Monday, May 11

9:30 a.m. HP-1 PVD Processes in High Aspect Ratio Features by HIPIMS

J. Weichart, M. Elghazzali, and S. Kadlec, OC Oerlikon Balzers AG, Balzers, Principality of Liechtenstein; and A.P. Ehiasarian, Materials and Engineering Research Institute, Sheffield Hallam University, Sheffield, United Kingdom

Invited 40 min. Talk

Highly ionized sputtering (HIPIMS) has been developed on rotating PVD magnetron sources for uniform deposition on 200mm as well as on 300mm single wafer tools for through silicon via (TSV) metallization in 3-dimensional packaging. The big advantage of HIPIMS is that the technology can be applied to regular PVD sources working at low target to substrate distance and by this providing a high transfer factor and a cost-effective process. The ionization degree and distribution of the plasma has been analyzed by atomic absorption spectroscopy, time and energy resolved mass spectroscopy and other methods. Processes have been optimized for Ti, Ta and Cu with RF bias applied on the substrate to accelerate the generated ions into deep silicon etched trenches and vias of very high aspect ratio (AR) up to 30:1 with vertical sidewalls. For Ti a bottom coverage of more than 20% in trenches with AR 10:1 and still more than 7% in trenches with AR 30:1 have been achieved at deposition rates of more than 28nm/s. Detailed studies in vias with scalloped sidewalls show the limitations of the ionized PVD process, the experiments are supported by Monte-Carlo-simulations of the deposition.

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10:10 a.m. HP-2 Effect of the High Ion Irradiation on the Structure, Tribological and High Temperature Performance of CrAlYN/CrN Nanoscale Multilayer Coatings Deposited by the HIPIMS Technology

P. Hovsepian, A.P. Ehiasarian, and Y. Purandare, Sheffield Hallam University, Sheffield, United Kingdom; R. Braun, DLR-German Aerospace Center, Cologne, Germany; and I.A. Ross, University of Sheffield, Sheffield, United Kingdom

The high degree of ionisation and high energy of the sputtered particles in the High Power Impulse Magnetron Sputtering Discharge (HIPIMS) provides excellent conditions for deposition of highly dense and very smooth coatings in particular due to the irradiation effects. These qualities were exploited in the newly developed nanoscale multilayer CrAlYN/CrN designed to meet the demands for highly oxidation resistant and wear resistant coatings. The coatings were produced by HIPIMS/HIPIMS technology where HIPIMS was employed both for adhesion enhancement surface pre treatment as well as for coating deposition. Cross Section Transmission Microscopy revealed extremely sharp interfaces between the individual layers in the nanolaminated material and almost no layer waviness. It was found that the coefficient of friction at room temperature was not affected strongly by the residual stress and retained low values of μ=0.56. High temperature tribometry revealed that after initial increase of the coefficient of friction to μ= 0.7 at 120˚C, the value drops to as low as μ= 0.47 for test temperature of 650˚C. At this temperature, extremely low wear coefficient of $Kc=1.8X10^{-17}m^3N^{-1}m^{-1}$ was measured. Quasi-isothermal oxidation tests carried out at 850˚C for exposure time of 1000 hours further confirmed the excellent high temperature behaviour of the coatings. In these conditions, HIPIMS/HIPIMS coatings showed by factor of 2 and 6 lower mass gain as compared to the UBM deposited coatings and uncoated TiAl substrate respectively.

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10:30 a.m. HP-3 Industrial Impact of HIPIMS+ Technology for Chromium Nitride Coatings

F. Papa, C. Strondl, I. Kolev, T. Krug, and R. Tietema, Hauzer Techno Coating BV, Venlo, The Netherlands

Chromium Nitride (CrN) is widely used for tribological and tool applications due to its toughness, abrasion resistance and chemical inertness. For tribological applications, it plays an important role in reducing fatigue and sliding wear. It is also used as an intermediate support layer for Diamond-like Carbon (DLC) coatings. For tools applications, it is used to resist cold welding and plastic adhesion as well as to provide impact fatigue resistance. The application determines which physical properties are needed in the CrN layer. High Power Impulse Magnetron Sputtering Plus (HIPIMS+) is a deposition technology in which a significant portion of the sputtered material is ionized. This offers many advantages with regards to the process window for depositing CrN. A comparative analysis of HIPIMS+ and closed field Unbalanced Magnetron Sputtering (UBM) coatings including x-ray diffraction results and mechanical properties will be presented. The potential advantages of HIPIMS+ deposited CrN coatings for tool and tribological applications will also be discussed.

