pressure plasmas the light emission takes place before the thermalisation of the rotational level population of the electronically excited state. Thus, the observed emission is a result of inelastic collisions and rotational mechanisms and the rotational level population of the electronic states which the upper electronic state of the chosen molecule band is populated from.

We used the first negative system of the nitrogen molecule ion for temperature determination in different kinds of low pressure discharges. The spectra were evaluated by fitting. We will show that the spectra can be fitted best assuming that they are composed of two contributions representing two populations of the nitrogen molecule ion with distinct different rotational temperatures. Thus, at least two excitation channels of the upper electronic state have to be considered. One excitation channel is the electron impact on the ground state of the neutral nitrogen molecule connected with ionisation and excitation. In this process the rotational level distribution remains essentially unchanged and the rotational temperature of the so generated molecule ions reflects the gas temperature. The second excitation channel is the impact of nitrogen molecules in high vibrational states on the ground state nitrogen molecule ions, which is connected with rotational excitation and thus the rotational temperature of the so generated excited molecule ions is much higher than the gas temperature.


In this study, the feasibility of fabrication of copper nano-wire for advanced interconnects was demonstrated. Various copper wires with a minimum diameter of 90nm by 180nm were used to characterize the resistance with cross-section area with the temperature range from 0°C to 180°C. For the smallest line, the resistivity was 2.65 times higher than the copper bulk value (1.76 Ω·cm). The proposed model, based on surface and grain boundary electron scattering, can explain the resistivity increase. In addition, a 2-D effect is taken into account, because the size dependency and conductivity only depend on size effects, but not on the thickness. Within the framework of Matthiessen's rule, a universal formula, which combines temperature and size effects, is proposed. Based on this model, a forecast down to the 22nm generation was conducted, the variation of Rs for various line width will be an important issue. It suggests some new design strategy and layout scheme is needed.


The TiAlCrN and TiAlCrN-Nanocomposite coatings were deposited by cathodic-arc evaporation with plasma enhanced deuterium. Chromium and Ti3Al2N alloy cathodes were used for the deposition of nanocomposite TiAlCrN coatings. The effects of bilayer thickness and chromium content on the microstructure and mechanical properties of nanocomposite TiAlCrN coatings were studied. The nanolayer thickness of the deposited coating was correlated with rotation of the substrate holder. In this study, field emission scanning electron microscope and X-ray diffraction using Bragg-Drezetano and X-ray photoelectron spectroscopy were performed to characterize the microstructure and stress of the deposited films. The composition and chemical bonding of deposited TiAIN, CrN and TiAlCrN coatings were evaluated by X-ray photoelectron spectroscopy and glow discharge optical emission spectroscopy. Hardness, Young's modulus and adhesion strength of the coatings were determined by nano-indentation and Rockwell indentation methods. It has been found that the structural and mechanical properties of the films were correlated with the addition of chromium and nanolayer thickness.


Nanometer scale multilayer materials exhibit a variety of interesting structural and mechanical properties, for example greater toughness and higher hardness as compared to the rule of mixture. For the purpose of understanding the fundamental aspects of phase stability and for exploring strengthening mechanisms in such composite structures, the TiAlN system was chosen for investigation. The crystalline structure of TiN in the system was investigated by X-ray diffraction and the equilibrium structure of TiN at atmospheric pressure is hexagonal wurzite, TiN crystallises in the fcc-NaCl, while the equilibrium structure of AIN at atmospheric pressure is hexagonal wurzite. Thus the formation of non-instructural multilayers is expected. Decreasing the bilayer thickness on the small range favors the stabilisation of fcc-AIN due to pseudomorphic effects and thereby to the formation of instructural layers and development of coherency stresses. In addition, AIN and TiN are inmiscible at low temperatures such that hard and stable interfaces are expected promoting large hardness enhancement at low temperature deposition. At higher deposition temperatures, however, substantial chemical reactions could occur leading to the formation of ternary alloy phases. These structural features play a major role on overall mechanical properties and fracture behaviour of multilayer thin films. By controlling the thickness of individual layers (2-50nm) and substrate temperatures (Room, 400°C, 800°C) a number of controlled microstructures were grown in reactive magnetron sputtering. The films were characterized using grazing incidence XRD, nanoindentation, and cross sectional TEM. Indentation induced crack modes and morphologies were also investigated using FESEM and AFM. The results will be presented and the results will be discussed in terms of characteristic features of magnetron sputtering deposition conditions together with different strengthening mechanisms operating in solid solutions and nanolayer materials relevant to AlN/TiN system.

