

Wednesday Morning Poster Sessions

Thin Films

Room: Exhibit Hall B2 - Session TF-WeP

Poster Session

TF-WeP1 Effects of Starting Material of Aluminum Doped Zinc Oxide Under-layer on the Electric Properties of Palladium Doped Silver Film. *T. Oyama, M. Maekawa, T. Yanagisawa, Asahi Glass Co., Ltd., Japan*

Silver-based multilayer has been widely utilized as heat mirror for Low-E coating or transparent conductor for electromagnetic shielding. In this study, deposition conditions of the AZO (Aluminum doped zinc oxide) film were investigated to show how they affected the crystallographic property of the film and the electric property of palladium doped silver layer formed on the film in the layer system of Glass/AZO(42nm)/AgPd(1%Pd:10.5nm) deposited by DC magnetron sputtering. Starting material for AZO was aluminum doped zinc metal or aluminum oxide doped zinc oxide. Metal target was sputtered in oxygen atmosphere or carbon dioxide atmosphere whereas oxide target was sputtered in argon or argon/oxygen atmosphere. AgPd layer was deposited under the same condition. The effects of the over-layer were also investigated. Electrical resistivity was changed by up to 17% according to the deposition process of the under-layer. AgPd film deposited on AZO showed the lowest resistivity of $7.1 \times 10^{-6} \Omega \text{cm}$ in the case of metal target with oxygen. On the contrary, the highest resistivity of $8.3 \times 10^{-6} \Omega \text{cm}$ was observed in the case of oxide target with argon/oxygen. XRD patterns showed the most developed Ag(111) peak coupled with ZnO(002) peak in the case of metal target with oxygen and AFM observation revealed the smallest surface roughness in this case. Deposition of thin metal(Zn-Al) over-layer increased the resistivity implying the diffusion of zinc atom into silver-based layer, however the resistivity decreased with storage time. Optical constants of the films determined by spectroscopic ellipsometry(SE) and surface roughness of the films estimated by SE will be discussed.

TF-WeP2 The Synthesis and Characterization of Indium Tin Oxide Films by Cesium Assisted Sputtering System at Low Temperature. *D.Y. Lee, H.K. Baik, Yonsei University, Korea, S.J. Lee, Kyungseong University, Korea, K.M. Song, Konkuk University, Korea*

In this study, we investigated the properties of indium tin oxide (ITO) thin films synthesized by using a cesium assisted sputtering method. Cesium assisted sputtering enables to supply a cesium vapors on the target surface of sputter and generate the negative ions of target materials. The flux and energy of negative ions are independently controlled by the changing target voltage and cesium contents. ITO target (SnO₂:In₂O₃ = 1:9) was sputtered by mixture gas of argon and oxygen. Oxygen partial pressure, working pressure and other deposition parameters were optimized. RF coupled DC was used as a power source and its voltage was changed from 45 V(only RF) to 350 V(only DC). The temperature of cesium reservoir was varied from 80 to 200 Å°C. Negative sputtered particles including In, Sn, O and electron were generated from the target surface and accelerated to the substrate by target voltage. We applied additional substrate bias to control deposition energy and flux. The main object of our study is the fabrication of ITO films with low resistivity and high transparency at room temperature by negative ion beam process. The effects of cesium addition not only enable to generate the negative ions by lowering the target work-function but increase the plasma density. From the result of XRD, we concluded that the ion beam effects induced by positive and negative ion enhance the crystallinity of ITO films. In the case of positive bias, negative ions and electrons play a main role in improvement of ITO crystallinity. For the negative bias, argon ions, which fluxes were increased by cesium, promote ITO crystallinity by enhancing the mobility of adatoms on the substrate surface. Also we found that the preferred orientation of ITO films was changed with applied bias. The characterization of deposited ITO films was performed by XRD, four point probe, AFM.

