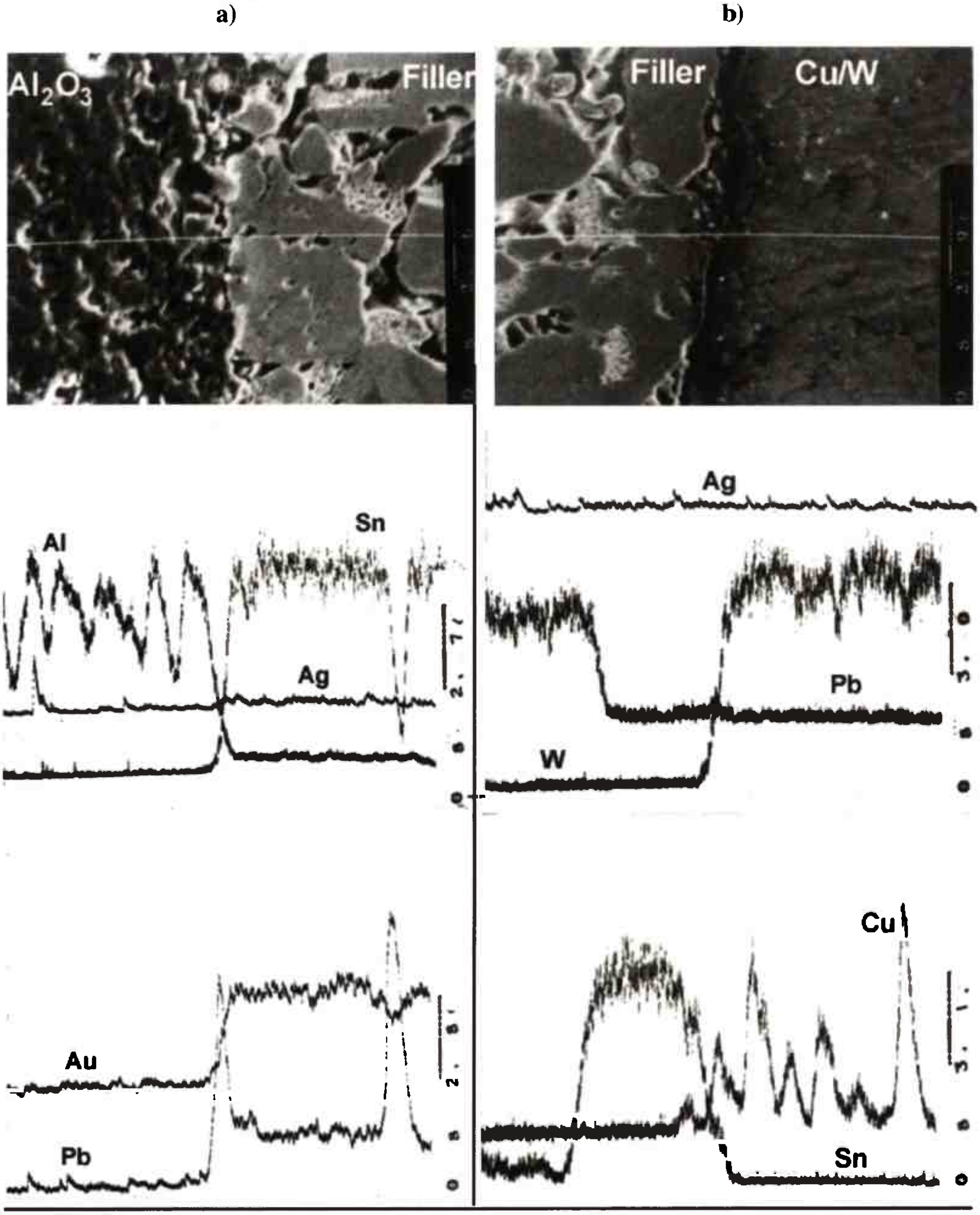

Fig.9. The linear distribution of the elements in the interface layer between Au coated Al_2O_3-60Sn3.5Ag36.5Pb- Cu/W (SEM x2000): a) Al_2O_3- filler material, b) filler material - Cu/W.

