Advanced Surface Engineering
Room Hall D - Session SE-TuP
Advanced Surface Engineering Poster Session

SE-TuP1 Room Temperature Bonding of Polymer and Silicon Wafer using Vacuum Ultraviolet Surface Activation, ***Yoshihiro Fujiwara***, *T. Utsunomiya, T. Ichii, H. Sugimura,* Kyoto University, Japan

Vacuum ultraviolet (VUV; $\lambda < 200$ nm) light and active oxygen species generated by VUV light chemically introduce polar functional groups to the surface of organic materials, which are related to adhesive property and wettability. In our previous research [1][2], we investigated the VUV decomposition and chemical conversion of the chemisorbed self-assembled monolayers (SAMs) and polymers surfaces. Using the VUV treatment under the atmospheric pressure, we have succeeded in bonding of Cyclo-olefin polymer (COP) films, which is a nonpolar hydrocarbon polymer, and in bonding between the polymer film and metals such as copper and aluminum at temperature lower than the glass transition temperature of each polymer. However, because of the surface roughness, thermal stress and the presence of intermediate oxide layer, the bonding mechanism is still unclear. In this research, we carried out the surface activated bonding of COP and silicon(111) single crystal wafer as a model surface with atomic-scale flatness. The atomically flat surface enables us to bond different materials at room temperature. Bonding condition without roughness and thermal effects is desirable to reveal the effectiveness of VUV treatment of the surface. A bond strength test was conducted to elucidate the effect of surface modification and bonding conditions such as VUV-irradiation distance, VUV-irradiation time, terminal functional groups of SAMs.

References:

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SE-TuP2 Improvement in Organic Solvent Resistance of Cyclo-Olefin Polymer by Coating with Silica-like Thin Film, ***Taiki Kanzawa***, *T. Utsunomiya, T. Ichi, H. Sugimura,* Kyoto University, Japan

Cyclo-olefin polymer (COP) is an amorphous polymer and has the great optical properties like silica glass.[1] Therefore, COP is suitable for microfluidic devices with the optical detection. However, COP is not durable to many organic solvents such as toluene and ether. For utilizing COP to wider range of application fields, this problem must be solved.

Several methods for fabricating the silica-like thin film on polymer substrates have been reported.[2,3] We optimized the coating methods to improve organic solvents resistance of COP. Vacuum ultra-violet (VUV) light of 172 nm wavelength was used in order to photochemically activate the hydrophobic surface of COP plate. Then, tetramethylcyclotetrasiloxane (TMCTS), which has similar component to silica, was chemisorbed onto VUV light-irradiated COP surface by vapor phase deposition. Finally, the sample coated with TMCTS thin film was irradiated by using VUV light again.

The X-ray photoelectron spectroscopy (XPS) and the attenuated total reflection Fourier transform infrared spectroscopy (ATR-FT-IR) measurements clearly indicated that TMCTS thin film was converted to silica-like thin film after VUV light-irradiation. Then, we dropped some organic solvents onto the sample coated with silica-like thin film. After evaporation, there were no traces of osmosis, showing the no permeation of organic solvents to bulk polymer. These results showed that coating with silica-like thin film greatly improved the resistance to organic solvents.

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SE-TuP3 Microstructure and Properties of (ZrHf)N Thin Films Deposited by Sputtering at Room Temperature, *N.N. Chu,* ***Yu-Wei Lin***, *C.-N. Hsiao,* ITRC, National Applied Research Laboratories, Tawain, Republic of China

This study investigated the microstructure and properties of nano-crystalline (ZrHf)N films on Si substrate at room temperature. (ZrHf)N films were prepared by reactive magnetron sputtering based on our previous optimum coating conditions (substrate temperature, system pressure, nitrogen flow etc.) for HfN and ZrN thin films. Based on the early studies, metal nitride coatings have attracted attention for good mechanical properties, hardness up to 30 GPa. In the study, we should have a generalized definition for substitutional solid solution. The addition of Hf into ZrN (or addition of Zr into HfN) forms the substitutional solid solution ZrHfN (or HfZrN). Different ratios of Hf/Zr will form various structure for $(Zr_xHf_{1-x})N$ with interesting properties, and many characteristics, such as nanostructure and hardness remain to be studied further. Characterizing the structure and properties of single ZrHfN layer coating with the different ratio of Hf-Zr to find out the optimum processing parameters, and further to tailor a variety of surface coating applications is the objective of this project.