BP-46 Microstructure and Mechanical Tribological Properties of Novel Multi-Component Nanolayered Nitride Coatings. Q. Yang, L.R. Zhao, National Research Council, Canada

Novel multi-component nanolayered nitride coatings, composed of alternating four layer coatings in a modulation period (A), i.e. TiN, Mo3N, ZrN and AlN, were synthesised using the unbalanced closed-field magnetron sputtering technique. The microstructural evolution and mechanical properties of the coatings were investigated over a wide range of the modulation period. X-ray diffraction studies indicated that at the smallest A of 1.8nm, all the layer constituents formed a single cubic B1 structure, with a lattice constant near the average of the individual constituent lattice constants. In addition, the layer period (2A) was found to be unimportant, the bilayer thickness to nm scale range favors the stabilisation of non-isostmctural phases. These structural features play a major role on overall mechanical properties of the films were correlated with the addition of chromium and nanolayer thickness.
In the other hand, the existence of the high-energy primary electrons of which the decay rates of the electron temperature and the electron density are decomposition can not occur. The important role of the nitrogen activity mechanism of biasing on the interfacial layer is also described in this paper. The temporal evolution of electron energy distribution function and plasma parameters in pulsed magnetron discharges, S.-H. Lee, J.-H. In, H.-Y. Chang, KAIST, South Korea, J.G. Han, Sungkyunkwan University, South Korea. Using a time-resolved Langmuir probe, the temporal evolution of electron energy distribution function and plasma parameters are investigated under various frequencies from 5 kHz to 50 kHz and various duty cycles from 10 to 90% at 20 kHz in unipolar pulsed dc magnetron discharge. With the substrate grounded, the measured electron distributions show a bi-Maxwellian distribution with higher-energy electron during the pulse-on, irrespective of the driving frequency. In the after-glow after the pulse-off, the decay rates of the electron temperature and the electron density are characterized by two characteristic decay times of the fast decay of order of few μssec and the slower decay of order of few tens μssec. On the other hand, the existence of the high-energy primary electrons of which energy reaches to a third of the cathode voltage is observable during few μssec after the pulse-off. These phenomena will be explained by considering the electron transport under the magnetic field. The constant-voltage mode at 20 kHz, the averaged electron temperature in the pulse-on period increases as the duty cycle is reduced, 4.1 eV at 10% and 2.7 eV at 90%. However, the averaged electron temperature weakly depends on the driving frequency in the present frequency range. From the detailed measurements of the electron energy distribution functions, the increased electron temperature is caused by the decrease of low-energy electrons and the increase of energetic electrons with decreasing the duty ratio. The formation of superhard nanocomposites nc-TiN/a-SiN coating with a high thermal stability and oxidation resistance was explained by strong, thermodymanically driven phase segregation. Later on, it was suggested that the segregation is of spinodal nature and, therefore, results in the formation of a stable nanostructure by self-organization (e.g.,), but this has been questioned by several researchers. In this paper we present thermodynamic calculations which clearly show that the second derivative of the free energy of the formation of the mixed TiSiN phase with the composition x is negative, i.e., it meets the condition of the spinodal nature of the phase segregation within the whole range of the pressure that was used during the deposition of these nanocomposites by Veprek et al. For the phase segregation in the ternary Ti-Si-N system, the results show that the phase segregation in the ternary Ti-Si-N systems is of spinodal nature at the nitrogen pressure typically used during the deposition of these coatings (i.e., about 1 mbar) in plasma CuV and 0.002 mbar for reactive sputtering) and deposition temperature of 550°C (823 K). Only at much lower nitrogen pressure and much higher temperature, the spinodal decomposition can not occur. The important role of the nitrogen activity during the deposition will be illustrated by several examples. The theoretical calculations are supported by experimental results available so far.

