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A Review on DC Magnetron Sputter Deposition over Various Alloys

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***Abstract*: Direct Current (DC) Magnetron sputtering has emerged to complement other vacuum coating techniques such as thermal evaporation and electron-beam evaporation. In addition, compounds can dissociate into their chemical constituents at the low evaporation pressures used. DC sputtering works with all conductive target materials. So the potential at the cathode drops and the positive ions are no longer accelerated towards the target. DC Magnetron Sputtering exhibits several important advantages over other vacuum coating techniques and this has led to the development of a number of commercial applications ranging from microelectronics fabrication to simple decorative coatings. There are several physical vapor deposition methods for producing coatings in a vacuum environment and these can be separated into two main groups: Those involving thermal evaporation techniques, where material is heated in vacuum until its vapor pressure is greater than the ambient pressure, and Those involving ionic sputtering methods, where high-energy ions strike a solid and knock off atoms from the surface. Ionic sputtering techniques include diode sputtering, ion-beam sputtering and magnetron sputtering.**

***Keywords*: Pulsed-Direct Current mechanical and thermal coating**

1. Introduction

Pulsed-Direct Current (p-DC) magnetron sputtering is a well- known technique used for the production of thin films. This technology is widely employed on the industrial scale due to its scalability and versatility, and to the repeatability and high quality of the obtained coatings. In fact, Magnetron Sputtering is exploited for many applications, ranging from solar glazing products to micro-electronic coatings, from tool protecting layers to packaging coatings, allowing the deposition of both metallic and non- metallic coatings over various substrates [1]. Concurrently innovative thin film processing techniques are also being developed, to meet the ever demanding requirements of the industries. Depending upon application thin films are categorized into optical, electrical, magnetic, chemical, mechanical and thermal coatings. Recently, Pulsed DC Magnetron Sputtering has been employed on the laboratory scale also for metal Nano particles production and deposition on the surface of solid or liquid supports, thus avoiding the contamination of solvents and or precursors typically occurring with more conventional techniques. Depending upon application thin films are categorized into optical, electrical, magnetic, chemical, mechanical and thermal coatings [2].

The sputtering or sputter erosion of solid material by positive-ion bombardment is widely used as a source of vapour for thin film deposition because of unique combination of advantages --over other techniques such as any materials can be volatilized, compounds are volatilized stoichiometrically, and film deposition rate can be made uniform over very large areas. the magnetron sputtering technology is suitable for large-area deposition of thin films with a relatively high deposition rate and has been used for the deposition of thin film metallic coating with less environmental pollution than electrochemical methods [3].

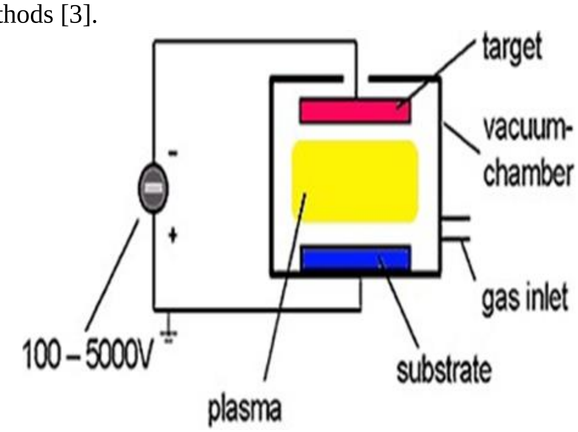

Fig. 1. Schematic drawing of DC Sputtering chamber

2. DC magnetron sputtering

A. *Cu and Pt clusters*

Copper and platinum were deposited onto commercial P25 TiO_2 powders by pulsed direct current magnetron sputtering. The magnetron was powered by an Advanced Energy Pinnacle Plus power supply. The metal targets were sputtered at 250W, 350 kHz, 50% duty cycle (corresponding to a pulse- off period of 1.4 µs, when the cathode voltage is reversed). The platinum loading is ca. twice the copper loading attained under analogous sputtering conditions, with ca.0.7wt. Ptvs. ca. 0.34wt. % Cu deposited after a 10min-long deposition. By comparing the two Cu-only modified photo catalyst series, sputtering copper in Ar-only gives better results than sputtering copper in an Ar+O_2 atmosphere. This is possibly related to the lower Cu loading achieved after the same deposition time, due to the lower copper sputtering rate in an O_2 containing plasma, and also to the different Cu oxidation state [4].

