Thin Films and Surface Modification
Room Naupaka Salon 1-3 - Session TF-TuP
Thin Films and Surface Modification Poster Session I

TF-TuP-1 Effect of Ag Layer Thickness on the Transmittance and Conductivity of Transparent Antennas Fabricated Using ITO/Ag/ITO Structures*, **Yoji Yasuda**, Y. Saitou,* Tokyo Polytechnic University, Japan*; F. Koshiji,* tokyo polytechnic university, Japan*; T. Uchida,* Tokyo Polytechnic University, Japan

In recent years, research and development efforts have focused on the Internet of Things and next-generation communication systems. In these systems, antennas are ideally placed on the surface of the chassis to improve communication characteristics. Hence, to maintain the appealing design features of these devices and systems, optically transparent antennas using transparent conductive films such as indium tin oxide (ITO) are attracting attention. However, there is a trade-off relationship between the optical transmittance and conductivity of transparent conductive films, and it has been challenging to achieve a good balance between the two. Nevertheless, it has been reported that multilayer composites with a dielectric-metal-dielectric (DMD) structure, in which a metallic thin film (e.g., Ag thin film) is introduced as an intermediate layer, can simultaneously achieve high transmittance and conductivity. In this study, we evaluated the transmittance and conductivity of a DMD structure composed of ITO/Ag/ITO with respect to changes in the thickness of Ag in the intermediate layer, and investigated the effects of the transmittance and conductivity on the antenna characteristics following annealing treatment.

ITO/Ag/ITO transparent conducting films were deposited by varying the thicknesses of the Ag and intermediate layers using a facing target sputtering system. The films were annealed at 200–500 °C in air, and their optical transmittance and electrical properties, such as sheet resistance and carrier density, were evaluated. In addition, a monopole antenna of 20 mm length and 5 mm width was fabricated and its radiation efficiency was measured. It was found that with an Ag layer thickness of 7.5 nm, the transmittance and conductivity of the ITO/Ag/ITO film were approximately 69.8% and 7.8 × 10^5 S/m, respectively. When the transparent conducting film with an Ag film thickness of 7.5 nm was annealed at 200 °C, the transmittance and conductivity of the film increased to approximately 73.4% and 8.5 × 10^5 S/m, respectively.

TF-TuP-2 Extending the Lifetime of Plasma Torch Electrodes Using a Layer of Carbon Nanotubes*, **Alexandr Ustimenko**, V. Messerle,* Affiliation, Kazakhstan

The lifetime of plasma torch electrodes is critical, however it is usually limited to 200 hours. Considered in this paper the long life direct current arc plasma torch has the cathode life significantly exceeded 200 hours. To ensure the electrodes' long life a process of hydrocarbon gas (propane/butane) dissociation in the electric arc discharge is used. In accordance to this method, atoms and ions of carbon from near-electrode plasma deposit on the active surface of the electrodes and form a carbon condensate in the form of carbon nanotubes. It operates as “actual” electrode. To realize aforesaid the construction of a plasma torch using air as the plasma forming gas has been developed and tested. Propane/butane mixture is supplied to the zone of the arc conjunction to the copper water-cooled electrodes (cathode and anode). As a result inside the cathode cavity and internal surface of the anode medium of carbonic gas is formed. Linked with the arc in series, the magnetic coils 3 guaranty stabilization of the discharge on the electrodes. The processes of propane/butane molecules dissociation and carbon atoms ionization start with the rise in temperature. Arisen from ionization positive carbon ions deposit onto the electrodes surface under the influence of near-cathode decline in potential and form coating of the electrode condensate. This coating is “actual” cathode, deterioration of which is compensated by the flow of carbon ions and atoms. The coating thickness depends mainly on ratio of the flows propane/butane and air and the arc current. It is found that when power of the plasma torch was in interval 76–132 kW and propane/butane flow in range of 0.4–0.7 LPM thermal efficiency of the plasma torch reached 90%. At that mass averaged temperature on the exit of the plasma torch increased to 5000 K. The electrode condensate was examined using scanning electron microscopy, transmission electron microscopy and Raman spectroscopy. It is found that the electrode condensate is composite carbonic stuff made of carbon nano-clusters which consists mainly of single and multi-wall carbon nanotubes. The following parameters of the conducting nano carbon deposited at the cathode were determined: chemical composition, wt %: C 96.74–98.47, H 2.26–1.24, Cu 1–0.30; interplanar spacing, nm: 0.333 (100%), 0.207 (1%), 0.168 (5%); apparent density, 1.63 g/cm^3; and resistivity, <10^{-8} Ohm·m.

TF-TuP-3 Comparative Depth Analysis of Crystalline Phases in Copper Thin Films Using OrbiSims*, **Jong Sung Jin**, J. Sung,* Korea Basic Science Institute (KBSI), Republic of Korea

Copper thin films with different crystallinities of poly and single crystal were formed on sapphire with excellent crystallinity. The latest OrbiSIMS equipment was used to analyze the depth from the surface to the interface where the sapphire substrate is exposed, and the three-dimensional structure of various ions was confirmed. Three thin films with different crystallinities, including copper foil, were analyzed. The internal oxygen showed a clear difference in the relative content and distribution pattern between poly and single crystal.In addition, the behavior of aluminum ions contained in sapphire was different. Naturally, the distribution of copper ions, which are the main raw material, was also different.From the results of this study, we were able to simultaneously confirm the distribution of oxygen that can control the oxidation of thin copper films, the correlation with the crystallinity of copper, and the behavioral changes of ions using OrbiSIMS. We are confident that these observations will provide basic data for the modification of solid surfaces, such as the prevention of oxidation of copper surfaces and the coating of ions of other metals in the future.

