APPLICATION OF THE RF PLASMA-CHEMICAL REACTOR WITH THE SYSTEM OF MULTI-CATHODES FOR DEPOSITION OF COMPOSITE THIN FILMS AND MULTILAYER STRUCTURES

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Abstract

A RF Multi-hollow cathode system has been developed for deposition of composite and multi-component thin films onto flat surfaces and also internal walls of hollow substrates. This system has been used for deposition of composite Si_xGe_y thin films. The possibility to continuously change the stoichiometry of the Si_xGe_y films composition has been achieved. The developed system was also used for deposition of CN_x and composite CN_xZr_y thin films in order to study the deposition of tribological low friction, wear resistant films. Chemical composition and microhardness have been measured for these films as well. In addition, some samples of the CN_x Zr_y films have been subjected to friction and adhesion measurements.

1. Introduction

In order to deposit the composite thin films and multi-layer structures onto flat surfaces, internal walls of cavities, tubes, or on the surface of components with complicated shapes, the plasma-chemical reactor with multi-hollow cathode system has been developed [1]. This system was developed as a modification to the RF hollow cathode plasma-chemical reactor with single supersonic nozzle [2]. The schematic of the system is shown in Fig.1. Two RF primary supersonic plasma-channels are created and one secondary plasma channel as well. The secondary plasma channel is created by the interaction of both primary channels at the crossing point. This channel falls on the substrate which is to be the coated surface.

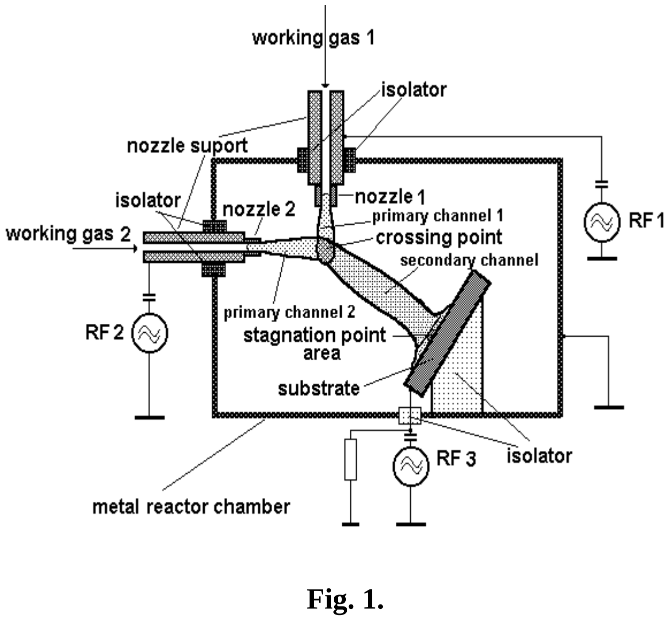

Fig. 1.

For certain applications the substrate is isolated from the reactor chamber and connected with an additional RF source in order to create the DC bias around the substrate. The DC bias controls the velocity of the ions which hit the substrate.

2. Applications of the RF multi - hollow cathode system

2.1. Deposition of composite Si_xGe_y thin films

The developed RF multi-hollow cathode plasma-chemical reactor has been used for the deposition of composite Si_xGe_y thin films. For deposition, sputtering of silicon and germanium nozzles in RF hollow cathode discharges have been utilized. Plasma-chemical reactions between the sputtered silicon and germanium particles occurred in the secondary plasma channel.

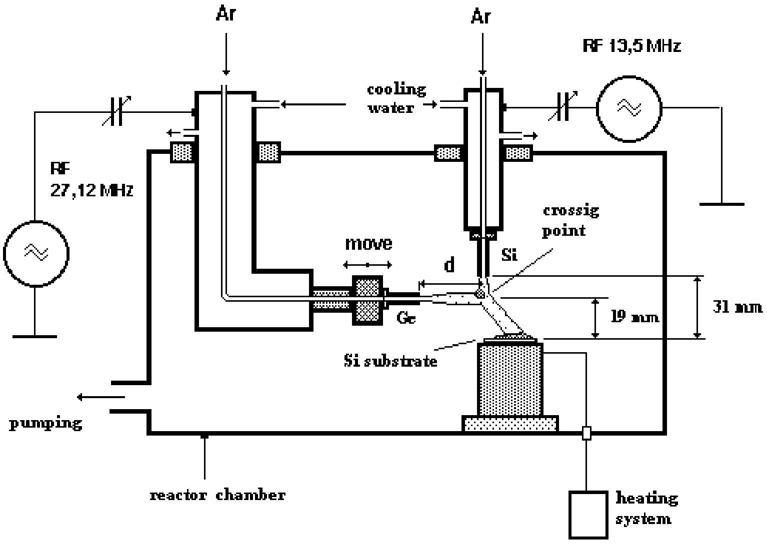

Fig. 2.

The setup of this experiment is shown in Fig. 2. Both supersonic nozzles were fed by pure argon whose mass flows were controlled by electronic flowmeters. The first nozzle, produced from silicon, was held by a vertical, water cooled support which was electrically isolated from the grounded reactor chamber and connected with a RF high power generator (13.56 MHz). The second nozzle, produced from germanium, was held by a horizontal support which was movable, making it possible to set the distance between the outlet of the germanium nozzle and the crossing point of the primary channels. This second holder was connected to a second RF source (27.12 MHz). Deposition has been performed on monocrystalline silicon which was fixed to the grounded bakable substrate holder.