B. *Aluminium thin film coatings*

Aluminium (Al) thin film deposited using DC Magnetron sputtering combines many properties such as Optical, Mechanical properties on ceramic substrates. Properties of thin film coating depend on the deposition parameters employed. The aim of this work was to study the optical and mechanical properties of aluminium thin films. In order to study the above property deposition parameters varied with different deposition rate, power and argon flow rate in the DC magnetron sputtering process on substrates. The thin film Aluminium coatings were deposited on ceramic substrate using DC Magnetron sputtering process. Desired substrates with a dimension 30mm x 30mm are used for deposition and substrates are cleaned by a solvent clean followed by de ionized water rinse, followed by mild acid clean, De Ionised rinse and blow dry[5]. Aluminium has a fairly broad spectral band of high reflectivity and therefore, it is not surprising to see that one of its prevailing uses is in solar reflector coatings where a thin film, typically in the order of nanometer, of pure aluminium is deposited on a substrate by DC magnetron sputtering in vacuum. Hardness and elastic modulus measurements are the two mechanical properties measured most frequently using indentation techniques are the hardness, H, and the elastic modulus, E. Pure aluminium reflectors are not protected with an overcoat. It is prone to oxidation tarnishing, and a barrier oxide layer is formed when aluminium is reacting with oxygen in air. The resulting oxide layer is tough and corrosion resistant in normal environments [6].

C. *Ti2AlC and Ti3AlC2*

Ti2AlC and Ti3AlC2 coatings were successfully prepared via a two-step method with initial DC magnetron sputtering at ambient temperature and post annealing at 800 °C for 1 hour. Particularly, cost- effective targets synthesized by hot- pressing Ti/Al/C powders at low temperature (800 °C) were used. The phase components and microstructure of the coatings were characterized by XRD, laser Raman spectroscopy, SEM and TEM. It was found that the phase components of the as-deposited and annealed coatings varied with the molar ratio of Ti, Al and C powders in the cost- effective targets. Phase-pure Ti2AlC and Ti3AlC2 could be obtained from the target with the Ti: Al: C molar ratios of 2:1.5:1 and 3:2:2, respectively. These two coatings were consisted of plate-like grains. Due to the high internal stress resulting from crystallization- or phase transformation-induced volume change, both of the Ti2AlC and Ti3AlC2 coatings cracked during the annealing process [7]. The element contents were different in the initial mixtures of Ti, Al and C powders, the as-sintered targets had similar phase compositions. In order to identify the existence of Al in the as-deposited coatings, the chemical compositions of the coatings were determined by EPMA [8].

D. *Indium Tin Oxide (ITO)*

ITO Nano rods were deposited by placing the substrate at three different locations inside the chamber. Films were found to be crystalline owing to secondary thermal effect when oxygen pressure is varied [9]. Due to varying oxygen pressure, morphology and transport properties changed significantly. The position of the substrates plays imperative role in achieving quality films which is to be optimized for every sputtering unit to achieve best TCO film. One can readily recognize the haystack like aligned Nano rods stemming from the substrate distributed evenly over the measured range. Raman spectroscopy analysis was used to confirm the formation of Ti2AlC and Ti3AlC2 in the coatings [10]. The ITO Nano rods deposited without intentional substrate heating were found to be crystalline due to the secondary thermal effect of the ejected energetic particles impinging on the substrate. The transparency of the deposited ITO films varied between 53 to 69 %. A systematic change over in morphology and transport property of the ITO thin films composed of Nano rods was observed with lateral position and varying oxygen pressure [11].

E. *Copper indium gallium selenide*

A pulsed-DC sputtering process at room temperature has been developed for the deposition of the CIGS absorber layer. It uses a single quaternary target and is followed by a high temperature post-deposition annealing process, the annealed layers have shown a high microstructural quality. All hereby mentioned sputtering processes were conducted using argon plasma. EDX quantitative analysis was performed on as deposited and annealed thin films in order to assess the changes in chemical composition after annealing. For better accuracy, the means over 10 measurements on the same point were calculated. X-ray diffraction data of the as deposited and annealed thin films were recorded and presented [12]. The short-circuit current is quite high, since no antireflective coating is used. The open-circuit voltage and the fill factor values are not as high as it can be expected (considering the high crystalline quality). The CIGS absorber layer of photovoltaic cells has been deposited by magnetron sputtering in the pulsed-DC mode from a single quaternary target. Deposition was made without intentional heating and under argon plasma [13].

