

PROCESS OF THIN FILM DEPOSITION USING DENSE PLASMA FOCUS

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Abstract

In our experiments, reported in this paper, dense plasma focus device was used for deposition of thin chromium containing films with the thickness up to a few nanometers. Ablating the chromium target by highly dense and temperature plasma, such films were produced on the silicon wafers placed under the anode of the device in the argon atmosphere. The influence of the electrode structure on the chromium film purity was studied by the example of two samples which were obtained under the same conditions of deposition with the exception of the anode end material. Depth profiles for these samples were studied by means of Auger Electron Spectroscopy (AES).

Introduction

At present, thin film deposition processes are being rapidly developed and are extensively applied for electronics and for medical purposes. Many various methods are used to produce a thin film with the desired parameters, for example thickness and composition. We propose one of them, to be used for chromium containing films deposition, by means of Plasma Focus (PF) device. Being an effective pulsed source of ion flux, PF is used for carbon [1] and fullerene film [2] deposition, zirconate titanate grains [3] deposition, surface nitriding [4] or carbon implantation [5]. In this paper we present the results of chromium film deposition. The preliminary results of deposition of chromium containing film were described in our earlier paper [6]. This material is very promising for electronics industry because of its possible use as a dopant of SrTiO₃ thin films during the process of their growth by means of rf magnetron sputtering. This supposes the produced material has got the certain parameters, e.g. its purity. For this reason the main problem to be solved for thin film deposition by PF device was the elimination of contaminations resulted from the electrodes material.

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Experimental set-up

The deposition experiments were carried out with a small PF device shown in Fig.1 (vacuum chamber and the electrodes).

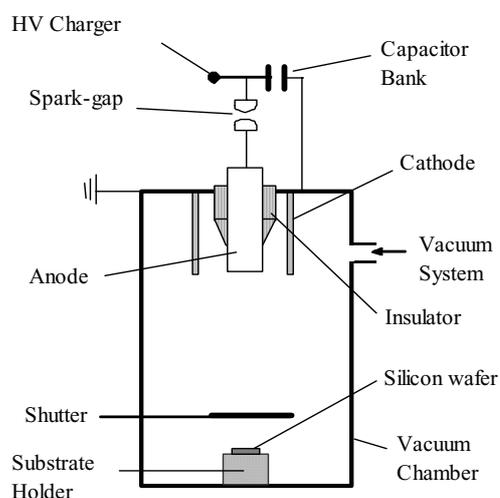


Fig. 1. Scheme of the experimental set-up.

The PF device was powered by a capacitor bank consisting of four capacitors, 19.3 μF of the total capacity, 30 kV of maximum charging voltage. The energy stored in the capacitor bank was released through spark-gap switch and a discharge (shot) was developed.

Thin film was deposited on silicon wafer, which was placed 400 mm under the anode. Between the silicon substrate and the anode a shutter was mounted protecting the sample from the first four conditioning shots when the pinch appears occasionally. The moment, pinch becomes regularly, the sample is uncovered and the film is deposited under the certain conditions (see Tab. I).

Tab. I. Parameters during the deposition.

Filling gas	Pressure	Energy stored in the capacitor bank	Number of shots	Number of conditioning shots
Argon	130 Pa	1 kJ	10	4

After the deposition the composition of the samples was checked by means of AES.

Results and discussion

chamber and the electrodes). The electrodes assembly consists of two coaxial electrodes isolated by alumina insulator sleeve. The outer electrode (cathode) was constructed from twelve stainless steel bars. The centre electrode (anode) was composed of copper and chromium target which was mounted in the middle of the anode tip. In these studies two different structures of the anode were used. The only difference between them is shown in Fig. 2.

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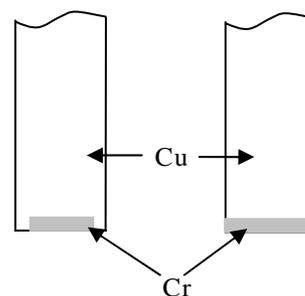


Fig. 2. Scheme of the anode ends

AES depth composition profiles for the grown samples are presented in Fig. 3-4. The first one corresponds to the film obtained using the anode with chromium and copper end (left-hand part in Fig. 2). The results show that the film was composed of chromium, silicon, carbon, copper and oxygen but free from iron and aluminum. It means that the cathode and the insulator walls are not a source of contamination material. The film thickness was approximated basing on the etching rate of the sample by argon ions, which were used during AES measurements. So, it can be evaluated as about 10 nm. In this way the deposition rate was 1 nm per shot.

