

ON THE INJECTED GAS/ELECTRIC POWER RELATION FOR BETTER CONTROL OF DEPOSITION EFFICIENCY DURING THE GIMS DEPOSITION

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1. Introduction

During the last AEPSE'2011 conference [1,2] there were presented the concept as well as the first results of the use of working gas injection to control the generation of pulsed plasma. The problem was discussed on the basis of two methods: Impulse Plasma Deposition (IPD) [3] and Magnetron Sputtering (MS) *e.g.*[4,5]. The first results indicated the desirability of a deeper interest in such a way of plasma process control.

The idea of using the working gas injection instead of stationary gas flow mode assumes in the first approximation that the lack of cold gas in the chamber space prior to gas injection could next avoid the kinetic energy dissipation on collision between the plasma particles and the cold gas.

Previously presented studies [6] have shown the initial experimental results proving the positives of proposed modification of the well known methods of plasma surface deposition (in the case of IPD - possibility of exceptionally effective producing of antiabrasive layers on unheated substrates and from the other hand - the positive change in the morphology of layers as well as a different way of target erosion during the layer deposition by MS).

Lately carried out experiments [1,2] have showed that during the **GIMS** deposition of AlN coatings (**GIMS** - *Gas Injection Magnetron Sputtering*) higher amounts of Al-Al bonds have occurred in comparison with the case of continuous gas flow mode. It seems to us that the reason of that metallic "tail" could be both the diminishing of the portion of reactive gas and/or self sputtering effect of the aluminum target arising during the last phase of working gas injection. The studies describes below concerns the very last our studies on the possibilities of control the gas/electric power relation during the GIMS process.

2. Experimental procedure

The processes of AlN synthesis were performed in two modes: mode A – gas injection in its initially variant as mentioned previously [1,2] and mode B – after the just introduced modification of the gas injection procedure. The modification of the gas injection procedure consisted of using a device specially designed by us to control the gas injection/electric power phase relation (patent procedure has been just now initiated).

As described earlier in [1,2] our apparatus for AlN deposition by the GIMS was equipped with two WMK100 type magnetrons working in special dual magnetron arrangements ("gemini type") supplied by the DPS pulse power supplier operated at frequency of 70 kHz with 2 kHz

modulation. AlN layers were deposited on non-heated 2-inch Si wafer. Prior to AlN layer synthesis the aluminum target of initial thickness of about 8 mm was preliminary typically conditioned for 10-15 min by sputtering in argon (shutter) continuously dosed to the chamber and next the process of AlN layer deposition was carried in the nitrogen injected by the pulsed valve with the frequency of 10^0 - 10^1 Hz and the valve time "ON" duration of order of 10^{-3} - 10^{-2} s. The pressure of nitrogen was periodically varied depending on the phase of gas injection. However, with an accuracy of the inertia of the pressure meter gauge in the case of mode B the plasma was excited at pressures of order of 10^{-3} Pa (!). The synthesis of AlN layers with the thickness of tens of nanometers was carried out at an effective power of several kW, using the ratio between the circulating and effective power as one of essential parameters controlling the course of plasma process (the circulating power as an important technological parameter results from a special, novel concept of DPS magnetron power supply [7]). The distribution of particular bonds, especially Al2p orbitals of the material of AlN layers was investigated by the use of the XPS spectroscopy.

3. Results and discussion

From our earlier experiments related to the synthesis of AlN layers by magnetron sputtering [1] by the GIMS deposition came out, that after synthesis under conditions of gas injection, the presence of the Al-Al bonds has been possible (as high as even 20% in the worst case). We assumed that these bonds probably appeared as a result of target sputtering aluminum in the final stage of gas injection pulse, very close to the metallic mode of magnetron operation. In order to minimize or even to the total elimination of the unfavorable presence of Al-Al bonds we have constructed a special control system of the gas injection phase.

The procedure and some specific features of the GIMS processes realized in mode A and mode B were described above. What is worth to note in the context of GIMS is way of reactive erosion of target surface for targets exploited in the conditions of GIMS and the conditions of continuous gas flow (in the case of GIMS the target was exploited in the nitrogen atmosphere only !). The difference between targets has been shown at the fig. 1.



Fig. 1 View of the Al targets exploited in the GIMS (left photo) and under the condition of continuous working gas flow (right photo), respectively in the nitrogen only and Ar+N₂ atmosphere.

The comparison between the XPS studies for Al_{2p} orbital for the layer materials produced in modes A and B has been shown in fig. 2. Deconvolution of spectra obtained for the mode A's material the presence the peak of about of 73.4 eV typical for the Al-N bonds and in addition to that also the presence of a small peak of about of 71.5 eV reflecting the binding of Al-Al (fig. 2a) *e.g.* [8]. In the case of layers produced in mod B *e.s.* with the use of the our special controller the repeatedly made XPS studies allowed us to exclude the presence of Al-Al bonds (fig. 2b).

