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***, *Yuka Saitou,* Tokyo Polytechnic University, Japan*; Fukuro Koshiji,* tokyo polytechnic university, Japan*; Takayuki 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***, *Vladimir 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***, *Ji Yeong 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***, *Jeongbin Lee, Woo-Hee 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***, *Jae Young Kim, Heung-Sik 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.

TF-TuP-7 UV Light Extinction Imaging Method for Monitoring Inkjet-Printed Organic Layer in Thin Film Encapsulation Process, ***Jun Young Hwang***, *Jun Ho Yu, Heui Seok Kang,* Korea Institute of Industrial Technology, Republic of Korea*; Dal Won Lee, Gyu-Young Yun,* LG Electronics, Republic of Korea*; Seong Woo Lee,* Poongsan System Co., Ltd., Republic of Korea

Organic thin layers are highlighted as crucial components of flexible and printed electronic products due to their ability to provide mechanical flexibility in various applications, such as flexible displays and wearable electronics. The thickness and uniformity of these layers are crucial factors that influence surface planarization, mechanical stress relief, and the enhancement of optical performance. Therefore, accurate measurement of their thickness distribution is essential. In this study, the two-dimensional thickness distributions of spin-coated and inkjet-printed organic microlayers on glass substrates, which are used in optically transparent resin for displays and thin film encapsulation for flexible OLEDs, were quantitatively and qualitatively measured using UV light extinction imaging method. Quantitatively, the organic materials tested absorbed 40 to 50% of light with a wavelength of 300 nm through a layer with a thickness of 3 to 4 μm. Consequently, a measurement error of less than a few nanometers could be achieved through image overlay and pixel binning. Qualitatively, this non-destructive, non-contact two-dimensional measurement method enables immediate and intuitive analysis of the thickness distribution or surface waviness of the coated layer.

TF-TuP-8 Room–Temperature Ferromagnetism Observed in Graphene Oxide Fabricated by AFM Lithography, *Bae Ho Park,* Department of Physics, Konkuk University, Republic of Korea*;* ***DaYea Oh****,* Deparment of Physcis, Konkuk University, Republic of Korea*; Duk Hyun Lee,* Department of Physics, Konkuk University, Republic of Korea*; Wondong Kim,* Korea Research Institute of Standards and Science, Republic of Korea*; Jun Woo Choi,* Center for Spintronics, Korea Institute of Science and Technology, Republic of Korea

Graphene is typically considered to be a nonmagnetic material with long spin lifetime and transport distance. The potential to induce magnetic properties in graphene by various methods has generated significant interest since it would enable the development of novel spintronic devices where charge and spin manipulation could be combined. Recent works have predicted the formation of ferromagnetic order in graphene with point defects or functionalization. Ferromagnetic signals at room temperature have been observed for graphene or graphite with point-defects produced by various methods. However, there are debates on (1) the role of possible contamination and (2) the mechanism responsible for the strong interaction required for the formation of ferromagnetic order. According to a more recent report, point-defects in graphene only produce spinhalf paramagnetism, and the ferromagnetic order observed in previous studies was caused by the presence of small amounts of magnetic impurities. In the case of functionalized graphene, it has been reported that the ferromagnetic order is predicted for the oxidized graphene layer where C atoms have C–OH, C–O–C, or C=O bonds, and for the semi-hydrogenated graphene sheet. Although the existence of ferromagnetic order below 100 K in the n-doped graphene oxide layer has been experimentally confirmed with superconducting quantum interference device measurement, the possibility of magnetic contamination was not examined strictly.

Here, we investigate magnetic properties of graphene oxide flake that have been locally oxidized using atomic force microscopy (AFM) lithography. This approach reduces the possibility of magnetic contamination. Our Raman spectroscopy analysis reveals that the graphene oxide contains crystalline defects or disorders and differs from the pristine graphene in terms of its atomic structure. Using magnetic force microscopy measurements, we observe that the graphene oxide has a net magnetization pointing out of the surface plane. Furthermore, our magneto-optical Kerr effect data show small but clear hysteresis loops with non-zero remanent magnetization. We also conduct x-ray magnetic circular dichroism (XMCD) photoemission electron microscope measurements and identify remarkable asymmetry in carbon K edge spectra, which strongly suggests that the observed ferromagnetic order in the graphene oxide layer is intrinsic. A careful analysis of XMCD signals depending on the oxidized condition reveals the effects of chemical states of carbon atoms on the formation of ferromagnetic order in the graphene oxide.

TF-TuP-9 Reactive Ion Etching of Contact Hole for LTPS Process Using Low Global Warming Potential Gas, ***Jun Won Jeong***, *Jong Woo Hong, Geun Young Yeom,* Sungkyunkwan University (SKKU), Republic of Korea

The evolution of display technology has increased the demand for thinner, lighter, and higher-resolution panels in digital devices such as mobile phones, TVs, and laptops. In response to these demands, Thin Film Transistor (TFT) technology has emerged as a critical factor in determining display performance. In the early stages of display panel manufacturing, **a-Si (Amorphous Silicon) processes** were widely adopted due to their low cost and ease of mass production. However, the limitations of low electron mobility of a-Si processes limited the resolution and response speed of display panels. To overcome these limitation**, LTPS (Low-Temperature Polycrystalline Silicon)** technology was introduced. [1-2] LTPS TFT uses the excimer laser annealing (ELA) for crystallizing silicon at lower temperatures, therefore LTPS achieves significantly higher electron mobility than a-Si process. [3] Consequently, LTPS has become an essential technology for high-performance displays. In the context of next-generation electronic devices, optimizing the contact hole etching process for LTPS is critical. This requires the development of new etching gas mixtures that exhibit enhanced etching characteristics, including high etch rates, minimal sidewall and underlying layer damage, and anisotropic etch profiles. This study compares the Perfluorocarbon (PFC) gas A and low global warming potential hydrofluorocarbon (HFC) gas B, analyzing the etch characteristics and proposes optimization process to enhance the etching process in LTPS.

In gas A, as the flow rate increased, the etching rates of SiO_x, SiN_x, and a-Si all increased. The etch selectivity between SiO_x and SiN_x slightly decreased, while the selectivity between SiO_x and a-Si showed minimal change. In contrast, in gas B, as the flow rate increased, the etching rates of SiO_x, SiN_x, and a-Si decreased slightly. The etch selectivity between SiO_x and SiN_x slightly decreased, while the selectivity between SiO_x and a-Si showed a steep increase.

Author Index

Bold page numbers indicate presenter