

Carbon-metal thin films deposited by thermionic vacuum arc method (TVA)

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The aim of this paper is to present and characterise some carbon-metal films (such as C-Cu and C-Sn) obtained by the TVA method. Carbon-metal deposition is interesting for the following reasons: a fundamental investigation means to study how carbon and metal behave when they are alloyed; the ability of manipulating the tribological properties by infiltrating metal inclusions and metal carbides inside the films of amorphous carbon as well as the ability of lowering the stress and improving the adhesion of the prepared films. By transmission electron microscopy (TEM) analysis performed with a Philips CM 120 microscope with 2Å resolution, the structure of the carbon-metal films was identified as nanosized metallic grains (5-10 nm in diameter) embedded in the carbon matrix. The tribological properties were analyzed by a CSM-Switzerland, ball-on-disc tribometer using 6mm diameter sapphire balls, 1N load at 0.1 m/s sliding speed in dry conditions. The coefficients of friction of the prepared carbon-metal films were found to be lowered by factors between 3 and 5 compared to those of the uncoated substrates.

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1. Introduction

Deposition technology of thin layers using Thermionic Vacuum Arc method or TVA is a genuine technology of covering some varied components. It consists in covering in high vacuum, the evaporating material which is being put in an adequate nacelle (linked to the “+” clamp of the direct current generator) and being the anode of the electric discharge ignited in the pure vapours of the evaporating material. The anode can be even the evaporated material under the form of a bar of a 8-15 mm diameter and 50-200 mm length. The electric arc ignites between the cathode, which is a heated filament which is inside of a Whenelt cylinder and the anode material continuously evaporated by the electrons accelerated at high voltage and incident of the anode.[1]

The layer deposited from the plasma vapours got from the anode, lacks and sign of particles and gaseous inclusions. During the deposition the forming layer is continuously bombed by the high energy ions developed in the plasma of the TVA. As a consequence of this ion bombing, the film we get is nanostructured, compact and adherent.[2]

The tribological properties of the thin layers are highly dependent on the link type. So, TiC, VC, WC, TiB₂ and TiN, basically have metal links. The Al, Si and B borons and carbons are covalent and the Al, Ti, Be and Zr oxides are ionic.[3]

The most important parameters of this kind of coverings are the melting temperature the chemical stability, the hardness, the adherence to the metallic substrate and tendency of interaction with this.

2. Experimental

The thin layers shown have been deposited by TVA method on inoxidable supports and ordinary glass.

With C-Cu layers, 300 nm Cu have been deposited as a intermediary layer and then C and Cu have been deposited simultaneously and we got a 2µm C-Cu layer thickness.

The work pressure was 1.5×10^{-5} Torr and the deposition time was 58 minutes, 11 seconds.

With C-Sn layers 300 nm Sn have been also deposited as an intermediary layer, continued with a simultaneous deposition of C and Sn.

The experimental arrangement for C-Metal simultaneous depositions is shown in Fig. 1.

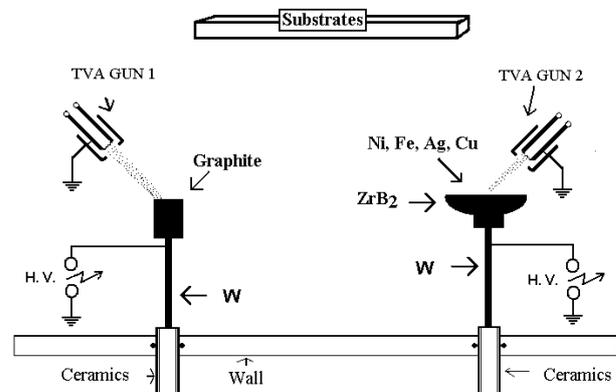


Fig. 1. Experimental arrangement for Carbon - Metal simultaneous deposition

For each test has been also measured the friction coefficient using Ball on Disc Tribometer made by CSM Switzerland for a 7N force, a 6 mm diameter sapphire ball and a sliding distance in dry condition of 1m.

The crystalline structure of C-Cu and C-Sn films has been measured by TEM, Philips CM 120.

3. Results and discussion

The high resolution microscopic image of the deposited C-Cu nanocomposite film, shown on a 20 nm scale, can be seen in figure 2, where you can notice its morphology and the corresponding crystalline structures.

