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PREIONISED PULSED MAGNETRON DISCHARGES FOR IONISED PHYSICAL VAPOUR DEPOSITION

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To improve the quality of thin film deposition by magnetron discharges, particularly by an effective ionisation of the sputtered vapour, we developed a new ionised physical vapour deposition (IPVD) method based on preionised pulsed magnetron discharges. By superposition of continuous, microwave or RF discharge, with a fast pulsed abnormal discharge, target current density is extended to very high values during short pulses. Efficient vapour ionisation is obtained and due to the current pulse shortness, electric arc development is avoided.

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1. Introduction

Ionised physical vapour deposition (IPVD) has recently become an efficient method for improving properties of thin layers deposited by magnetron sputtering techniques.

Various procedures were investigated using additional vapour ionisation using RF [1] or microwaves [2]. Despite the good results concerning vapour ionisation there are some difficulties concerning internal antennas subjected to sputtering or vapour deposition. Also the high working pressure thermalizes the sputtered vapour.

A very promising alternative technique was developed by Kuznetsov et al [3,4] using high power pulses applied directly on the magnetron cathode. For a short time (a few tens of microseconds) the high target current density (several A/cm^2) sustains very dense plasma near the cathode which induces efficient sputtered vapour ionisation. This method is limited by a too high breakdown delay and a relative high probability of arc development.

In this paper some results are reported concerning a new pulsed magnetron discharge operating in a preionised pulsed regime [5] with lower breakdown delay, high ion-to-neutral flux ratio at the substrate, no arc development and high stability.

2. Experimental

The experimental device includes a classical magnetron discharge with a rectangular or circular cathode made from different metals: titanium, copper, ruthenium etc. An adapted pulse

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generator system was used to apply high power pulses (1-50 μs, 10-200 A, 500-1200 V, 0-1 kHz) directly on the cathode and insuring short fall time (<1 μs) of magnetron current pulses. Also it allows the superposition of a DC, RF or microwave additional preionisation discharge. The microwave and RF discharges can be induced in the region between the target and the substrate by microwave applicators [2] or by a coil antenna [6]. The emission and absorption spectroscopy measurements used in this study have been described elsewhere [6,7].

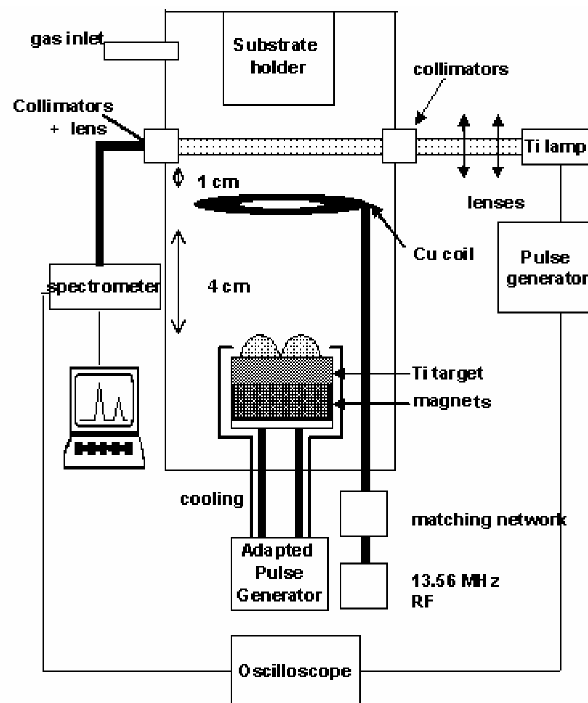

Fig. 1. Experimental set-up.

3. Results

A typical pulsed applied voltage on the cathode (target) and magnetron current for argon working gas at 1.4 Pa and DC preionisation of 10 mA are presented in Fig. 2. In a pressure range of 0.4 -5 Pa and for different cathode geometries we obtained maximum current density of 1 to 20 A/cm^2.

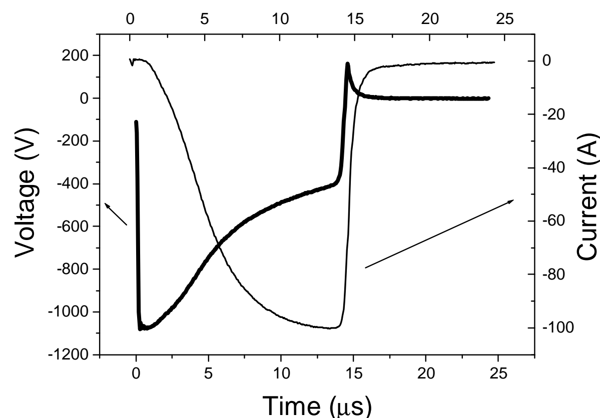

Fig. 2. Typical cathode voltage and current waveforms.