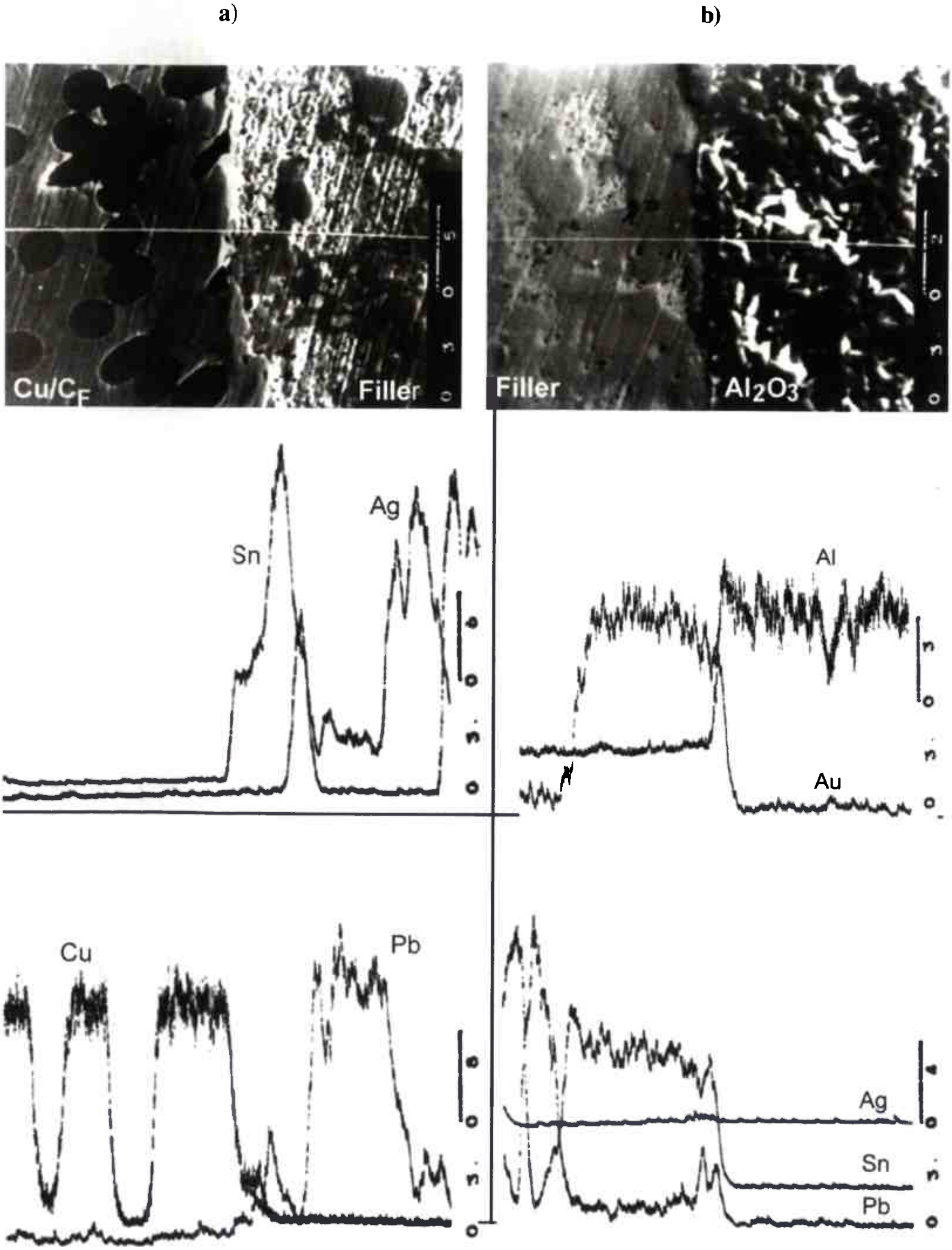

Fig.10. The linear distribution of the elements in the interface layer between Au coated Al_2O_3-60Sn3.5Ag36.5Pb- Cu/C_f (SEM x2000): a) Al_2O_3- filler material, b) filler material- Cu/C_f

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