Thirteenth International Conference on Plasma Surface Engineering
Conference and Exhibition

First Circular and Call for Papers

PSE 2012

September 10–14, 2012
Garmisch-Partenkirchen
(Germany)

www.pse-conferences.net/pse2012

Organized by:
European Joint Committee on Plasma and Ion Surface Engineering
(EJC/PISE)

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Electrical and optical properties of AlNₓOᵧ thin films deposited by reactive DC magnetron sputtering

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Aluminium, Al, is a metallic material used in a large variety of technological fields, such as surface plasmon-coupled emission (SPCE) devices for biochemical applications and it is also a good candidate to be used as nonresonante plasmonic nanoparticle in thin-film silicon solar cells. Aluminium nitride, AlN, is a semiconductor material and it can be used in the fabrication of optical sensors, LEDs, surface/bulk acoustic wave devices and in electronic packaging. aluminium oxide, Al₂O₃, is an insulator material, used as protective film, as gate dielectric in flash memory circuits, OTFTs, MOSFET, etc. The AlOₓ system is also important in solar selective coatings since it exhibits very high solar selectivity. The possibility to associate the overall set of properties of the above mentioned base-materials might be the starting point for a material that may combine specific advantages of each of the three systems. Al, AlN, and AlOₓ, according to the particular requirements of a given application. In fact, the addition of small amounts of oxygen and nitrogen to a growing Al film can give rise to an oxynitride film with a wide range of different properties, where the optical and electrical ones may be tailored between those of the pure aluminium and those of aluminium nitride and oxide. In this work thin films of AlNₓOᵧ were prepared by reactive DC magnetron sputtering, using a pure Al target and an Ar/(N₂O₂) gas mixture. Preliminary Transmission Electron Microscopy and EELS analysis suggested the growth of films with Al nanoparticles randomly embedded in an AlNₓOᵧ matrix. The particular structure, morphology and composition of the films induced a wide variation in the electrical properties, which can be explained using a tunnel barrier conduction mechanism for the electric charge transport through the films, as well as distinct optical responses, such as an unusual large broadband absorption for some films, with potential applications in solar cells and thermal photovoltaics.

Keywords
AlNₓOᵧ
Electrical and optical properties
In this work a set of films of AlN, O, and two sets of the correspondent binary systems, AlN and AlO, were produced using reactive DC magnetron sputtering, using an aluminium target and an Ar + (N2 + O2) gas mixture. The discharge characteristics (target potential) and deposition rate, chemical composition, structure and optical properties of the ternary system were compared to those of the binary systems in order to test whether the oxynitride films have a unique behaviour or are simply a transition between AlN and AlO.

**RESULTS AND DISCUSSION**

The transition from sub-stoichiometric to close-stoichiometric films is relatively smooth in AlN, very abrupt in AlO, and different tendencies can be found in AlN O system according to the particular zones defined.

**DEPOSITION CHARACTERISTICS**

The deposition rate (thickness/deposition time) has also distinct variations in each system.

**CONCLUSIONS**

The composition and structure of the films are strongly dependent on the target condition and deposition characteristics. It was found that the three systems have distinct electrical and optical responses opening the possibility to tailor the properties of the AlN, O, from those of the correspondent binary systems, according to the application envisaged. The properties of the ternary system can be explained assuming that the films come to exist as in fact a percolation network of aluminium nanocrystals dispersed in an oxide matrix. The aluminium grains can form irregularly shaped clusters with different sizes through the matrix, inducing a broadband absorption nearly independent of the wavelength. The conductivity is also governed by the constitution between grains that can be in contact or separated by insulating barriers (oxynitride and/or voids). The barrier component of the film’s resistance has a negative dependence on the temperature and thus explains the negative TCR for some films.