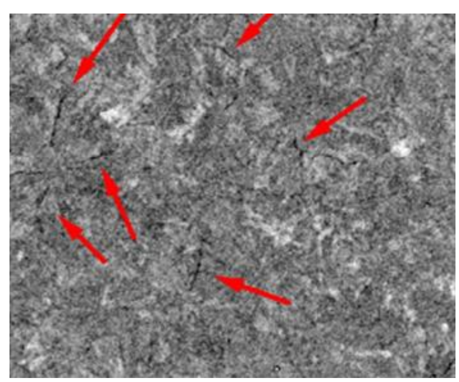

Fig. 2. The arrows highlight the fractures

F. *Niobium doped TiO2*

The long-term stability of electrical resistivity in Nb-doped TiO2 thin films grown at a high rate by a reactive DC magnetron sputtering from metallic targets. The high deposition rate is obtained by an active control of the oxygen flow during the growth process. Film microstructure and preferential orientation of the crystallites are controlled by the total working pressure in the film growth process [14].

G. Nano crystalline silicon films

Hydrogenated Nano crystalline silicon films were prepared by a pulsed-DC magnetron sputtering method using an argon/hydrogen mixture gas. The effects of working pressure and hydrogen concentration on the structural an electrical propertiesof the films were systematically investigated using grazing incidence X-ray diffraction (GIXRD), Raman spectroscopy, and conductivity measurement. The nc- Si:H films were deposited on Corning 1737 glass substrates by pulsed-DC magnetron sputtering. The crystallinity of a series of hydrogenated silicon films sputtered at various working pressures can be evaluated by GIXRD, there is no diffraction peaks found except amorphous background [15].

H. TiC and TiC/Ti (Titanium Carbide)

The formation of TiC and Ti phases and their influence on their mechanical properties was studied in this work. Thin layers were deposited by DC magnetron sputtering at room temperature in ultrahigh vacuum from Ti and C targets. The mechanical property of TiC coatings or films deposited at RT, namely hardness, is typically ranged between 17 and 35 GPa. The thin films were deposited in the compositional range of 57 to 95 at. % Ti concentration by DC magnetron sputtering at room temperature [16]. The composition of the samples was measured by XPS analysis, and also was calculated from the pre-growth rates. As anticipated, the measured and calculated results are not the same, however strictly following the same Trend [17].

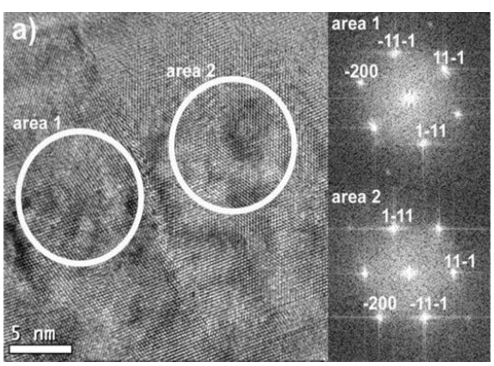

Fig. 3. HRTEM image, an incoherent twin boundary and the FFTs from twin boundary two side

I. Polycrystalline CZTS

Polycrystalline CZTS is an emerging candidate for photovoltaic, optoelectronic and gas sensing applications due to its availability and enviro-friendly nature and also favourable light harvesting properties. The properties of polycrystalline materials depend upon the grain size [18]. First, we prepared Sn-Cu-Zn films on glass substrate at room temperature by using stacked layer DC (direct current) magnetron sputtering. Then, Sodium Fluoride (NaF) was thermally evaporated on deposited Sn-Cu-Zn film followed by post sulfurization in H2S atmosphere. The sulfurization temperature was 5502 and sulfurization time was 30 min. NaF layer was deposited on sample S2 using thermal evaporationand thickness of NaF film was ~30 nm. After NaF deposition sample were shifted into tubular furnace for sulfurization/annealing process [19].

J. Molybdenum films

Molybdenum (Mo) thin films have been deposited on soda-lime glasssubstratesusing a DC magnetron sputtering system. The electrical resistivity of the Mo films could be reduced by increasing any of the above parameters. The cross hatch tape adhesion test (hatch cutter) was used to investigate the adhesion property of the deposited Mo films on the soda-lime glass [20]. Because of its low resistivity and high melting point, sputter deposited thin films of molybdenum (Mo) are increasingly being used as the gate electrode in GaAs-based metal gate field effect transistors (MESFETs) and silicon-based metal oxide semiconductor (MOS) devices. The basic configuration of a DC Sputtering coating system is the target material to be used as a coating is placed in a vacuum chamber parallel to the substrate to be coated. [21].