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10:50 a.m. HP-4 HIPIMS-MPP Deposited Ta and Cr Coatings for High Temperature Wear and Erosion Applications

S.L. Lee, F. Yee, M. Cipollo, and S. Smith, U.S. Army ARDEC-Benét Laboratories, Watervliet, NY; and R. Chistyakov and B. Abraham, Zond Inc./Zpulser LLC, Mansfield, MA

HIPIMS-MPP technology is being investigated for the deposition of protective coatings for high temperature wear and erosion applications. MPP (modulated pulse power) is a variation of HIPIMS (high power impulse magnetron sputtering) that overcomes the rate loss issue through modulation of the pulse shape, intensity, and duration. In MPP, the pulse shape and duration and plasma perturbations directly affect the degree of ionization of the plasma. The typical pulse duration is in the range of 1-2 msec. In this study, tantalum and chromium films with thickness in the range of 10-100 microns are deposited using modulated pulse power. The films are deposited under floatings potential on surfaces of ASTM A723 steel components with complex geometry. The applied voltage pulse shape to the magnetron generated a high power pulse discharge and directly affected the degree of ionization of the sputtered material. The thickness and structure of each material was controlled by varying the output voltage pulse shape of the MPP plasma generator. The film structure, residual stress, and orientation are being investigated and film adhesion to the substrate is being tested. The deposition process and results from analysis of the films will be presented.

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11:10 a.m. HP-5 Pulsed Magnetron Sputtering of Metallic Films Using a Hot Target

J. Vlcek, B. Zustin, J. Rezek, K. Burcalova, and J. Tesar, University of West Bohemia, Plzen, Czech Republic

Pulsed magnetron sputtering of titanium films was performed using a directly water-cooled target and a hot target of 100mm diameter to investigate the effect of the target temperature on the sputtering process. The repetition frequency of the pulsed dc power supply was 10 kHz at a 20% duty cycle and an argon pressure of 0.5 Pa. Almost constant target temperatures during depositions with the hot target, being heated by the ion bombardment itself, were controlled by preset values of the average pulse current at a target power density in a pulse up to 340 Wcm^{-2}. The temperature fields of the target surfaces were measured using a FLIR ThermaCAM SC2000 thermovision system. It has been shown that an increase in the surface temperature (up to 1700˚C) of the hot target resulted in a rise in the deposition rate (up to 1.9 times) at a decreasing average pulse voltage (up to 1.5 times) compared to the cooled target with the same average pulse target current density (up to 0.33 Acm^{-2}). The effects of the secondary electron emission and thermoemission on the discharge characteristics, and of an enhanced sputtering, sublimation and evaporation on the deposition rate will be discussed.

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11:30 a.m. HP-6 Magnetron Configuration to Enhance Deposition Rate in High Power Impulse Magnetron Sputtering

A.P. Ehiasarian and A. Vetushka, Sheffield Hallam University, Sheffield, United Kingdom

High power impulse magnetron sputtering (HIPIMS) discharges are known to produce a highly ionised metal deposition flux with ionisation degree of up to 70%. It has been shown that the geometry of magnetic fields near the substrate can strongly influence the spatial distribution of film thickness. This research shows that varying the magnetic field strength at the cathode can influence the deposition rate without affecting uniformity. The magnetron's magnetic field was changed in a way that the shape of magnetic field near the substrates remained constant while the size of magnetic trapping tunnel near the target and the maximum tangential component Bt reduced. By decreasing Bt from 50 mT to 17 mT, the specific deposition rate of Cr increased from 270 to 360 $nmh^{-1}kW^{-1}$. Since the peak and average discharge power were maintained constant, the total peak plasma density remained constant at $9x10^{11}cm^{-3}$ as measured by Langmuir probes. The metal ion-to-gas ion ratio was high at 1.5:1 as measured with energy-resolved mass spectrometry. The ratio was maintained high for magnetic fields down to Bt = 25 mT and was associated with a dense film microstructure. As the field reduced to very low values of Bt = 17 mT, the metal ion-to-gas ion ratio dropped to 1:1 and the film microstructure developed well defined columns.

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11:50 a.m. HP-7 Mass/Energy Analysis of a Modulated Pulse Power Plasma Compared to a DC Plasma

W.D. Sproul, Reactive Sputtering, Inc., San Marcos, CA; J. Lin, J.J. Moore, Z. Wu, and X. Zhang, Department of Metallurgical and Materials Engineering, Colorado School of Mines, Golden, CO; R. Chistyakov and B. Abraham, Zpulser LLC, Mansfield, MA; and A. Rees, Hiden Analytical, Ltd., Warrington, United Kingdom

An energy/mass analyzer was used to characterize the plasmas during modulated pulse power (MPP) and conventional DC sputter deposition of Cr and reactive CrN films in a two-cathode closed field unbalanced magnetron sputtering system. Experiments were run with the different types of power applied to either just one of the cathodes or to both of the cathodes. The mass analysis detected Cr plus one, Ar plus one, and Cr plus two ions. The intensity of the Cr plus one ions when the MPP power is used is significantly higher compared to when DC power is used. As the peak power and the average power of the MPP pulse were increased, the intensity of the ions also increased in the closed field condition as it did when DC power was used. The energy analysis revealed that the average energy for the Cr and Ar plus one ions is about 2 eV and that the energy distribution is very small. There is a slight high energy tail to the ion energy distribution, but there is almost a mono-energetic source of ions from the MPP sputtering process.