TF-WeP3 Deposition of ZnO Films by Reactive Sputtering in CO₂ Atmosphere. *N. Aomine, K. Sato, E. Shidouji, J. Ebisawa, Asahi Glass Co., Ltd., Japan*

Transparent oxide films are often deposited by reactive sputtering from metal target in Ar/O₂ atmosphere because of cheap target cost. It is well known that deposition rate and absorbance of obtained films change drastically with a ratio of O₂ flow to total gas flow, and a transparent film can be obtained with a maximum deposition rate in the transition region from metallic to oxide mode. However, it is difficult to keep sputtering process in the transition region without monitoring plasma state e.g., emission, impedance, gas fraction, feed-backing to the process. In this

work, reactive sputtering using CO₂ gas instead of Ar/O₂ gas was studied. ZnO films were deposited by reactive sputtering of a 10 cm-diameter Zn metal target. Process-film property relationship such as discharge voltage, deposition rate, film absorbance, and carbon content was investigated. Furthermore, gas fraction of CO₂ sputtering atmosphere was analyzed by quadrupole mass spectrometer (Q-mass). It was found that CO₂ sputtering has advantage to enable reactive sputtering in the transition region by only simply adjusting CO₂ flow rate. Films obtained with small CO₂ flow rate were absorptive, while films, with increasing CO₂ flow rate, became transparent and deposition rate finally began to decrease. Result from Q-mass spectra, showing CO₂ was partially decomposed into O₂ and CO by glow discharge, was analyzed based on gas supply and consumption balance model. It was concluded that CO₂ sputtering was advantageous owing not only to low O₂ partial pressure but also to deoxidation effect by CO. The advantage of CO₂ sputtering will be detailed.

TF-WeP4 Fabrication of ZnO Thin Films by Pulsed Laser Ablation with Remote Radical Source. *T. Suzuki, M. Hiramatsu, N. Shimizu, Meiji University, Japan*

Zinc oxide (ZnO) is a II-VI compound semiconductor with wide direct bandgap of 3.3 eV at room temperature. ZnO exhibits good piezoelectric, photoelectric and optical properties, and might be a good candidate for an electroluminescence device such as ultra-violet (UV) laser diode. ZnO films also have potential applications for surface acoustic wave devices and low loss wave-guides. In this study, ZnO thin films have been fabricated on Si(100) substrate at temperatures of 300 - 400°C by pulsed laser ablation using a KrF excimer laser with the wavelength of 248 nm. During the deposition, a remote microwave O₂/N₂ plasma as a radical source was used in order to improve the optical quality of the film. We have investigated the effect of the radical source on the optical and structural properties of ZnO films using photoluminescence (PL). From the PL measurement, all the films fabricated with and without using radical source showed a typical luminescence behavior with the two emissions of a narrow UV and a broad visible band. It is reported that the visible luminescence of ZnO was caused by the defects, such as oxygen vacancies and zinc interstitials in the films. As the partial pressure of N₂ in the microwave O₂/N₂ plasma increased, the intensity of UV luminescence increased and that of visible luminescence decreased. From this result, it was suggested that the injection of the nitrogen radicals into plasma plume might be effective to reduce the visible luminescence of ZnO and to improve the optical quality of the film.

TF-WeP5 XPS Study of First Stages of ZnO Growth and Nanostructure Dependence of the Polarisation Effects at ZnO/SiO₂ and ZnO/Al₂O₃ Interfaces. *A.I. Martin-Concepcion, F. Yubero, J.P. Espinos, A.R. Gonzalez-Elipe, CSIC-Univ. Sevilla, Spain, S. Tougaard, University of Southern Denmark*

