

# Artificially modulated hard coatings produced with a vacuum arc evaporator

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**Abstract.** The experimental set for artificially modulated structures production through an advanced vacuum arc evaporator with a magnetically-driven cathode spots on the cathode surface is described. The main features of vacuum arc as a vapor source with time-modulated compositions are discussed. The characteristics of the obtained multilayer coatings with artificially modulated Ti/TiB structures are presented.

## 1. Introduction

Modern advanced coatings for wide area applications represent the multilayer periodic structures with a bilayer thickness of 15-50nm and the total thickness of up to 10 $\mu$ m. A comprehensive guide to a microstructural design of hard coating is presented in [1]. The multilayers can be manufactured as a structure consisting of different materials, such as TiCN/AlN bilayers, or can be artificially modulated. The latter compositions consist of the layers, each possessing individual distribution of the same chemical element, i.e. the concentration of one or more chemical components is varied periodically, for example, titanium in Ti/TiN structure. Certain multilayer coatings are characterized by a good combination of high hardness and shock-stress resistance, crack and heat resistance properties; that is why these coating are now widely applied in industry. As a rule, the composites of sintered powder materials are widely used in PVD technologies to fabricate the targets. The sintered composite targets based on titanium carbonitride, boride, silicide and aluminide compounds [2-4] are assumed as promising materials for production of the super hard and multifunctional coatings.

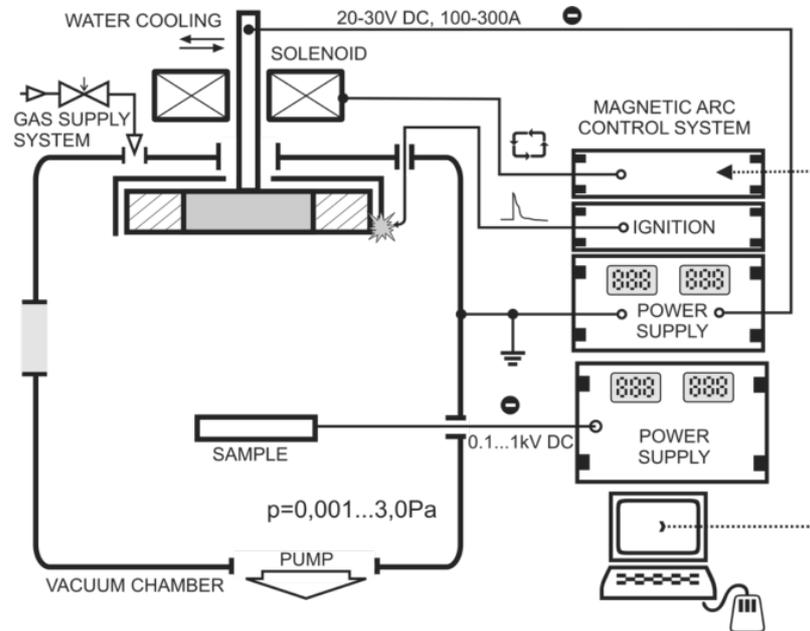
One of the most productive sources of metal vapour is a vacuum arc evaporator with an integrally cold cathode [5]. However, a specific property of this type of discharge consists in significant thermal stress in the cathode spots [6] which restricts the use of sintered powder cathodes. The paper presents the experimental results on the artificially modulated Ti-B and Ti-B-N systems through the advanced vacuum arc evaporator with magnetically-driven arc spots.