TF-TuP-4 Surface Chemistry and Growth Characteristics of SiNx Films via Plasma-Enhanced Atomic Layer Deposition*, **Ilkwon Oh**,* Ajou University, Republic of Korea

Recent advancements in semiconductor applications have emphasized the growing importance of SiN_x due to its exceptional operational reliability.[1,2] In the scaling trends, the need to deposit gate spacers has underscored the significance of SiN_x atomic layer deposition (ALD), which offers uniformity and conformality, andthickness control at the Angstrom level. [3, 4] However, the role of Si precursor chemistry in growth and electrical characteristics of SiN_x films has not been fully explored. Understanding this relationship is crucial, as growth characteristics directly impact the electrical performance and leakage current behavior of SiN_x, which is vital for its effectiveness in electrical insulation applications. This study investigates the relationship between three different Si precursors and the electrical properties of SiN_x films.Three alkyl amine precursors, bis(tertiarybutylamino)silane (BTBAS), bis(diethylamino)silane (BDEAS), and NSi-01 were used for this study. The deposition was done on the substrate temperature of 200 °C with 60 MHz very high frequency (VHF) N_2 plasma as a reactant. Density functional theory (DFT) calculations, Monte Carlo (MC) simulations, and ellipsometry were employed to analyze the growth characteristics during ALD process. Additionally, the film quality evaluation was done by using X-ray photoelectron spectroscopy (XPS), and transmission electron microscope (TEM). The correlation between electrical and growth characteristics was investigated by fabricating and evaluating metal-oxide-semiconductor (MOS) capacitors. This study provides key insights into optimizing precursor selection to enhance device performance, demonstrating how the choice of ligands can significantly impact the leakage characteristics and reliability of SiN_x-based devices.

References [1] Kern et al, Handbook of Thin Film Deposition Process and Techniques, 2, 11-43 (2001). [2] Woochool Jang et al, Physica Status Solidi, 212, 2785-2790 (2015). [3] F. Koehler, IOP conference Series: Materials Science and Engineering, 41, 012006 (2012). [4] Stacey F. Bent et al. Materials Today, volume 17, number 5 (2014).

TF-TuP-5 Enhanced Oxide versus Nitride Selectivity in Area-Selective Atomic Layer Deposition of SiO2 Thin Films Combining Small Molecule Inhibitors with Atomic Layer Etching*, **Jiwoo Oh**, J. Lee, W. Kim,* Hanyang University, Korea

As the semiconductor industry advances towards complex multilayered devices with smaller features, area-selective atomic layer deposition (AS-ALD), a bottom-up method, has gained significant interest for its capability to enable precise and self-aligned deposition within specified areas, i.e., the growth areas. In this study, we primarily utilized small molecular inhibitors as vapor-phase deactivating agents to non-growth areas, due to their small size, high volatility, and ease of process integration into 3D structured devices. More particularly, this AS-ALD methodology is advantageous for manufacturing high aspect ratio SiO_2/SiN structures in V-NAND, where the reduction in tier size leads to cell-to-cell crosstalk between vertically downscaled SiO_2/SiN stacks. To mitigate this issue, it is essential to apply

AS-ALD of SiO_2 thin films on SiO_2 surfaces while preventing deposition on SiN surfaces. For this purpose, we employed a vapor-dosing process using silane-based small molecule inhibitors that chemo-selectively adsorb on -NH terminated surface groups of the SiN surface. Moreover, to further improve deposition selectivity, we periodically introduced a post-atomic layer etching step with atomic scale fidelity after a certain number of ALD SiO_2 cycles, which effectively removed SiO_2 moieties from the SiN surfaces. Finally, we achieved a deposition selectivity greater than ~10 nm on blanket SiO_2 and SiN substrates. The approach we present here contributes to the advancement of the manufacturing process for next-generation bottom-up 3D nanofabrication.

TF-TuP-6 Conductive Polymer Film Formation Using Plasma Process in Organic Solution According to Driving Power Condition*, **Hyojun Jang**, J. Kim, H. Tae,* Kyungpook National University, Republic of Korea

Plasma material process in an organic solution uses the interaction between plasma and solution substances. Plasma generated in the solution occurs a strong discharge through an electrode structure designed for ease of ignition. Therefore, most plasma materials processes conducted in solution have been used to form metal or carbon nanoparticles by erosion of electrodes or carbonization of solutions. Recently, studies have been reported on igniting plasma that limits strong discharges in liquid phases and controlling chemical activity (oxidation, reduction) according to the driving waveform. As a result, this method succeeded in creating π-conjugated polymer film, as well as nanoparticles with the molecular structure of the starting solution.

In this study, we conducted research on controlling properties of conductive polymer films synthesized by the plasma process in organic solution. Plasma characteristics affect the chemical activity of the material and consequently change the properties of the polymer film. Therefore, this process is performed using various driving power conditions to control the plasma characteristics. The electrical and optical characteristics of plasma and the changes in solution are analyzed according to driving power conditions. Moreover, the differences in the properties of conductive polymer films are investigated in detail. Finally, it is confirmed that the conductive polymer synthesized in this method has stable electrical properties in room condition.

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