A critical characteristic of nanoparticles and, in general, nanomaterials, is the overweighing importance of the surface and interface layers in respect to the bulk because of the small size of the aggregates (in 3D) or thickness of the layers (in the case of 2D) that constitute the nanomaterial. The present paper reports about the characterization of these interface layers in the particular case of ZnO/MO (MO: Al₂O₃ and SiO₂) interfaces by using X-ray photoelectron spectroscopy (XPS). Careful experiments have been performed consisting in the deposition of ZnO material on SiO₂ and Al₂O₃ substrates. Several samples were produced and characterized in situ. The nanostructure of the first stages of growth of the ZnO deposited was determined by Tougaard -peak shape analysis of several photoelectron peaks from both substrate and overlayer to check the consistency of the determined growth mechanisms. Thus the actual nanostructure of the growing ZnO films were carefully determined. In addition, the chemical interaction at the ZnO/MO interface was monitored by following the variation of the Auger parameter of the Zn atoms, as the amount of ZnO deposited was increased. Thus, the changes of the Auger parameter of the ZnO atoms have been correlated with the actual nanostructures formed by the ZnO deposits. From this information, a model is presented that accounts for the changes in the electronic parameters determined by XPS as a result of bonding and polarization interactions at the interface.

TF-WeP6 Fabrication of CuIn_{1-x}Ga_xSe₂ Thin Film Solar Cells by Two-step Process. *H.K. Song, Seoul National University, Korea, S.G. Kim, Kyungwon University, Korea, H.J. Kim, Seoul National University, Korea, S.K. Kim, K.H. Yoon, Korea Institute of Energy Research, Korea*
Photovoltaic (PV) modules based on CuIn_{1-x}Ga_xSe₂ polycrystalline thin films have been promising candidates as an effective absorber material for solar cells. It has been reported that solar efficiency over 17% by co-evaporation of elemental sources (Cu, In, Ga, and Se) through three-stage

process. But this process is difficult to scale-up for a large-manufacturing system. So we prepared $\text{CuIn}_{1-x}\text{Ga}_x\text{Se}_2$ thin films by 2-step process that can be easily scaled-up to industrial process. Metallic precursors were deposited on Mo coated soda-lime-silicate glass by DC magnetron sputtering followed by selenization process using Se vapor in an evaporation system. Ga was incorporated by using a Cu-Ga(23 at.%) alloy target. CdS buffer layer, intrinsic and n-type ZnO layer and Al top contact electrode were deposited by CBD (chemical bath deposition), RF sputtering system, and Ebeam evaporator system, respectively. Fabricated $\text{CuIn}_{1-x}\text{Ga}_x\text{Se}_2$ thin film solar cells have relatively smooth surface morphology and mono-crystalline chalcopyrite phase. The efficiency of solar cell are measured by solar simulator and the characteristics of $\text{CuIn}_{1-x}\text{Ga}_x\text{Se}_2$ films are analyzed by X-ray diffraction (XRD), Auger Electron Spectroscopy (AES), Electron Probe Micro Analysis (EPMA), and Field Emission Scanning Electron Microscope (FESEM).

TF-WeP8 Structural and Optical Properties of the Novel Semiconducting Alloy Films $\text{Cu}_x\text{Cd}_{1-x}\text{Te}$ O Grown by rf Sputtering. *J. Santos-Cruz, G. Torres-Delgado, R. Castanedo-Pérez, O. Jiménez-Sandoval, CINVESTAV, Mexico, B.S. Chao, Energy Conversion Devices, S. Jiménez-Sandoval, CINVESTAV, Mexico*

Current efforts towards understanding the degradation processes in CdS/CdTe heterojunction solar cells are strongly focused on the role of copper and oxygen in these two materials. We have studied the effects of incorporating both Cu and O in a controlled manner, during growth, on the structural and optical properties of CdTe films. When only Cu is introduced up to a concentration of around 3 at.%, the obtained material has a composition of the form $\text{Cu}_x\text{Cd}_{1-x}\text{Te}$ which does not present significant changes in its physical properties as compared to those of CdTe. However, when oxygen is incorporated in the chamber during the growth of the $\text{Cu}_x\text{Cd}_{1-x}\text{Te}$ films, the structural and optical properties may be varied significantly: depending upon the oxygen partial pressure, the structure of the films may be changed from polycrystalline to amorphous, and the optical band gap may present values between 1.4 and 2.8 eV. These results are addressed in terms of the chemical composition, structural properties and on the known behavior of copper and oxygen in the CdTe host.

