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Deposition of amorphous carbon–silver composites

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ABSTRACT

Composites of amorphous carbon films and silver were deposited by co-sputtering, where the target (10 cm diameter) was of pure graphite with small inclusion of pure silver (less than 1 cm^2). The films were deposited under different powers, from 40 to 250 W, and different target-substrate distances. The substrate was earthed and rotated in order to obtain a uniform distribution of the silver content. The addition of the Ag piece into the target increased the deposition rate of the carbon films, which could be related to the higher sputter yield of the silver, but there seems to be also a contribution from a larger emission of secondary electrons from the Ag that enhances the plasma and therefore the sputtering process becomes more efficient. Scanning electron micrographs acquired using backscattered electrons showed that the silver was segregated from the carbon matrix, forming nanoparticles or larger clusters as the power was increased. The X-ray diffraction pattern showed that the silver was crystalline and the carbon matrix remained amorphous, although for certain conditions a peak attributed to fullerene-like structures was obtained. Finally, we used Raman spectroscopy to understand the bonding characteristics of the carbon–silver composites, finding that there are variations in the D/G ratio, which can be correlated to the observed structure and X-ray diffraction results.

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1. Introduction

Recently, a lot of interest has been given to metal-containing amorphous carbon films as a way to control the stress and adhesion of the films, as well due to their potential biomedical and optical applications [1–4]. The addition of silver into carbon films has been proposed for a wide range of applications [2,5–7]. The addition of metals (including silver) has been mainly investigated for hydrogenated carbon films, where the metal introduction is by sputtering of a metal target in hydrocarbon plasma [8,9] or by hybrid methods [10]. For non-hydrogenated carbon samples, filtered cathodic arc [11], sputtering of a metal target [12] and pulsed laser ablation [13] have been tried. In most cases a self-assembled array of metallic nanoparticles within the carbon matrix has been reported, although in some cases substrate temperature has been used to induce the diffusion and growth of the nanoparticles. The purpose of the present paper was to determine the grade of control that can be achieved from the sputtering of a multicomponent target (graphite/silver) under argon atmosphere and the effect of different power and substrate-target distances (d_{s-t}) on the Ag content, the particle size and distribution, as well on the microstructure of the composite films.

2. Experimental details

The a-C:Ag composites were deposited by magnetron sputtering on silicon substrates using a multicomponent target (4 in. in diameter) consisting of pure graphite (99.99 at.%) and a pure silver piece of approximately 1 cm^2 attached to the graphite race track, that corresponds to approximately 2.7% in area. The substrate was rotated at constant speed (80 rpm) in order to obtain a uniform distribution of the silver particles. The base pressure in the chamber was 1×10^{-4} Pa, the argon flux was fixed at 10 sccm and the deposition pressure was 20 mTorr. The deposition power, time and the d_{s-t} were varied as indicated in Table 1.

In order to evaluate the variations induced by the silver incorporation in the microstructural and bonding characteristics of the composite films different characterization techniques were used. The thickness was measured using a DEKTAK IIA profilometer, and Ag content and surface morphology were studied using a scanning electron microscope (SEM; Cambridge-Leica 4400) with elemental analysis facilities (EDS). The microstructure and grain size of the silver nanoparticles was evaluated by parallel beam grazing angle X-ray diffraction (Rigaku mod. 2200, CuKα radiation). Raman spectra were obtained in the visible range (632.8 nm) using a Jobin-Yvon spectrometer (Micro-Raman HR-800 HJY).

3. Results

The growth conditions, thickness, deposition rates, Ag at.%, grain size and Ag lattice parameter are summarized in Table 1, including

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Table 1
Variable deposition conditions: power and substrate-target distance (d_{s-t}), deposition time (s), thickness (nm), Ag content, lattice parameter and grain size.

Sample name	Power (W)	d_{s-t} (mm)	Deposition rate (nm/s)		Thickness (nm)		Lattice parameter Ag (nm)	Ag (at.%)	Ag grain size (nm)
			a-C matrix	a-C:Ag	a-C matrix	a-C:Ag	Ag: 0.40862		
40d1	40	40	0.043	0.12	77 ± 0.45	220.5 ± 2.5	0.41019	22.6	8.2
40d2	40	34	0.049	0.14	58.7 ± 1.1	165.9 ± 1.7	0.40915	17.3	4.7
40d3	40	28	0.08	0.17	48.7 ± 1.3	100.6 ± 4.7	0.40935	6	5.3
100d1	100	40	0.12	0.23	209.4 ± 1.85	417.3 ± 15	0.40878	29	22.2
100d2	100	34	0.14	0.3	164.3 ± 3.5	358 ± 2.4	0.40878	17.7	15.3
100d3	100	28	0.19	0.37	115.3 ± 1.6	220.6 ± 7	0.41005	9	30
250d1	250	40	0.32	0.35	579.8 ± 4.7	638.8 ± 6.6	0.40523	7.1	1.9
250d2	250	34	0.4	0.34	479.4 ± 7.6	413.9 ± 9.4	–	3.4	–
250d3	250	28	0.47	0.38	284.2 ± 2.7	230.4 ± 7.2	–	2.7	–

information from the a-C matrix. As observed from the data, there is an enhancement in the deposition rate for the a-C:Ag films in comparison to the a-C matrix, and this enhancement is more notorious at low power. The Ag at.% values were obtained from the EDS analysis, which is not the more accurate elemental analysis technique for carbon-based materials, therefore the values have to be considered as estimates. The amount of silver was strongly reduced as the power was increased, may be due to the deposition of carbon onto the silver piece when working at very high powers. This leads to a decrease in both the Ag at.% and the loss of the enhancement in the deposition rate.