## 2. Experimental

The schematic view of the experimental set is shown in Figure 1. A stainless vacuum chamber is pumped out up to the residual pressure of 0.1mPa by 1500l/s turbomolecular pump. The vacuum arc evaporator, which works with the disk-type cathode of 178mm in diameter, is mounted on the chamber top wall opposite the substrates on the bottom flange of the chamber. The arc current can be varied in the range of 100-300A at the voltage of 20-30V [7-9]. The cathode is water cooled to

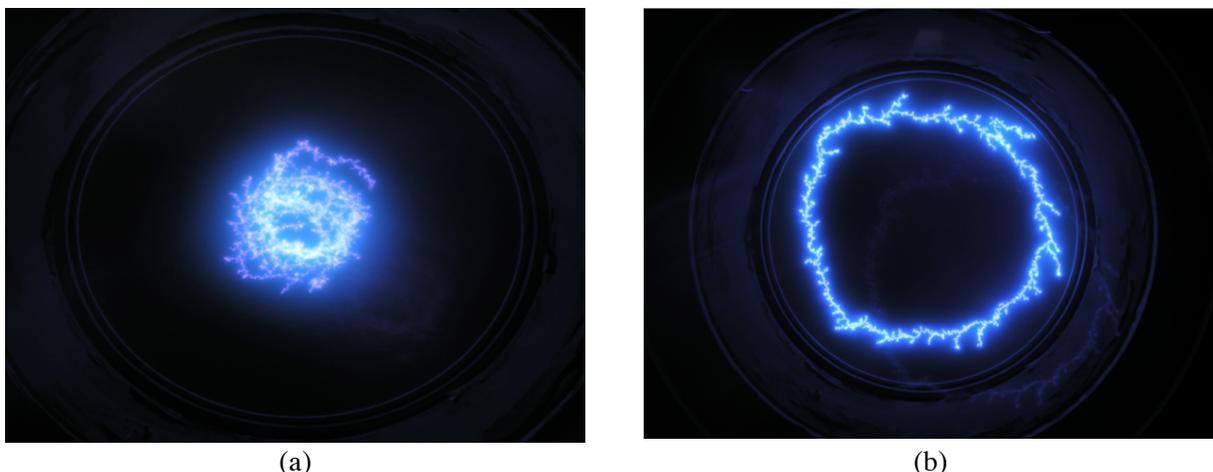


maintain it in integrally cold conditions close to the ambient temperature. It is well known [5,6] that vacuum arc evaporators are highly productive; our experimental set provides thin films growth with a rate up to 10nm/s.



**Figure 1.** Experimental setup scheme.

To allow the magnetic control over the arc discharge, a solenoid system with magnetic circuit is housed on the back side of the cathode disc to predetermine the localization and motion of the arc spots on the cathode surface. The used solenoid is supplied by DC-modulated current which is specified by a programmed source. Figures 2(a) and 2(b) demonstrate the cathode spot trajectories and their location on the cathode surface according to the solenoid magnetic field amplitude: in the first case (Figure 2(a)) the amplitude is low and the spot trajectories are located near the central area of the cathode in the current feed area where the spots velocity is very high. In the second case (Figure 2(b)), the superposition of the external magnetic field and the field produced by the arc forces the spots to move along the ring trajectories located on the cathode outer area. The duration of the spot stay in different cathode areas is also programmed by the magnetic control system.



(a)

(b)

**Figure 2.** Cathode spot trajectories for different levels of external magnetic field.

The spot velocity determined experimentally by using a digital registration camera is found in the range of 15-20m/s, which is three times higher than the value obtained when the external magnetic field is turned off. These data correlate well with the concepts of vacuum arc movement on the cathode surface [10,11]. Furthermore, the external magnetic field does not only control the spot trajectories but it produces a higher number of spots in comparison with the case of this field absence. Of importance is the fact that the spot velocity increases and the increase of the total number of spots results in a reduction of the thermal tension in the area where the spots vaporize the cathode material.

The fact that the cathode thermal load can be stepped significantly makes it possible to apply the powder cathodes in the arc coating technologies. For the regular arc evaporators, it is impossible to employ the powder cathode owing to its fissuring at high thermal tensions. It is significant that the use of the arc cathode fabricated of the composite powder stimulates the production of new surface coatings with predicted properties.

To create the multilayer systems, we use a composite cathode which consists of two parts (see Figure 3). The inner part is a disc made of titanium and boron powders mixed in equal atomic proportions (TiB) and later sintered by self-propagated reaction [4]. The external part, which is a plane ring, is made of titanium of 99.9% purity through the traditional metallurgical technology. The external magnetic field which is generated by the solenoid current in the pre-established regime localizes the cathode spot zones in the central or outer cathode areas, thus producing a stoichiometrically modulated film.