For a titanium target a typical optical emission spectrum near the cathode is presented in Fig. 3a.

With RF preionisation we have been able to make emission spectroscopy measurements near the substrate (Fig. 3 b).

Pulsing a conventional hollow cathode lamp [6,7] synchronously with magnetron current pulses we estimated vapour ionisation ratio ~ 70% by absorption spectroscopy measurements.

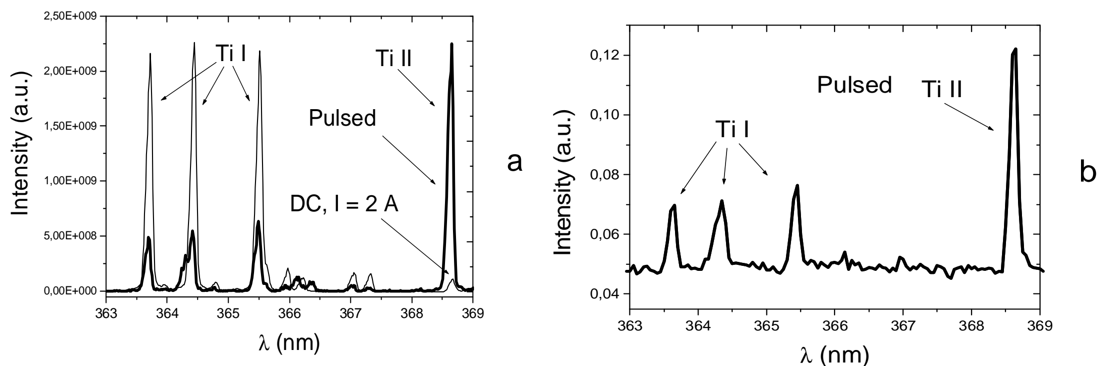

Fig. 3. Optical emission spectrum near the target (a) and near the substrate (b).

The pulsed ion current has been measured on the substrate biased at -40V and for different RF preionisation conditions. The time evolution of ion current on the substrate for different RF power is presented in Fig. 4.

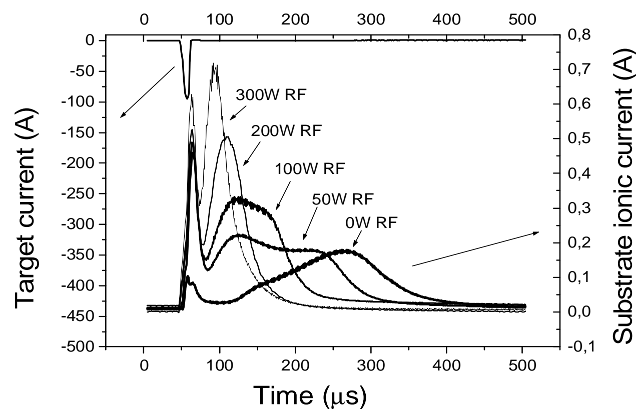

Fig. 4. Target current and ion current on the substrate for different RF power; target to substrate distance of 8 cm.

Thin titanium film layers were deposited on glass and silicon substrates for different working conditions. SEM, RBS and NRA analyses were performed on these samples and on a reference sample (normal DC magnetron sputtering 2 A, argon at 1.4 Pa). The layers obtained in pulsed regime are more compact and with lower oxygen contamination.

4. Discussion and conclusions

For cathode current densities higher than $1A/cm^2$, we observed an enhancement of Ti II lines, similarly to observations by Ehiasarian et al [4] in pulsed magnetron discharges [3]. Moreover we also observed this enhancement near the substrate (Fig. 2b).

By proper preionisation we have been able to reduce the breakdown delay to the acceptable range to work in very short pulse regime so that electric arcs are avoided. Thus, stable operation are obtained at high frequency pulse repetition rate (~ 1 kHz) and high current densities (1-20 A/cm^2).

An efficient gas ionisation between cathode and substrate can optimise ionised vapour collection as is suggested in Fig. 4. This ionisation can be obtained in different ways (DC, RF, microwave, multi pulse operation)

The pulse duration can be adapted for every magnetron configuration to obtain maximum of ion-to-neutral ratio without electric arc development. In reactive mode operation the pulse duration was in the range of 1-5 μs and for non reactive mode it was in the range of 10–30 μs.

The SEM analysis and the low oxygen concentration in the samples have provided evidence for a higher compactness of titanium thin layer deposited by pulsed sputtering.

Thus we have shown that this new sputtering technique based on preionised pulsed magnetron discharges seems to be very promising as an IPVD method.

Studies are in progress to improve control of ionised vapour transport to the substrate for different targets and working gases [8] and to extend our technique at an industrial scale particularly for oxide and hard coating deposition.

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