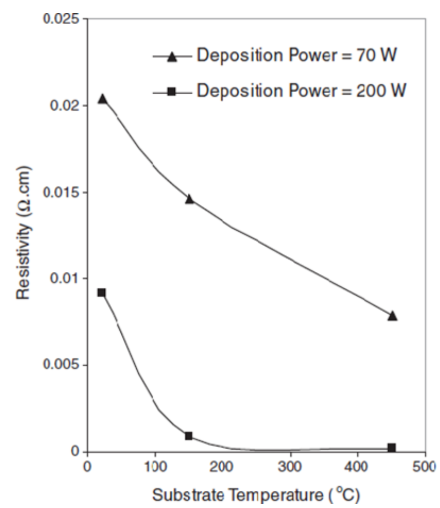

Fig. 4. Resistivity vs. Substrate temperature

K. Cobalt doped zinc oxide

Thin films of cobalt-doped ZnO were prepared by DC magnetron sputtering on glasses. The cobalt dopant concentration was at 3%wt. The sputtering power was set at 200 watts and sputtered for 20 mins. All films are transparent. The films were then annealed at 100- 5000C under air atmosphere. The optical transmission and absorption of as-deposited (room temp) and annealed cobalt-doped ZnO thin films were characterized by UV-Vis spectrometry [22]. The spectra were obtained in the range of 300 - 800 nm. Thin films of cobalt-doped ZnO with 3%wt cobalt were fabricated by DC magnetron sputtering on glass substrates. The films were then annealed at 100-5000C in air. The

XRD patterns confirm the films have crystal structure as hexagonal quartzite without secondary phase [23].

L. Fe-Pt Thin films

The films prepared by conventional dc sputtering, Fe-Pt films fabricated by pulse dc sputtering show higher ordering parameter (S) of 0.6-0.8 at the post annealing temperature (Ta) in the range of 500-7000C [24]. X-ray diffraction patterns of Fe-Pt films prepared by dc and pulse dc sputtering post annealed at various temperatures in the range of 300- 7000C. The ordering parameter (S) and Lotgering orientation factor (LOF), obtained by XRD analysis, and are adopted to understand phase constitution and degree of texture of Fe-Pt films post-annealed at various temperature [25]. Pulse dc sputtering was used to deposit Fe-Pt thin films on SiO2/Si (100) substrates. A post annealing was then followed for ordering phase transformation [26]. Microstructure results indicate enhanced grain growth in pulse dc prepared films after post annealing, and it could be an explanation for higher extent of ordering [27]. The results of this study suggest pulse dc sputtering as an effective approach to prepare high quality Fe-Pt thin films with strong perpendicular magnetic anisotropy [28].

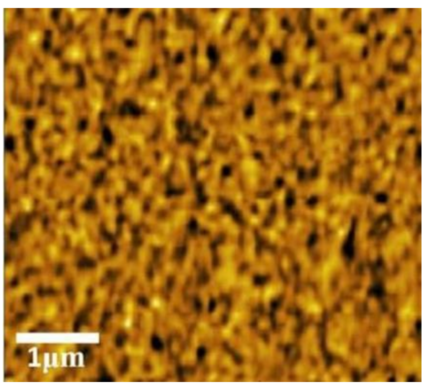

Fig. 5. DC Sputtering

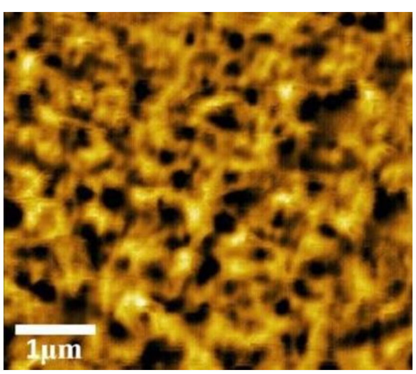

Fig. 6. Pulsed DC Sputtering

3. Conclusion

DC Sputtering is the economical solution of choice for many types of metal coatings, its primary limitation is that non-conducting dielectric insulating materials take on a charge over time which can result in quality issues like arcing, or the poisoning of the target material with a charge that can result in the complete cessation of sputtering. DC Magnetron Sputtering allows for higher current at lower gas pressure that achieves an even higher thin film deposition rate. DC Sputtering is used extensively in the semiconductor industry producing microchip circuitry in the molecular level. It is used for gold sputter coatings of jeweler, watches and other decorative finishes, for non- reflective coatings on glass and optical components, as well as for metalized packaging plastics.

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