DLC Thin Films for Cardiovascular Stents

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Abstract — **Diamond-like carbon films (DLC films) for cardiovascular implants have successfully been prepared by dual-target unbalanced magnetron sputtering and Rapid Photothermal Processing (RPP). It is found that the sputtering current of target plays an important role in the DLC film deposition. Deposition rate of 3.5 µm/h is obtained by using the sputtering current of 30 A. Rapid Photothermal Processing at 400°C essentially reduced the carbon content and have improved the surface morphology structure of deposited coatings, which depend on the intensity of the ion impingement on the growing interface.**

Keywords — **Diamond-like carbon, nanocomposite DLC, RPP.**

I. Introduction

Diamond-like carbon (DLC) films have found widespread application in biological coatings for implantable medical devices, as a result of their good chemical resistance, temperature stability and biocompatibility. The biological behavior of an implant can be tuned by modifying the element composition. DLC can be easily alloyed with other biocompatible materials such as titanium as well as toxic materials such as silver, copper and vanadium by normal co-deposition methods [1]. Nanocrystalline diamond-coated medical steel has shown a high level resistance to blood platelet adhesion and thrombi formation [2]. Diamond and DLC coatings have successfully been proposed for applications as artificial heart valves, prosthetic devices, joint replacements, catheters and stents, orthopedic pins, roots of false teeth, surgical scalpels and dental instruments [3-6].

II. Experimental

Pulsed direct current (p-DC) magnetron sputtering in combination with an unbalanced magnetron configuration has become a major technique in the deposition of advanced coatings during the last decade. It has the significant advantage over DC magnetron sputtering in suppressing arcing at the targets during reactive sputtering and in sputtering nonconductive materials.

In this paper we present the results of the microstructural control of Ti/DLC nanocomposite coatings with pulsed direct current (DC) magnetron sputtering. The sputtering system was configured of Ti target (99.7%), and graphite target (99.99%). The diameter of all the was 3 inches. All the power supplies for sputtering were operated at current regulation mode via a computer-controlled system. The thin metal layers were deposited on nonannealed and annealed stainless steel. Annealing was performed according the technology sequence for stents-electropolishing and high temperature annealing for grain enlargement and improving of the stents elasticity. A number of analytic methods were applied SEM, AFM and EDX.

The Ti/DLC films were deposited onto pre-etched nonannealed and high temperature annealed stainless steel type 316L. The morphological analyses demonstrated the essential grain enlargement. The high temperature annealing increased the grain size from 10 to 60 µm, which is necessary for the required elasticity of the arterial stents. The grain structure can influence the structure of the deposited biocompatible nanolayers, which is demonstrated further for deposited at high temperatures layers on stainless steel substrates.

The images of the grain structure of the pre-etched 316L type stainless steel annealed at high temperatures and the initial non-annealed sample are shown in Fig. 1.

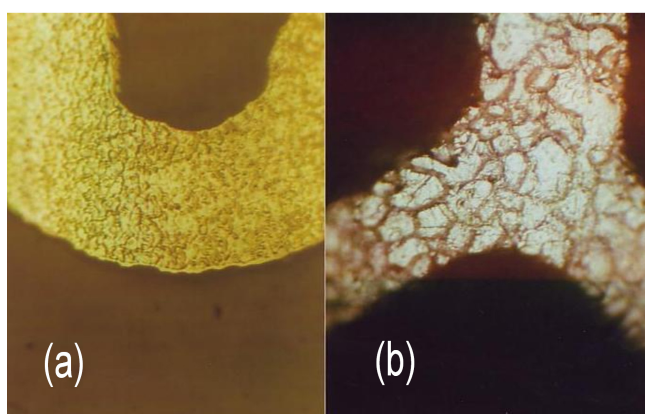

Fig. 1 (a,b) Grain structure of pre-etched high temperature annealed (a) and non-annealed (b) 316L type stainless steel.

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The investigated Ti/DLC nanocomposite films have been deposited onto the coronary stainless steel stent with the following dimensions: diameter 3mm, length 13mm fabricated by Company ISMA Ltd presented in Fig. 2.

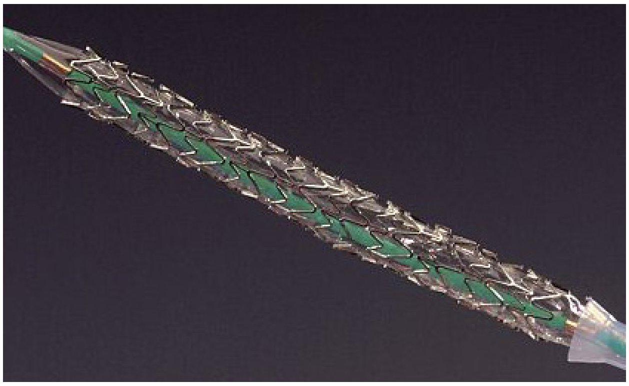

Fig. 2 Photography of the coronary stainless steel stent, diameter 3mm, length 13mm.