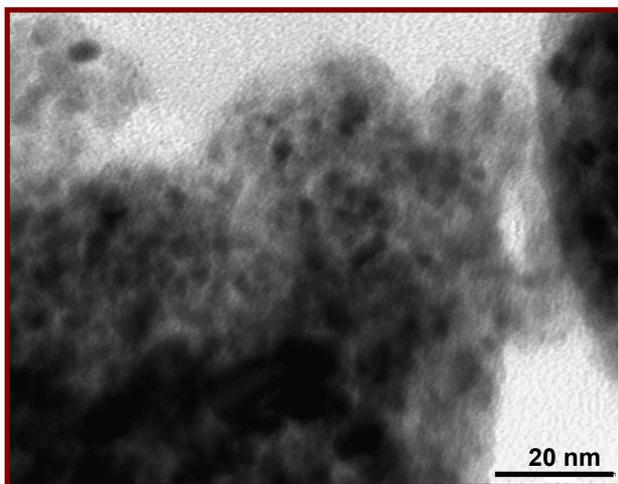


Fig. 2 A 20 nm scale detailed image of the C-Cu nanocomposite film

The next image will show, on the same 20 nm scale, the grains we got with a maximum appearance frequency corresponding to an average diameter of 4.69 nm.

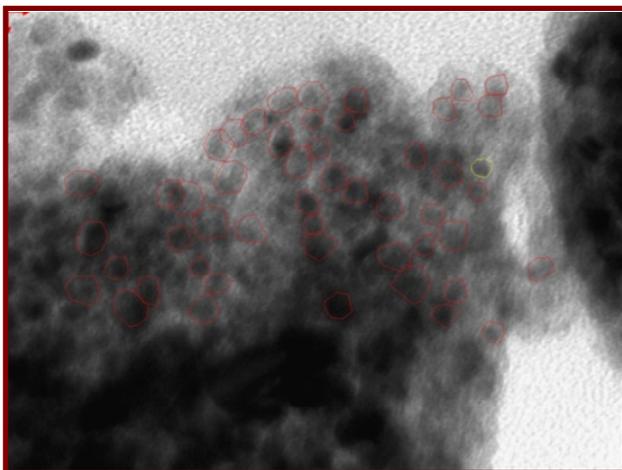


Fig. 3 Image (20 nm) where the considered grain areas are marked

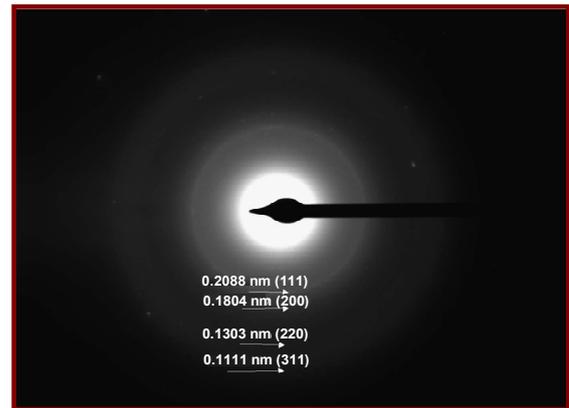


Fig. 4. Details determined by the electrons diffraction on the C-Cu nanocomposite film.

In Fig. 4 there are the measured interplanar distances and indexes using the Cu cubic structure (JCPDS 04-0836). The SAED studies confirm the Cu cubic structure with a 0.3615 nm constant network.

With a C-Sn films, we can notice their complex morphology in the following images. The film is made of Sn nanoparticles its presence being confirmed by the electrons diffraction shown below. The nanoparticle dimensions range is 10-30 nm.

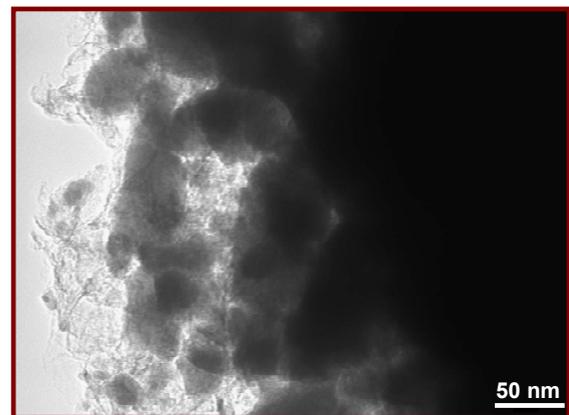


Fig. 5 A whole TEM image got on the film edge to notice its morphological and structural details (50 nm scale)

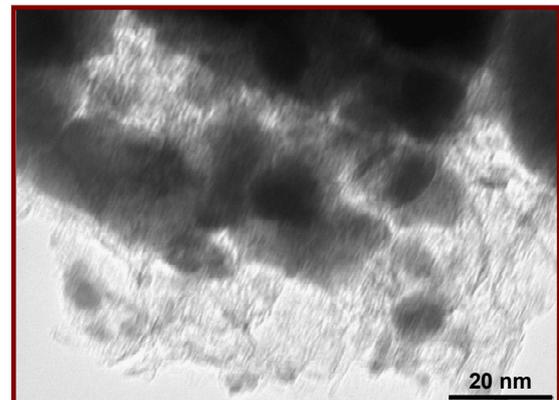


Fig. 6 C-Sn film detailed image (20 nm scale).