Before deposition, both nozzles were cleaned by DC hollow cathode discharge which is suitable for cleaning the internal walls of the nozzles [3].

During the deposition, all conditions in the reactor chamber were held constant except the distance **d** between the outlet of the germanium nozzle and the crossing point. The distance was varied between 8 mm and 23 mm.

The chemical composition of the deposited samples has been investigated by electron probe microanalysis (EPMA) with x-ray microanalyser. In Fig. 3 it is possible to see the dependence of the stoichiometric ratio Ge/Si on the distance **d**. From this curve it is seen that with increasing the distance **d**, the amount of Ge in the film decreases. The results show that variation of the Ge/Si ratio has been achieved without any change in the parameters of either RF hollow cathode discharge, but only by varying the distance of the nozzles.

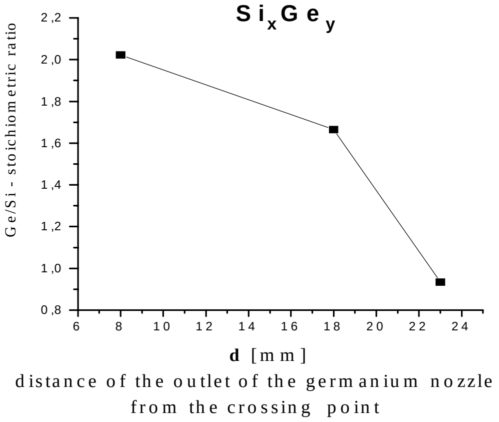

Fig. 3.

2.2. Deposition of tribological CN_x and CN_xZr_y thin films

The RF multi-hollow cathode plasma-chemical reactor is also used for deposition of hard, low friction, wear resistant thin films. CN_x [4] and composite CN_xZr_y thin films have been deposited thus far.

2.2.1. Deposition of CN_x thin films

For deposition of CN_x thin films, reactive sputtering of the carbon nozzle in working gas mixture Ar + N2 has been used. In the reactor, only one carbon nozzle has been used. In order to improve the deposited film properties, an additional RF source has been applied to the isolated substrate which creates the DC bias in the neighbourhood of the substrate. For deposition, either a CW RF source (13.5 MHz) or a RF (13.5 MHz) source modulated with square impulses have been used.

CN_x thin films have also been deposited on internal walls of steel bearing rings by using two carbon nozzles in the configuration which is shown in Fig. 4.

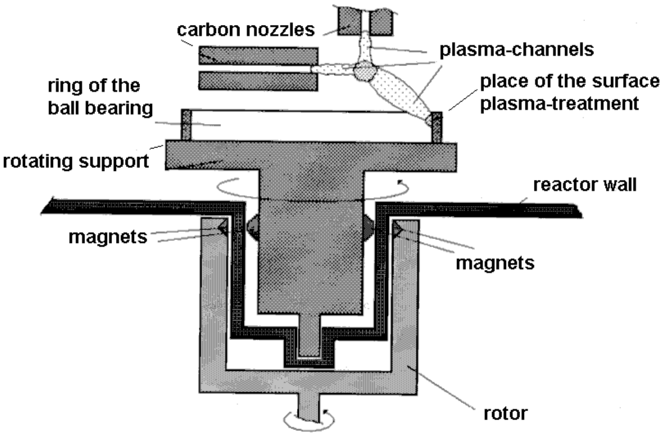

Fig. 4.

2.2.2 Deposition of CN_xZr_y composite thin films

The RF multi-hollow cathode plasma-chemical reactor has been applied for deposition of composite CN_xZr_y thin films. Reactive sputtering of carbon and zircon nozzles have been done for this purpose. The experimental arrangement is similar to the arrangement for $Si_x Ge_y$ except for the type of the nozzle materials and the applied DC bias on the substrate.

In Fig.5 it is possible to see the dependence of the friction force on the time of the measurement for two samples of $CN_x Zr_y$ deposited at the same conditions in the reactor chamber except for the DC bias applied to the substrate. From this, it is seen that by applying a DC bias (U_{DC} = -100 V) it is possible to decrease the friction force and prolong the lifetime of these films.

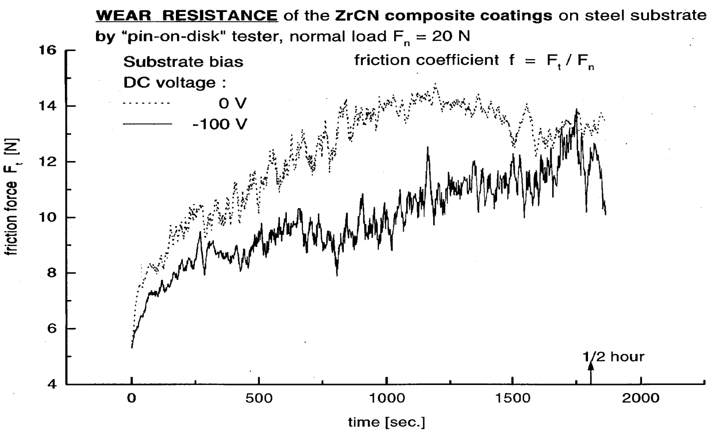

Fig. 5.

Microhardness has also been measured for these samples. The highest value that has been achieved for the samples with an applied DC bias is H = 10.5 Gpa.

Acknowledgment

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