TF-WeP9 Properties of Co-deposited ITO and ZnO Films Using a Bipolar Pulse Power Supply and a Dual Magnetron Sputter Source. *M.S. Hwang, H.S. Jeong, Y.W. Seo, ITM, Inc., Korea*

Multilayer coatings consisting of metal layers sandwiched between transparent conducting oxide(TCO) layers are widely used for flat panel display electrodes and electromagnetic shield coatings for plasma displays, due to their high electrical conductivity and light transmittance. The electrical and optical properties of these multilayer films depend largely on the surface characteristics of the TCO thin films. A smoother surface on the TCO thin films makes it easier for the metal layer to form a continuous film, thus resulting in a higher conductivity and visible light transmittance. ITO and ZnO films were co-deposited, using a dual magnetron sputter and a bi-polar pulse power supply, to decrease the surface roughness of the TCO films. The symmetric pulse mode of the power supply was used to simultaneously sputter an In_2O_3 (90wt%) : SnO_2 (10wt%) target and a ZnO target. We varied the duty of the pulses to control the ratio of ITO : ZnO in the thin films. The electrical and optical properties of the films were studied, and special attention was paid to the surface roughness and the crystallinity of the films.

TF-WeP10 The Effects of Substrate Temperature and Ion Flux on the Opto-electronic Properties of dc Magnetron Sputtered Aluminum-doped Zinc Oxide. *N.W. Schmidt, T.S. Totushek, W. Kimes, J.R. Doyle, Macalester College*

We present a study of the effects of substrate temperature and ion flux on the opto-electronics properties of reactive dc magnetron sputtered aluminum-doped zinc oxide (AZO). Near-substrate plasma density is varied using an unbalanced magnetron with external coils which allow variation of the ion-to-neutral ratio from 0.2 to 2. The substrates are electrically floating with a floating voltage of about -10 V, implying that the ions have 10 eV of energy upon arrival at the growing film. The ion flux is measured using cylindrical and flat plasma probes. Film quality is characterized by conductivity, visible transmission, x-ray diffraction, scanning electron microscopy, and Hall effect measurements. Film quality is found to be very sensitive to substrate temperature in the range of room temperature to 120 C, with transparency increasing and resistivity decreasing with increasing temperature. Film quality is also improved with increasing near-substrate plasma density up to 120 C. The best films have resistivities less than 0.0004 Ohm-cm with average transmission above 85% in the visible. Film quality maximizes in the range 120 - 150 C and then becomes independent of ion flux. The improvement in film quality observed with increasing ion flux at lower temperatures is similar to that found with increasing

temperature. However, careful calibration of the substrate temperature indicates that the beneficial effect of increased ion flux is not simply due to substrate heating, implying that kinetic or momentum transfer effects are also important during ion bombardment.

TF-WeP11 Electronic Properties of $\text{Cu}(\text{In,Ga})\text{Se}_2$ (CIGS)-Based Solar Cells. *J. AbuShama, Colorado School of Mines*