SE-TuP4 Nanopatterned ZnO on Si-based Materials via Decoupled Ion Beam Modification and Metal Co-deposition, ***Zachariah Koyn***, *B. Holybee, J.P. Allain,* University of Illinois at Urbana-Champaign

Ion beams have been shown to create nano-scale surface patterning on polycrystalline thin metal films, including ripples and dots [1,2]. Additionally, oxygen ion beams have been shown to induce fluence-dependent surface oxidation on metal surfaces [3]. This work seeks to unravel the directed irradiation synthesis of metal oxide thin-films and nanostructures, specifically ZnO, with irradiation-driven mechanisms on dissimilar, polymer-based substrates via in-situ, in-operando high-pressure XPS. This examines the dual effects of oxygen irradiation as a means to both oxidize and pattern metal thin-films at ambient temperatures. This represents a scalable process in growing and functionalizing metal-oxide thin-films on polymers, which are sensitive to the high temperatures required in thermal oxidation processes. Recent work utilized a single ion beam to simultaneously irradiate and sputter deposit metal impurities on Si, creating nanostructures [4]. The work here decouples these processes by using two ion beams to independently control the metal deposition and surface modification fluxes and energy distributions. The ratio of these fluxes is the primary tool used to explore the creation and control over size and shape of nanostructures. Beam energies of 500-1500 eV are used at ambient temperatures to protect the substrate, with an inert beam used for metal sputter deposition and both inert and reactive (O_2^+) normal incidence beams used for surface modification. Both Si and PDMS substrates are explored with fluences of 1E16–1E18 ions/cm^2. Surface chemistry is monitored in-operando in the new Ion-Gas-Neutral Interactions with Surfaces (IGNIS) facility. XPS is performed at pressures up to 5 mTorr, allowing for the real-time monitoring of Zn deposition and oxidation. The ability to functionalize flexible, transparent substrates with metal-oxide nanostructures offers exciting applications in areas such as flexible and wearable electronics, gas sensors, biosensors, and photonics [5].

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SE-TuP5 Propagating Exothermic Reactions in Al/Pt Multilayers of Varied Stoichiometry, *D.P. Adams,* Sandia National Laboratories*; R.V. Reeves,* Lawrence Livermore National Laboratory*; M. Abere,* ***Cathy Sobczak***, Sandia National Laboratories

Reactive bimetallic multilayers are a form of energetic material that can be ignited at a point and undergo rapid, exothermic, self-propagating reactions. Providing a burst of heat, these materials continue to find use for different joining, battery and fusing applications. Much has been learned about the properties of these materials, yet little is known about the compositional limits of reactivity. In this presentation, we describe the propensity of sputter-deposited Al/Pt multilayers to undergo rapid, self-propagating formation reactions. Reactivity has been evaluated across a broad range of stoichiometry (nAl:mPt) and layer periodicity. Experiments demonstrate self-propagating reactions in ~1.6 micron-thick Al/Pt multilayers when the molar ratio of reactants is in the range 4Al:1Pt to 1Al:4Pt. This rather large compositional range is characterized by different reaction rates and behaviors. High-speed photography shows that equimolar Al/Pt multilayers undergo the most rapid reactions with wavefront speeds as large as 80 m/s. Al- and Pt-rich multilayers react at reduced rates with speeds as low as 1 m/s. A previously developed, analytical method by Mann et al. (J. Appl. Phys. 1997) is utilized to reveal additional details of reactions in the various multilayers. Models that account for the reactant layer thicknesses, composition, the adiabatic temperatures, the flame temperatures, and the measured heats of reaction are used to predict wavefront speeds that closely match measured values. These results are further analyzed to extract information regarding the mass transport characteristics of reactant species.

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SE-TuP7 Time-resolved Ion Energies in the Pulsed Cathodic Arc Plasma from Composite Niobium-aluminum Cathodes*, Siegfried Zoehrer,* Montanuniversität Leoben, Austria*; A. Anders,* Lawrence Berkeley National Laboratory*; R. Franz,* Montanuniversität Leoben, Austria

Cathodic arc plasmas are utilized in industry to synthesize a wide variety of functional thin films and coatings. However, the plasma properties present during the deposition processes are not yet fully understood, in particular when composite cathodes are used.

For pulsed cathodic arc plasmas, it is known that the plasma properties like ion energies and ion charge states are time dependent, but the influence of the cathode composition is not much studied. We therefore recorded time-resolved ion energy distribution functions in vacuum arc plasmas from composite NbAl cathodes with the Nb/Al atomic ratios 75/25, 67/33 and 25/75, as well as from single-element Nb and Al cathodes. The mass and charge-state-resolved detection of ions was realized using a commercial mass-energy analyzer modified to allow us having a time resolution of 100 ns (Tanaka et al., 2015). Three dimensional data sets were obtained, where the intensity, that is proportional to the ion count rate, is displayed as a function of time and energy for Nb and Al ions with charge states up to 5+ and 4+, respectively.

Regardless of the cathode composition, the highest mean charge states and ion energies were observed in the beginning of the pulses. There is also a clear influence of the cathode composition. Namely, the fraction of higher ion charge states being significantly lower in the plasma from the composite compared to the single-element cathodes. The current results regarding the time dependence of the ion charge state and energy distributions represent a first step towards a comprehensive understanding of how the cathode composition is affecting the plasma properties.

Tanaka, K.; Han, L.; Zhou, X. & Anders, A. (2015), 'Adding high time resolution to charge-state-specific ion energy measurements for pulsed copper vacuum arc plasmas', Plasma Sources Science and Technology 24(4), 045010.

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