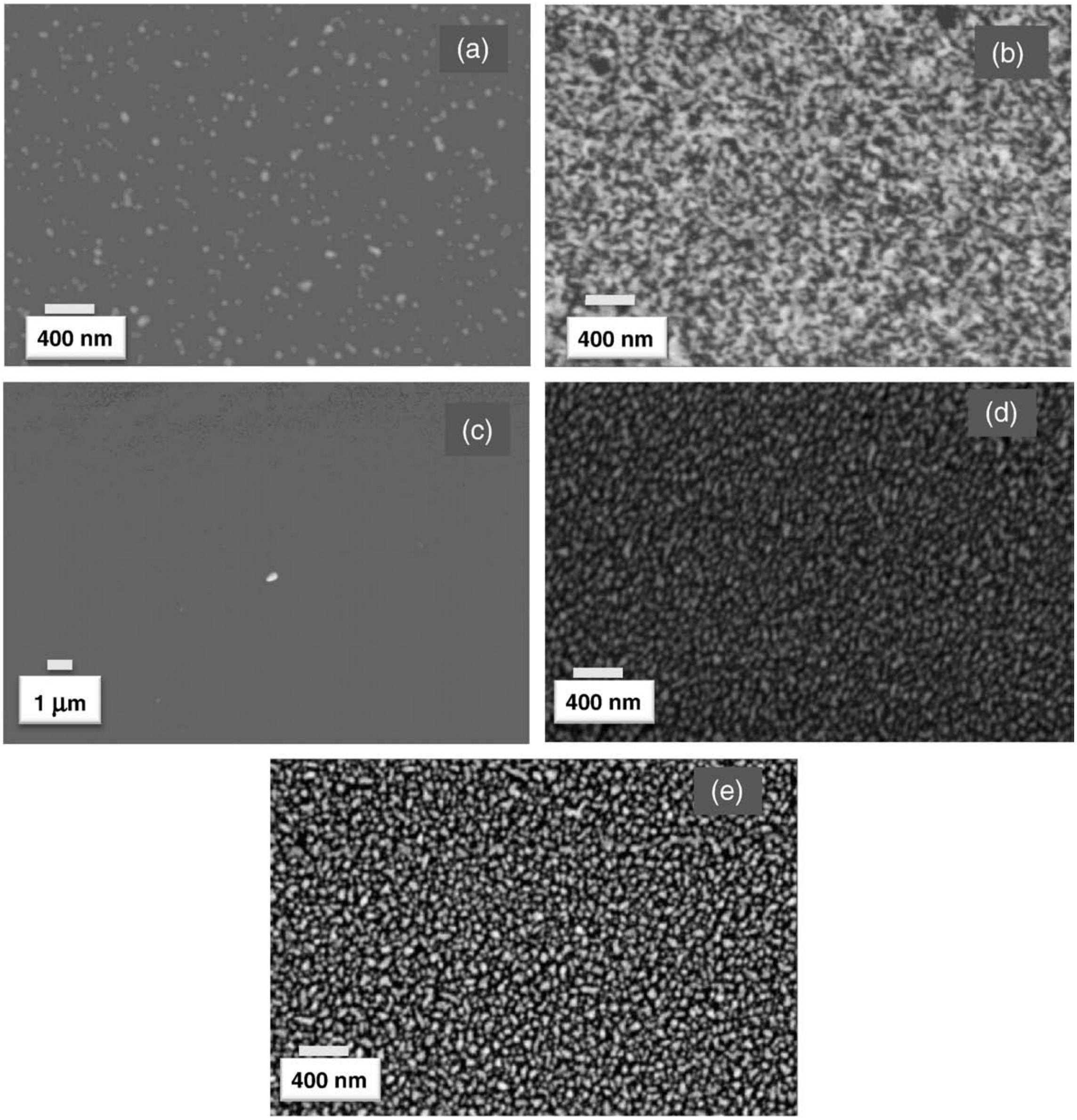

Fig. 1. Backscattering electron images of the a-C:Ag samples for different powers and d_{s-t}. (a) 40d3, (b) 100d3, (c) 250d3, (d) 40d2 and (e) 40d1. The magnification used for the 250d3 sample was reduced to show that Ag is not segregated as in the other samples.

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