We examined the electronic properties of CIGS-based polycrystalline thin-film solar cells by Deep Level Transient Spectroscopy (DLTS) and Capacitance-Voltage (C-V) measurements. We prepared four CIGS thin films (by Physical Vapor Deposition) in the region where the film transitions from Cu-rich to In(Ga)-rich. Cu-rich sample exhibits a shallow majority carrier trap with an activation energy of 0.12 eV and another deeper trap with an activation energy of 0.27 eV. The shallow trap with a concentration of about $2.1 \times 10^{14} \text{ cm}^{-3}$ yields the dominant emission in Cu-rich CIGS in the observed temperature and frequency range. The In-rich sample has a shallow minority carrier trap with an activation energy of 0.12 eV. This trap with a concentration of $6 \times 10^{14} \text{ cm}^{-3}$ yields the dominant emission in In(Ga)-rich CIGS in the observed temperature and frequency range. The two samples show evidence of a deeper trap at higher temperature. C-V measurements showed that the carrier concentration around the junction of the cell changed as the film transitions from Cu-rich to In-rich. We see that the acceptor (donor)-like traps are dominant in the Cu(In)-rich samples. The transition from the Cu-rich to the In(Ga)-rich compositions causes an extensive transformation of intrinsic defects from acceptor-like traps (e.g. Cu on In(Ga) sites) to donor-like traps (e.g. In(Ga) on Cu sites).

TF-WeP12 Low Temperature Indium Tin Oxide Films Using Dual Magnetron Sputtering. *H.S. Jeong, M.S. Hwang, H.J. Lee, Y.W. Seo, ITM Inc., Korea, S.J. Kwon, Kyungwon University, Korea*

Recently, the needs of low temperature deposition processes for transparent conducting oxide(TCO) films on a plastic substrate are increasing. Flexible plastic substrates have been used in liquid crystal displays, organic lighting-emitting diodes, and organic EL displays. Indium tin oxide films were deposited in a horizontal in-line sputter system equipped with a pulsed dual magnetron sputter source[DC ~50kHz]. An ITO target of In_2O_3 (90 wt%): SnO_2 (10 wt%) has been used. The substrates(glass and flexible plastic) were cleaned by an O_2 plasma processes. The properties of ITO films such as electrical resistivity, optical transmission, and surface roughness were investigated with respect to O_2 partial pressure, pulse frequencies, and substrate temperature(room temperature ~ 150°C). Also, we will investigate the film structure and plasma contamination difference between the pulsed single magnetron and the pulsed dual magnetron sources by XRD and RGA, respectively.

TF-WeP13 High Rate Deposition of ZnO Thin Films by Vacuum Arc Plasma Evaporation. *T. Miyata, S. Ida, T. Minami, Kanazawa Institute of Technology, Japan*

Present requirements for zinc oxide (ZnO) thin films in various applications call for achieving further preparation cost reductions and higher deposition rates on larger area substrates. Recently, a newly developed vacuum arc plasma evaporation (VAPE) method providing high-rate film depositions on large area substrates has attracted much attention. In this paper, we describe the preparation of undoped and impurity-doped ZnO thin films on large area substrates by a VAPE method using oxide fragments as a low-cost source material. For example, the difficulty of preparing FZO thin films by sputtering deposition is well known. However, fluorine-doped ZnO (FZO) thin films suitable for transparent and conductive thin-film applications could be prepared. The film depositions were carried out under the following conditions: substrate, large area glass; substrate temperature, RT to 450°C; oxide fragments, sintered mixture of ZnO and ZnF_2 powders; pressure, 0.08 to 1 Pa; Ar and O_2 gas flow rates, 10 to 50 and 0 to 10 ccm; and cathode plasma power, 2.5 to 10 kW. A deposition rate of 150 nm/min and a resistivity on the order of $10^{-4} \Omega\text{cm}$ as well as a uniform distribution of resistivity and thickness on the substrate surface were obtained for FZO films deposited at a pressure of 0.15 Pa, an Ar gas flow rate of 20 ccm, a cathode plasma power of 4.5 kW and a substrate temperature of 250°C. In film depositions by VAPE, the rate was easily controlled by varying the cathode plasma power. It should be noted that deposition rates from 55 to 375 nm/min were obtained in ZnO films deposited at a deposition pressure of 0.25 Pa with a cathode plasma power that ranged from 2.5 to 10kW.