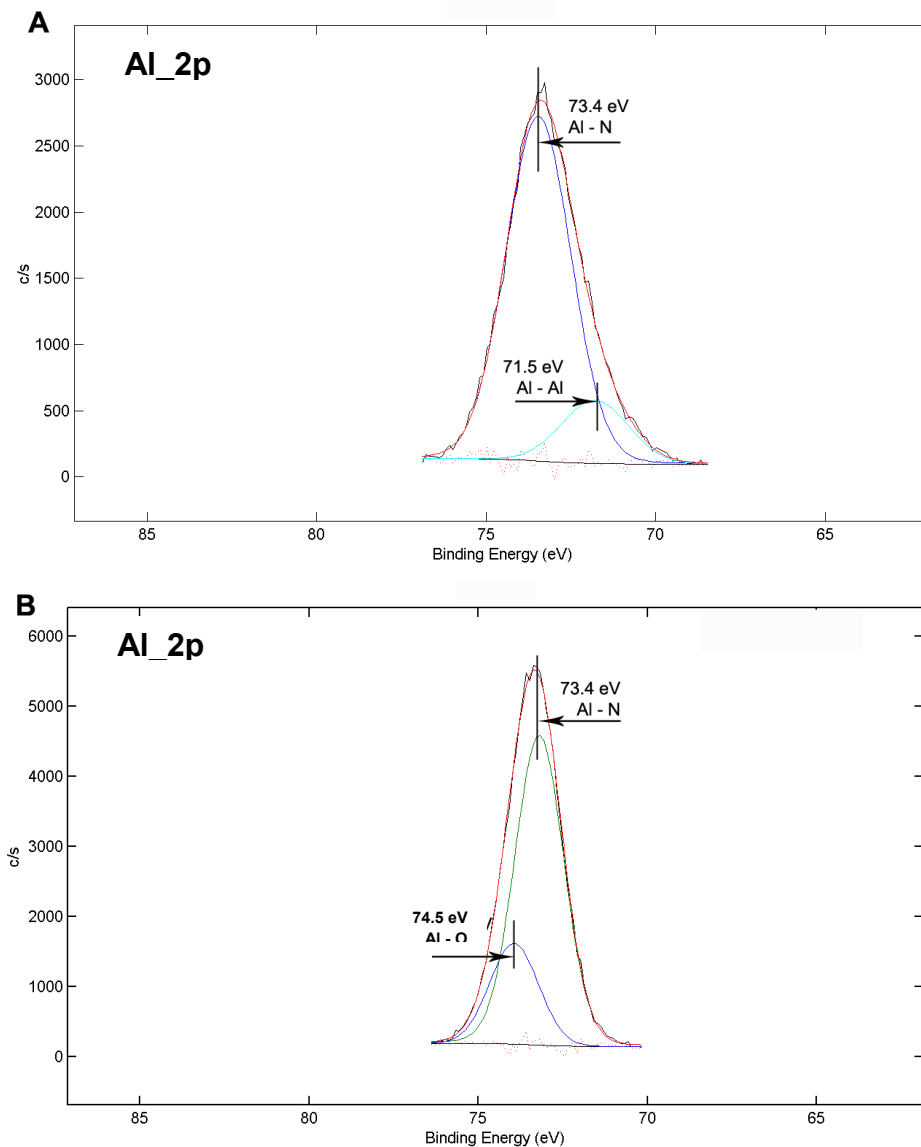


Fig. 2 XPS spectra of the Al_{2p} orbitals for the AlN layer materials deposited in modes: A (a) and B (b)

Deconvolution of the Al₂p spectra obtained for AlN layers materials produced in mode B revealed the interesting relation between the controlled gas injection phase and the relative content of the Al-N and Al-O bonds (respectively, about 73.4 eV and about 74.5 eV). The studies showed that the relative content of the “oxygen bonds” in the layer materials increases with the shortening of the individual pulse duration during the gas injection. In our opinion this probably indicates that during the AlN deposition by the GIMS technology the Al-O bond are formed in the first stage of the AlN layer synthesis as a result of binding of the residual oxygen content (chamber, target material) by a aluminum vapors. In recent years we have focused our attention on how to implement a new magnetron sputtering process. Based on our previous experience in the application of gas injection to control the production of layers by IPD, we used a similar technique in the case of MS methods. Described in this abstract studies included a successful attempt to gain better control over the phenomena associated with the synthesis of layers in a GIMS. It seems to us that we can effectively cut off the tail of aluminum vapor produced in the final phase of the individual targetu sputtering gas injection.

4. Conclusions

In recent time we have focused our attention on new magnetron sputtering (MS) technology by the use the gas injection as a tool for initiating and effective control of plasma generation process during the MS layer deposition (MS -> **GIMS**). Based on our previous experience in the application of gas injection to control the production of layers by IPD, we used a similar technique in the case of MS methods. Studies described above concerns a successful attempt to gain better control over the phenomena associated with the developed by us GIMS technique. It seems to us that by applying the specially designed controller integrated into the electric supply system of the magnetrons we can effectively cut off the tail of aluminum vapor produced in the final stage during the injection of an each individual portion of working gas during the GIMS.

Literature:

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