BP-51 Diffusion Barrier Performance of Amorphous/Nanocrystalline Ta-Zr-N Thin Films in Cu Metallization, Z.Z. Tang, J.H. Hsieh, S.Y. Zhang, Nanyang Technological University, Singapore. Thermally stable amorphous/nanocrystalline Ta-Zr-N diffusion barrier layer between Cu and SiOx/Si substrate was deposited by reactive co-sputtering. In the Cu/Ta-Zr-N/SiOx/Si system, a 50 nm thick Ta-Zr-N film can suppress penetration of Cu into SiOx substrate upon annealing up to 700°C without significant structure change and chemical reaction in the stack. At higher temperatures, amorphous/nanocrystalline Ta-Zr-N decomposes into crystalline TaN and ZrN during annealing. Cu atoms then diffuse into the substrate through the grain boundaries and formed copper silicide at the interface. In addition to the study of barrier property of Ta-Zr-N, the effect of composition on the formation of amorphous/nanocrystalline structure was also discussed. BP-52 Time Evolutions of Electron Energy Distribution Function and Plasma Parameters in Pulsed Magnetron Discharges, S.-H. Lee, J.-H. In, H.-Y. Chang, KAIST, South Korea, J.G. Han, Sungkyunkwan University, South Korea. Using a time-resolved Langmuir probe, the temporal evolution of electron energy distribution function and plasma parameters are investigated under various frequencies from 5 kHz to 50 kHz and various duty cycles from 10 to 90% at 20 kHz in unipolar pulsed dc magnetron discharge. With the substrate grounded, the measured electron distributions show a bi-Maxwellian distribution with higher-energy electron during the pulse-on, irrespective of the driving frequency. In the after-glow after the pulse-off, the decay rates of the electron temperature and the electron density are characterized by two characteristic decay times of the fast decay of order of few μssec and the slower decay of order of few tens μssec. On the other hand, the existence of the high-energy primary electrons of which energy reaches to a third of the cathode voltage is observable during few μssec after the pulse-off. These phenomena will be explained by considering the electron transport under the magnetic field. In the constant-voltage mode at 20 kHz, the averaged electron temperature in the pulse-on period increases as the duty cycle is reduced, 4.1 eV at 10% and 2.7 eV at 90%. However, the averaged electron temperature weakly depends on the driving frequency in the present frequency range. From the detailed measurements of the electron energy distribution functions, the increased electron temperature is caused by the decrease of low-energy electrons and the increase of energetic electrons with decreasing the duty ratio. The formation of superhard nanocomposites nc-TiN/a-SiN coating with a high thermal stability and oxidation resistance was explained by strong, thermodymanically driven phase segregation. Later on, it was suggested that the segregation is of spinodal nature and, therefore, results in the formation of a stable nanostructure by self-organization (e.g.,), but this has been questioned by several researchers. In this paper we present thermodynamic calculations which clearly show that the second derivative of the free energy of the formation of the mixed TiSiN phase with the composition x is negative, i.e., it meets the condition of the spinodal nature of the phase segregation within the whole range of the pressure that was used during the deposition of these nanocomposites by Veprek et al. For the phase segregation in the ternary Ti-Si-N system, the results show that the phase segregation in the ternary Ti-Si-N systems is of spinodal nature at the nitrogen pressure typically used during the deposition of these coatings (i.e., about 1 mbar) in plasma CuV and 0.002 mbar for reactive sputtering) and deposition temperature of 550°C (823 K). Only at much lower nitrogen pressure and much higher temperature, the spinodal decomposition can not occur. The important role of the nitrogen activity during the deposition will be illustrated by several examples. The theoretical calculations are supported by experimental results available so far.