TF-WeP14 Photocatalytic Properties of TiO_2/WO_3 Bilayers Deposited by Reactive Sputtering. *T. Takahashi, H. Nakabayashi, J. Tanabe, N. Yamada, Toyama University, Japan*

Titanium dioxide (TiO_2) has attracted considerable attention because it is known to have strong activity as a photocatalyst under irradiation of ultraviolet rays. However, TiO_2 photocatalyst can only react slightly to solar

energy because of its optical band gap E_G smaller than 3.2 eV (λ of 380 nm). So, it is desirable for most solar energy applications to have new materials that can highly react strongly to visible-light. In this study, the bilayers composed of TiO_2 and WO_3 films have been prepared by reactive sputtering at room temperature. At first, TiO_2 films with a thickness of about 1.4 μm have been deposited on glass-slide substrates at working gas pressure P_W of 1 mTorr and a mixed atmosphere of Ar and O_2 , using the facing targets sputtering with dc power supply. Then WO_3 films have been deposited onto as-deposited TiO_2 ones at various P_W ranging from 1 to 8 mTorr in an atmosphere of mixture gas of 80%Ar and 20% O_2 , using RF magnetron sputtering. The gaseous methyl alcohol by using the bilayers have been decomposed under irradiation with artificial sunrays of wavelength λ ranging from 330 to 750 nm for 2 h at room temperature. The bilayers were successful in carrying out a photocatalytic reaction of the decomposition of CH_3OH into CO_2 and H_2O from measurement of infrared transmittance spectra. Its decomposition rate using the bilayers significantly increases, as compared with that using the monolayers of TiO_2 films. It is found that the bilayers can decompose CH_3OH under irradiation of only slight visible-light. Consequently, the bilayers deposited in this study have a good photocatalytic reaction and activate the decomposition of gaseous methyl alcohol.

TF-WeP15 Influence of Preparation Conditions on Structure and Properties of WO_3 Films Reactively Deposited by RF Magnetron Sputtering. *T. Takahashi, J. Tanabe, H. Nakabayashi, N. Yamada*, Toyama University, Japan

TiO_2 photocatalyst can only react slightly to solar energy because of its optical band gap E_G smaller than 3.2 eV (λ of 380 nm). So, it is desirable for most solar energy applications to have new materials that can highly react strongly to visible-light. Therefore, WO_3 films with E_G of 2.5 eV are very useful for the underlayer of TiO_2 photocatalyst. In this study, WO_3 films with thickness of 0.9-6.7 μm have been deposited on glass-slide substrates, using RF magnetron sputtering in an atmosphere of mixture gas of 80%Ar and 20% O_2 . The crystallographic and the surface structures and the optical properties of WO_3 films deposited at the working gas pressure P_W ranging from 1 to 8 mTorr have been investigated in detail. The as-deposited films showed dark metallic color as like as target at P_W of 1 mTorr. The as-deposited films were yellow at P_W of 3 mTorr. With further increase of P_W , the color of the films changed to pale yellow. From the X-ray diffraction patterns, the as-deposited films were polycrystalline crystallizing in the monoclinic or the triclinic crystal structure with high c-axis orientation perpendicular to the film plane. The optical transmittance of the films deposited at P_W of 1 mTorr is nearly zero. However, the transmittance of the films deposited at other P_W are larger than 70 % in the wavelength λ ranging from 500 to 900 nm. With decreasing λ to 400 nm, the transmittance steeply become zero. The λ at this absorption edge is longer than that in TiO_2 and comes in the visible region. The surface morphology of the films depends on P_W . As P_W increased, the surfaces of the films become rougher and grain sizes of the films also become larger. The WO_3 films deposited in this study may be available for the underlayer of TiO_2 photocatalyst.