From the corresponding data got in the previous images we can find Sn nanoparticles caught in an amorphous Carbon film.

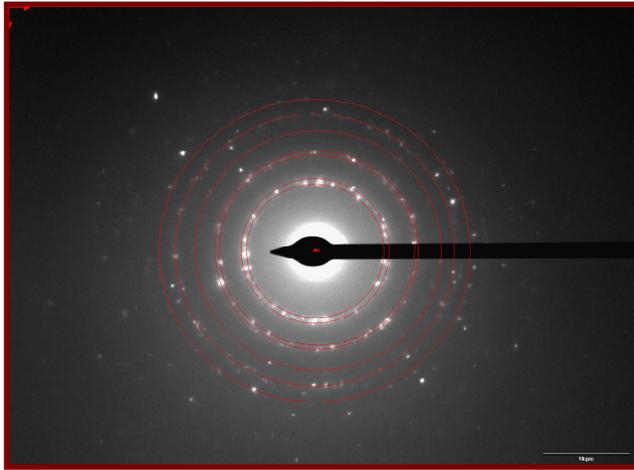


Fig. 7 Image of electron diffraction got on the above area (10 nm scale).

The values and indexes for diffraction image got for C-Sn film are shown in Table 1.

Table 1.

Diameter (nm)	dhkl (nm)	hkl
15.99	0.292763	200
22.73	0.209524	220
28.63	0.169769	301
32.42	0.149909	112
36.10	0.134608	420

The measurements concerning tribological characteristics are shown below.

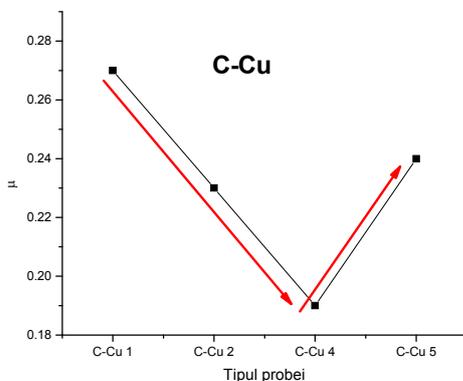
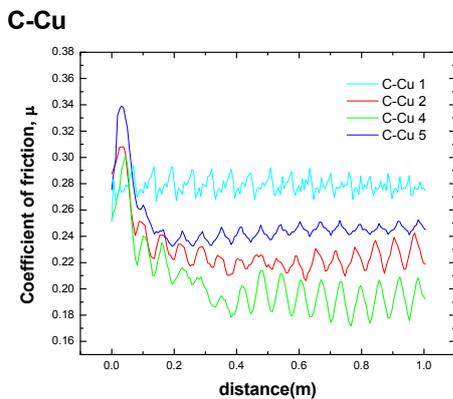


Fig. 8. Tribological characterisation of C-Cu films: Normal force : 1N, Ball : saphire 6 mm diameter; sliding speed in dry condition : 0.1 m/s.

C-Sn

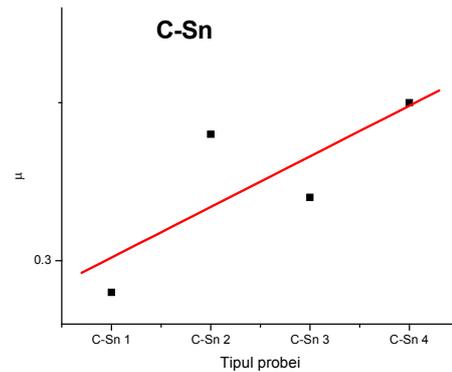
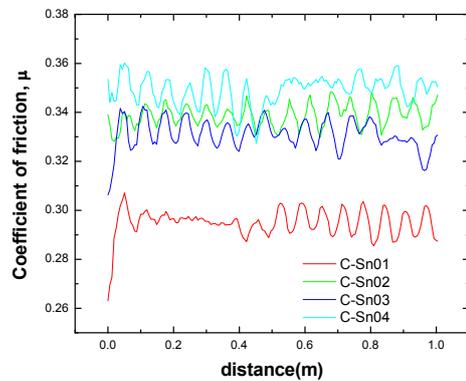


Fig. 9. Tribological characterisation of C-Sn films: Normal force : 1N, Ball : saphire 6 mm diameter; sliding speed in dry condition : 0.1 m/s.

4. Conclusions

The distances between the crystalline planes determined by diffraction measurements with TEM led to the conclusions that: the Sn nanoparticle dimensions from C-Sn test range between 10-30 nm and they confirm the cubic structure with a 0.3615 nm network constant for the C-Cu test.

References

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