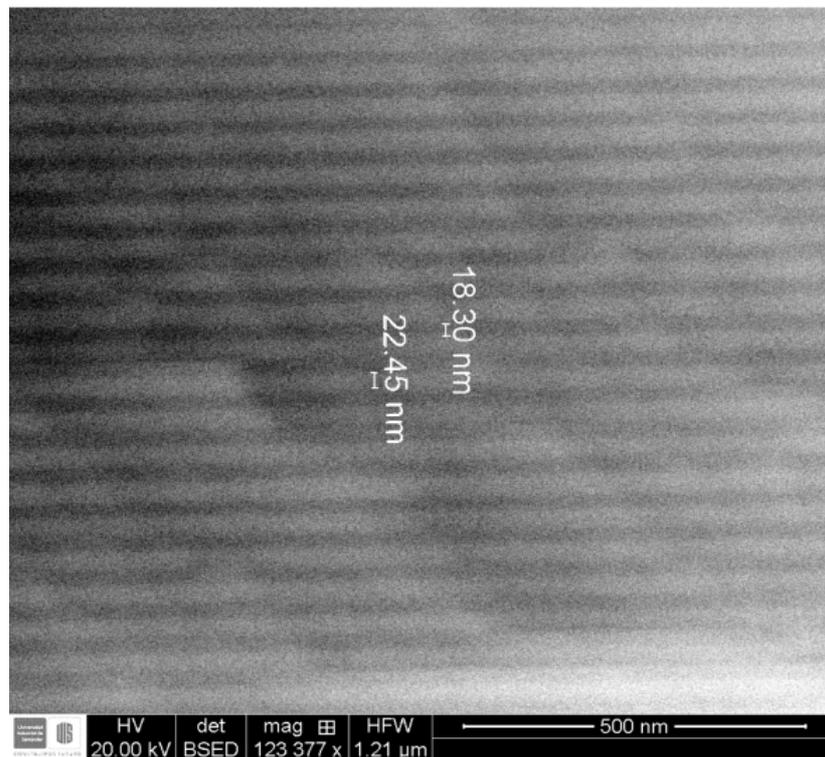


**Figure 3.** Composite cathode: the inner disc part is formed of mixed titanium and boron powders and the external ring part made of 99.9% titanium.

It is important to note that the vacuum arc discharge generates a highly ionized vapor of the cathode material that makes it possible to control the particle flux onto the substrate and to program the properties of a growing film and its crystallite structure [12]. The detailed mechanism of the thin film growth will be presented in the upcoming papers. This unique feature provides a powerful tool for producing the high quality and industry applicable coatings.

### 3. Results

Scanning electron microscope (SEM) pattern of cross-section of the multilayers structure obtained through the above described vacuum arc technique is presented in Figure 4. The space period of this artificially modulated structure is of 40.75nm, whose bilayers are composed of deposited titanium and boron titanium layers, Ti/TiB. The arc current of 180A at an operating voltage of 25V provides a growth rate of the multilayer of approximately 3nm/s. The magnetic field is modulated by a rectangular control signal ensuring a periodical localization of the arc in the central part of the disc cathode and its periphery. This technology can easily be extended for processing in the reactive nitrogen atmosphere to guarantee the superhard TiN/TiN-BN systems formation.



**Figure 4.** Cross-section of the SEM image of the obtained Ti/TiB multilayer structure.

#### 4. Conclusions

In our experiments, the multilayers with the bilayer structure basic element composed of deposited titanium and boron titanium nanolayers Ti/TiB are obtained. The process of this structure shaping is controlled by a magnetic field in such a manner that the discharge is ignited sequentially on the central disc and the outer ring parts of the composite cathode. Furthermore, the possibility to evaporate composite cathodes made from sintered powder compositions due to decreasing of the local power release level is shown.

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