TF-WeP16 Ti Target Characteristics of Medium Frequency Reactive Sputtering: Process Modeling Improvement and Experimental Verification. *Lai Zhao*, Tsinghua University, China, *S. Xu, C. Fan, W. Gao*, HVAC Technology (Group) Co. Ltd., China, *X. Hou, Liangzhen Cha*, Tsinghua University, China

Deposition of TiO_2 with reactive dual magnetron sputtering (DMS) is difficult to control due to its critical transition region of hysteresis curve caused by the high metallicity of Ti target. To stabilize the sputtering process, electrical characteristics of the Ti target is investigated in an on-line experiment. An improvement to the sputtering process modeling developed by S.Berg is proposed based on these experimental data. To better explain the hysteresis curve, it is found that the accumulation of positive argon ion charges on the oxidized target surface affects the electrical field and argon ion incident current density. Hence, the coverage of oxide component on the target will change correspondently. The changing argon ion current density due to charge accumulation is introduced to the equations. The simulated result fits well with the measured hysteresis curve.

TF-WeP17 Effects of Deposition Conditions on Step Coverage Quality in Metal-organic Chemical Vapor Deposition of TiO_2 . *S.Y. No, J.H. Oh, C.S. Hwang, H.J. Kim*, Seoul National University, Korea

Dielectric thin films including Ti element such as $(Ba,Sr)TiO_3$ (BST), $SrTiO_3$ (STO) have been investigated intensively by many researchers for next generation DRAM capacitor. Recently, the problem of cationic composition non-uniformity was reported when these multi-component films were deposited on patterned structure by metal-organic chemical

vapor deposition(MOCVD) method. To understand the problem of composition non-uniformity in multi-component films, it needs to know the step-coverage variation of each component film. In this study, the step coverage of TiO_2 thin films were investigated, which were grown on patterned Si substrates by liquid-injection MOCVD using $Ti(O-i-Pr)_2(thd)_2$ at substrate temperature ranging from 410°C to 500°C. The effects of various deposition parameters such as the chamber-wall and gas-line temperature, the source injection rate, the substrate temperature, solvents and deposition atmosphere on the step coverage quality were investigated and activation energy of deposition was also evaluated in each case. As the chamber-wall temperature increased from 230°C to 400°C, the step-coverage improved while degraded when gas line temperature was changed from 230°C to 400°C. With increasing the partial pressure of Ti source, the step-coverage improved slightly. When the substrate temperature was changed from 470°C to 410°C, the step-coverage quality enhanced, and the degree of variation in step-coverage was larger in oxygen-rich atmosphere than in Ar-rich atmosphere. Tetrahydrofuran(THF) and ethyl alcohol were used as solvents for Ti precursor dissolution and step-coverage is better when THF is used.

TF-WeP18 Raman Spectroscopy Measurement of TiO_2 Sputtered Films Changing Degree of Plasma Exposure. *T. Takahashi, H. Nakabayashi, J. Tanabe, N. Yamada*, Toyama University, Japan, *W. Mizuno*, Toyama Industrial Technology Center, Japan

The relationship between the Raman spectra and the crystallographic orientation of the TiO_2 films deposited at different working gas pressures have been investigated in detail. The TiO_2 films with thickness of about 800-2300 nm have been reactively deposited on glass-slide substrates at an atmosphere of Ar and O_2 mixture, using the facing targets sputtering. The maximum deposition rate of the film was 12.8 nm/min. The Raman spectra, and the crystallographic orientation of the films were measured using Raman spectroscopy, and X-ray diffractometry, respectively. Most of films deposited in this study were transparent and had anatase crystal structure, while some of them were semitransparent. The anatase phase of as-deposited TiO_2 films has revealed in the Raman spectra with a Raman shift of 145 cm^{-1} and the X-ray diffraction patterns. When the TiO_2 films have been deposited at the working gas pressures of 3 mTorr with increasing plasma exposure, the highest peak intensity with a Raman shift of 145 cm^{-1} steeply increased, while the X-ray peak intensity of A(220) with preferential crystallographic orientation also steeply increased, where A shows the anatase phase of TiO_2 . On the other hand, in the films deposited at the working gas pressures of 1 mTorr with decreasing plasma exposure, the Raman peak intensity at 145 cm^{-1} gradually decreased at the condition that the preferential crystal orientation changed from A(220) to A(101). This implies that the change in the Raman peak intensity at 145 cm^{-1} may be closely related to the change in the A(220) peak intensity. The A(220) peak was significantly higher than other peaks when the TiO_2 crystallites became larger regardless of the working gas pressure. Consequently, it was found that the Raman peak intensity at 145 cm^{-1} in as-deposited TiO_2 films were strongly affected by the plasma exposure related to the substrate position during film deposition.

