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Optical emission spectroscopy study of a DC magnetron discharge in Ar/(O2-N2)

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Metallic (Me) oxynitrides (MeNₓOᵧ) are attracting the attention of many researchers for the last two decades due to a unique set of versatile properties, resulting from the combination of those from the pure metals and those of the correspondent binary nitrides and oxides. Among the group of already studied oxynitrides, and due to the combination of aluminium and aluminium nitride and oxide, aluminium oxynitride (AlNₓOᵧ) has some interesting potential applications in different technological fields, but the available knowledge of this system is very reduced and mostly related with its spinel structure. Recent results showed that AlNₓOᵧ thin films deposited by PVD present a particular changing morphology, consisting of Al nanoparticles embedded in a AlNₓOᵧ matrix and, depending on the amount of oxygen and nitrogen in the matrix, very different electrical and optical responses. This work presents a study of the evolution of several discharge parameters (target voltage, reactive gases partial pressures) and plasma emission spectrum responses during thin film deposition, for different N₂ and/or O₂ gas flows, in order to understand the effect of processing conditions on the chemical composition and bonding characteristics, and its effect on the morphological and structural features, which, all together, explain the wide range of property variations that can be obtained in the AlNₓOᵧ film system. The partial pressure of each reactive gas was monitored using a mass spectrometer and the Al, Ar, N₂ and O₂ emission lines were recorded using an optical emission spectrometer at two different discharge spots, one close to the target and the other close to the substrate. For the Ar-N₂ based reactive gas mixtures, a smooth evolution of the different discharge parameters was observed as a function of reactive gas flow. On the other hand, for Ar-O₂ mixtures, there was an abrupt transition in the different parameters for certain critical O₂ flows. For the pure Ar discharge, the plasma density and temperature could be obtained, using a simple collisional radiative model, based on the Ar emission lines.

Keywords
AlNₓOᵧ
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OPTICAL EMISSION SPECTROSCOPY STUDY of a DC MAGNETRON DISCHARGE in Ar/(O2+H2)

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ABSTRACT

Metallic (M) oxynitrides (M(NOx)) are attracting the attention of many researchers for the last two decades due to the unique set of versatile properties, resulting from the combination of those from the pure metals and those of the correspondent binary nitrides and oxides. Among the group of already studied oxynitrides, and due to the combination of aluminum and aluminum nitrides and oxides, aluminum oxynitrides (Al(NOx)) have shown interesting potential applications in different technological fields, but the intrinsic knowledge of this system is very reduced [1,2]. This work presents a study of the evolution of surface discharge and plasma parameters as well as the plasma emission spectrum responses during thin film deposition, for different N2/O2 partial pressures, in order to better understand and control the deposition conditions of the Al(NOx) films system.

EXPERIMENTAL DETAILS

DC magnetron sputtering

Target: Aluminum, 99.999% purity
Substrate: glass, silicon <100>
Substrate temperature (before discharge): 275 °C
Partial pressure of Argon, 0.3 Pa
Reference gas: N2/O2; 1:9 (v/v)
Bias: 500 V
Target current density: 75 A/m²
Discharge parameters: monitored by a Data Acquisition Switch unit Agilent 8010A
Plasma parameters: radio frequency (RF) magnetic method
Plasma composition: Optical emission spectroscopy

RESULTS AND DISCUSSION: Plasma parameters (near the cathode)

Fig. 1: Electron temperature estimated using the harmonic method by applying (a) sinusoidal waves and (b) triangular waves.

The electron temperature (near the cathode) gradually increases as a function of the reactive gas partial pressure mainly due to the ion induced secondary electron emission coefficient of the target which increases the population of fast electrons accelerated in the cathode sheath.

Fig. 2: Ion flux estimated using the harmonic method by applying (a) sinusoidal waves and (b) triangular waves.

The ion flux, measured at a region of the plasma near the cathode, is approximately constant at the partial pressure of reactive gas increases. This is due to the fact that the current was kept constant during the deposition.

Optical Emission Spectroscopy

Fig. 3: Optical emission spectroscopy spectra for different partial pressures of N2/O2 reactive mixture.

For the plasma emission spectrum one can observe the excited aluminum peaks and some typical emission lines of Ar. Nonmetallic or Oxygen lines are visible.

CONCLUSIONS

When the N2/O2 reactive gas mixture is added to the argon atmosphere not only reacts with the sputtered aluminum to form compounds in the substrate, but also interacts with the surface of the cathode leading to chemisorption, on implantation and, consequently, compound formation. These processes increase the ion induced secondary electron emission coefficient of the target, manifested in the decrease of the target potential and the increase of the electron temperature; and, on the other hand, diminish the sputtering yield, manifested in the decrease of Ar ion intensity and in the values of the deposition rate.


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