Presence of every element in the sample is understandable. Chromium is emitted from the anode end. Silicon rises from the substrate material (silicon wafer) and can be mixed with the depositing material during the process of deposition or during AES measurements. In both

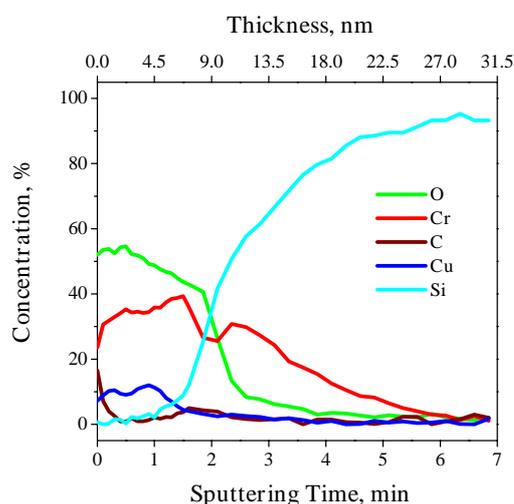


Fig. 3. AES depth profiles for the film deposited using the chromium-copper anode end.

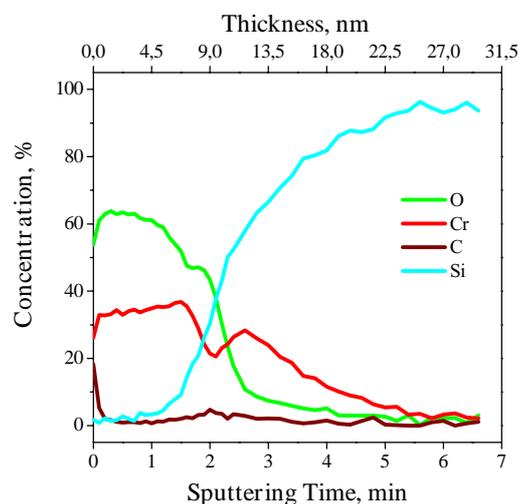


Fig. 4. AES depth profiles for the film deposited using the entire chromium end.

cases the sample surface was exposed on action of high-energetic particles. Therefore, some silicon atoms can be moved up. Presence of carbon in the film suggests that in the vacuum chamber was a vapor of oil from the pumping system. In these experiments an oil rotary pump and a diffusion pump were used. Copper, also presented in the film, can come from the anode wall or from a copper part of the anode end. As it can be seen in Fig. 3-4, both of the samples have a considerable amount of oxygen inside the film. The chamber and the electrode walls can be one of the sources of oxygen including the chromium target. Although PF worked at the low pressures of argon, the simple construction of the vacuum chamber did not

allow us to put inside a sample without opening the chamber. Every time, when the sample is put in, the vacuum chamber is aired. At the same time oxygen is absorbed at all the elements of PF. Absorbed oxygen is not removed during the chamber evacuation and its part is released during each shot and is deposited on Si wafer. As another source of oxygen the oxide films of Si substrate and the oxide films of produced Cr containing layers can be considered. We did not apply any treatments for cleaning the Si substrate surface as well as the obtained chromium films were exposed on air before the AES measurements. While it is known that 10-20 nm thickness oxide film is formed after 10-30 min airing of cleaned metal surface.

Composition of the film, obtained using the anode with the entire chromium end, is shown in Fig. 4. Copper was not observed for the film produced with this construction of the anode. Therefore, we can conclude that the anode wall does not carry copper in the film.

Conclusions

The successful effort to apply PF device for thin film deposition was made. Such a technique is an effective and cheap tool for thin film production. The deposition rate was estimated to be about 1 nm per shot. The deposited material is emitted from the whole surface of the anode end. The obtained film is free from the contaminations from the insulator and the cathode material.

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