TF-WeP19 Growth Morphology of Sputter Deposited Vitreous Titanium Dioxide Films. *J.D. DeLoach*, Texas Instruments, *R.S. Sorbello*, University of Wisconsin-Milwaukee, *G. Scarel*, Laboratorio MDM-INFM, Italy, *C.R. Aita*, University of Wisconsin-Milwaukee

Room temperature growth of a ceramic film usually occurs by coalescence of three-dimensional nuclei. This initial morphology leads to column formation. The boundaries between columns can be open and can have a different physiochemistry than the column interior. In this study, we use high resolution transmission electron microscopy and electron diffraction to study the growth structure of TiO_2 films. The films were sputter deposited at room temperature on $\langle 111 \rangle$ Si substrates from which the nascent SiO_2 layer had not been removed. The film thickness ranged from 250 to 700 nm. The films' atomic structure was vitreous, that is, had no long range order. Most of the films' volume was amorphous with short-range order characteristic of anatase Ti-O nearest neighbor coordination. The remaining volume consisted of both anatase and rutile nanocrystallites. The most striking morphological feature observed by HREM was a network structure encompassing both amorphous and nanocrystalline regions in all films. Isolated regions within this network were on the order of tens of nanometers, increasing in size with increasing film thickness. Suboxide rings on electron diffraction patterns indicate that the network may be conducting. We suggest that this network has a profound effect on the properties of as-grown TiO_2 films, in particular on their ultraviolet and infrared optical absorption behavior. A recent¹ infrared absorption-reflection study showed that the model dielectric function which best fit the experimental data was obtained by averaging the dielectric functions of weakly interacting TiO_2 regions of different orientations. This result was surprising because of the large polarizability of TiO_2 . Further analysis in the

present study using a Maxwell-Garnett approach shows that this dielectric function is consistent with TiO_2 units embedded in a conducting network.

¹G.S. Scarel et al. J. Appl. Phys. 91 1118 (2002).

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Schmidt, N.W.: TF-WeP10, **2**
Seo, Y.W.: TF-WeP12, **2**; TF-WeP9, **2**
Shidouji, E.: TF-WeP3, **1**
Shimizu, N.: TF-WeP4, **1**
Song, H.K.: TF-WeP6, **1**
Song, K.M.: TF-WeP2, **1**
Sorbelli, R.S.: TF-WeP19, **3**
Suzuki, T.: TF-WeP4, **1**

— T —

Takahashi, T.: TF-WeP14, **2**; TF-WeP15, **3**; TF-WeP18, **3**
Tanabe, J.: TF-WeP14, **2**; TF-WeP15, **3**; TF-WeP18, **3**
Torres-Delgado, G.: TF-WeP8, **2**
Totushek, T.S.: TF-WeP10, **2**
Tougaard, S.: TF-WeP5, **1**

— X —

Xu, S.: TF-WeP16, **3**

— Y —

Yamada, N.: TF-WeP14, **2**; TF-WeP15, **3**; TF-WeP18, **3**
Yanagisawa, T.: TF-WeP1, **1**
Yoon, K.H.: TF-WeP6, **1**
Yubero, F.: TF-WeP5, **1**

— Z —

Zhao, Lai: TF-WeP16, **3**