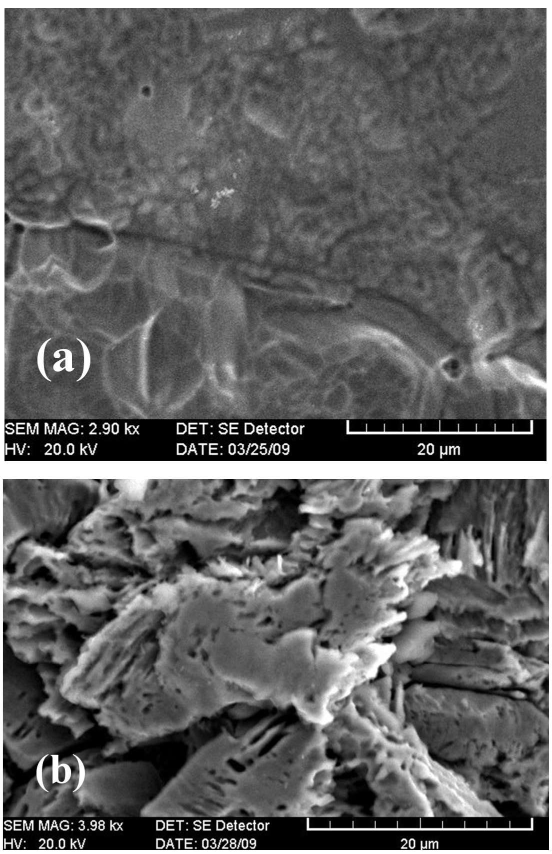

Fig. 3 (a,b) SEM of RPP DLC layers on stainless steel deposited at temperatures: a - 250°C, b - 270°C.

The SEM images of the DLC layers deposited on stainless steel at temperatures 250°C and 270°C, the RPP was performed at 300°C in vacuum, are presented in Fig. 3.

The thermal annealing of the stainless steel substrate during deposition at high temperatures do not change essential the elemental content of the substrate. Only a small oxidation is observed. But the surface and the structure of the deposited carbon layers is not smooth, as it is for layers deposited on the glass and these temperatures are not applicable for the stents technology.

AFM study images of the DLC layers deposited on stainless steel at 250°C, RPP 400°C are presented in Fig. 4.

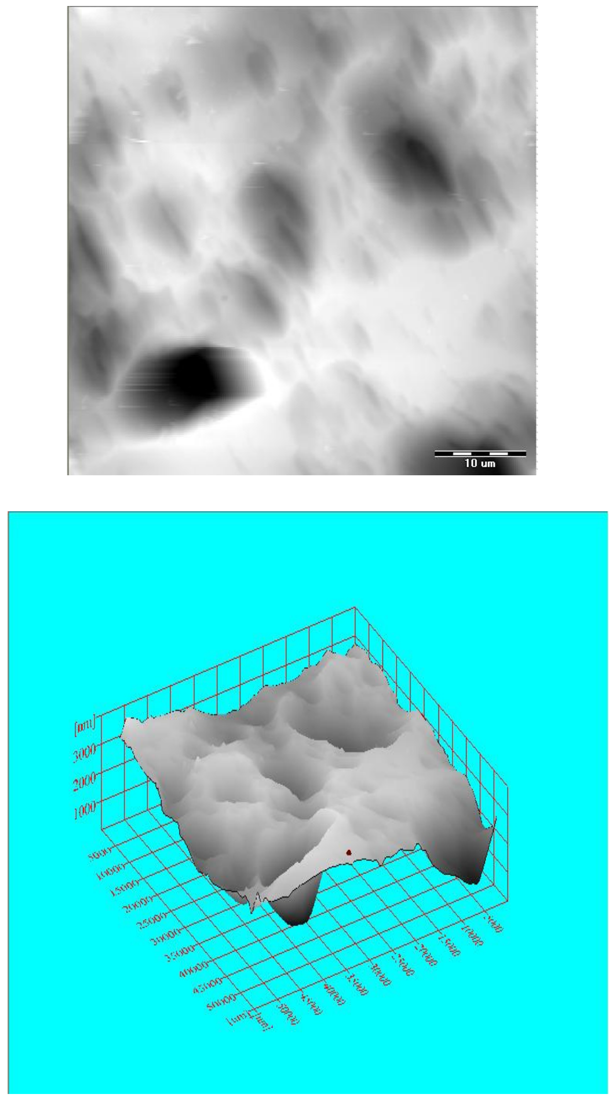

Fig. 4 (a,b) 2D and 3D AFM images of layer deposited at 250°C on nonannealed stainless steel.