BP-54 Silicon Nitride Films by Chemical Vapor Deposition in Fluidized Bed Reactors at Atmospheric Pressure (AP/FBR-CVD), J. Perez-Mariano, S. Borros, Institut Quimic de Sarria, Spain, J.A. Picas, A. For Env. Universitat Politècnica de Catalunya, Spain, C. Molinarios, Institut Quimic de Sarria, Spain. Silicon nitride thin films can be deposited by several chemical and physical methods. In this work we study the Chemical Vapor Deposition in Fluidized Bed Reactors at Atmospheric Pressure (AP/FBR-CVD) for the deposition of silicon nitride coatings on AISI316 steel. The unique thermal and transport properties of the fluidized bed minimize some of the limitations of conventional CVD methods, such as inhomogeneties that lead to variations in thickness, and sometimes difficulty in maintaining the substrate at uniform temperature. Additionally, the particles of the bed can be activated through alternating reaction steps to promote the formation in situ of highly reactive silicon-containing species and thus increase the deposition rate. It is suggested that these thin and very homogeneous FBR-CVD ceramic films could be used as a part of a multilayer strategy to build more sophisticated coatings. The coatings were obtained by the reaction of silicon tetrachloride and ammonia in a reducing atmosphere at temperatures in the range 700°C to 800°C. The composition and structure of the coating were determined by means of X-ray Diffraction (XRD), Scanning Electronic Microscopy (SEM), Energy Dispersive X-ray analysis (EDX), Infrared Spectroscopy (FT-IR), Glow Discharge Optical Emission Spectroscopy (GD-OES) and X-ray Photoelectron Spectroscopy (XPS). Silicon nitride films were amorphous and substoichiometric. We found that the deposition temperature has a great influence in their morphology and mechanical properties. An underlayer containing chromium nitride was found at the coating-steel interface. BP-55 Formation Behavior of Nano-Structured CrAlN Coatings by Cathodic Arc Plasma Deposition, S.S. Kim, Institute for Advanced Engineering, South Korea, J.G. Han, Sungkyunkwan University, South Korea. CrN coatings are successfully applied for various metal working molds and dies, for plastic manufacturing as well as for machinery parts. However, with a reported oxidation threshold temperature of 700°C, CrN coatings may be limited for oxidation resistant application at elevated temperature. For this reason, higher oxidation resistance than that of CrN coatings is required. It is well known that the TiAIN coatings have higher oxidation resistance because of the AI2O3 layer formation on the film surface at elevated temperature. In this study the Cr-Al-N films were deposited on the hot working tool steels (AISI H13steel) by cathodic arc plasma deposition (CAPD) process. The films were deposited at various substrate bias voltages of 0-400V and different target current ratio of chromium and aluminum and also different chemisorbed nitrogen gas flow. The Cr-Al-N films were evaluated by EDX as well as AES. The as deposited microstructure and morphology were studied by XRD and SEM respectively, and micro-knoop hardness tester was employed to measure a hardness of the CrAlN films. Preliminary results indicated that the structural characterization of the Cr-Al-N films were strongly depended upon target current ratio of the chromium and aluminum as well as substrate bias voltage. Moreover, we found that the microhardness of the Cr-Al-N films were higher than that of the CrN film. Detail result on experiments such as oxidation property on progress will be presented. BP-56 Development of Thick, Hard Coatings for Erosion Protection Applications, R. Wei, C. Rincon, E. Langa, J. Arps, Southwest Research Institute. Next generations of turbine engine compressor blades, vanes and rotor blades in advanced aircraft and fluid pump impellers require very thick and very hard coatings. Ceramic and cermet coatings are best suited for harsh conditions in exhaust and diesel engines also require thick wear resistant coatings. To meet these needs, a novel plasma enhanced magnetron sputtering technology is being developed at SwRI to deposit thick and hard coatings (>30 μm). The technique combines conventional magnetron sputtering technique with externally generated plasma from which high current density can be obtained. By using heavy ion bombardment prior to and during deposition to increase the coating adhesion and modulate the film stress, thick TiN, CrN, and TiCrN coatings over 50 μm have been obtained. In addition to conventional hard coatings, thick nanocomposite coatings TiN/Si3N4 and...