Hard Coatings and Vapor Deposition Technologies Room On Demand - Session BP

Hard Coatings and Vapor Deposition Technologies (Symposium B) Poster Session

BP-1 Investigation of Ionized Density Fraction in Reactive Hipims, ***Katarína Bernátová (kbernatova@mail.muni.cz)***, Masaryk University, Czechia

In High Power Impulse Magnetron Sputtering (HiPIMS), high plasma density is achieved by focusing the applied power into the short pulses with a duty cycle of around 2%. Discharge properties, such as a density of sputtered species, are strongly nonlinearly dependent on the reactive gas supply influencing properties as well as the stoichiometry of the deposited layers.

In our study, the effect of nitrogen gas admixture on the temporal evolution of discharge current, voltage, pressure, and ionized density fraction of sputtered species in the HiPIMS process is analyzed. The ionized density fraction is estimated from the sputtered titanium atom and ion absolute ground state number densities both near the target surface and near the substrate region. For the determination of sputtered species density, a well-established spectroscopic method based on effective branching fractions was utilized.

Three regimes within the hysteresis curve were investigated and compared: metal, transition, and compound regime. In both, target and substrate regions, after the pulse ignition, the nonzero value of titanium atom density is always detected, indicating the presence of residual particles originating from the preceding pulse. Near the target, in the metal regime, the Ti atom density increases through the pulse, causing enhanced argon rarefaction near the target. From the quarter of the pulse, the concentration of Ti ions is always higher than Ti atoms and the ionized density fraction is most pronounced around middle of a pulse. With the nitrogen gas addition, the ionized density fraction increases, despite the overall Ti atom and ion densities decrease. In the substrate region, the evolution of Ti atom and ion densities changes, as the distance from the target is increased, therefore the transport time of particles to the measured area is higher. Furthermore, when operating in the transition and compound regime the pressure increases, resulting in even stronger delay of particle transport. Due to argon rarefaction near the target in the metal regime, Ti atoms travel towards the substrate where they are accumulating over the second half of the pulse. In contrast, in the transition and compound regime, the sputtering is not effective, and the transport is strongly delayed, therefore the Ti atom and ion densities are decreasing through the pulse. Here, the ionized density fraction is again enhanced with nitrogen gas admixture.

BP-2 Increasing Oxidation Resistance of Reactive Magnetron Sputtered ($Al_vCr_wNb_xTa_yTi_z$)N Thin Films by Si-alloying, ***Andreas Kretschmer (andreas.kretschmer@tuwien.ac.at)***, TU Wien, Institute of Materials Science and Technology, Austria*; K. Yalamanchili, H. Rudigier,* Oerlikon Balzers, Oerlikon Surface Solutions AG, Liechtenstein*; P. Mayrhofer,* TU Wien, Institute of Materials Science and Technology, Austria

High-entropy alloyed nitrides are promising materials for hard coatings. One major drawback is a lack of oxidation resistance in most coatings, which limits high-temperature applications in ambient conditions. In this work we report a method to increase the oxidation resistance of these materials.

($Al_vCr_wNb_xTa_yTi_z$)N coatings were formed in a cubic (c) solid solution in thin film form by reactive magnetron sputtering in N_2-atmosphere using a powder metallurgically prepared metal target (Plansee) with nominal composition of 20 at% of each element. Si was alloyed by placing different numbers of pieces (about 2x2x0.4 mm^3 each) of Si on the cathode racetrack during deposition.

We measured the oxidation resistance of the coatings by placing the samples in a furnace in ambient air at 850 °C for 0.5, 1, 5, 10, 30, and 100 h. After these durations we extracted the samples from the hot zone and analysed them with X-ray diffraction, Energy-Dispersive-X-Ray-Analysis, and Transmission Electron Microscopy (TEM). After 100 h the oxide scales on coatings without and with Si were 2800 and 300 nm thick, respectively. Plotting the oxide scale thickness against the oxidation time reveals a parabolic oxide growth behaviour without Si, which changes to logarithmic growth with Si in the solid solution. This different behaviour can be explained with the oxide morphology, visible in TEM. Without Si, the oxide is porous, whereas with Si the oxide is separated into a dense inner region and a porous outer region.

Therefore, we can conclude that Si-alloying improves the oxidation resistance tremendously and may be applicable to increase the performance of other high-entropy nitride coatings in oxidative environments.

BP-3 Properties of Boron Carbide Thin Films Deposited by Pulsed Laser Deposition, ***Falko Jahn (falko.jahn@hs-mittweida.de)***, *S. Weissmantel,* Laserinstitut Hochschule Mittweida, Germany

Boron carbide is the third hardest known material behind diamond or ta-C and cubic boron nitride (c-BN). Intensive contact of diamond or ta-C with ferrous materials lead to carbide formation and thus a chemical wear of the layer. Because of this, films of diamondlike carbon are not suited for applications e.g. as wear protective layers in steel processing. For cubic boron nitride on the other hand there is yet no successful deposition method that meets industrial requirements.

Boron carbide could be a promising compromise for these applications. Indeed, it doesn't reach the hardness values of ta-C or c-BN, but due to its better thermal and chemical stability it is suitable for ferrous materials.

Using Pulsed Laser Deposition (PLD) super hard coatings of boron carbide have been produced with a resulting indentation hardness up to 47 GPa which almost reaches the highest values reported so far. The substrate temperature during deposition has been varied between room temperature and more than 500°C. That temperature has been found to have the most impact on the mechanical properties of the coatings. The influence of the ablation fluence on the mechanical properties is shown although it is less significant. The produced layers show good film adherence properties but a very bad surface quality at layer thicknesses sufficient for practical applications and which is characterized by too many particulates and droplets.

Following, research results of applying an alternative boron carbide target are presented. This target is produced by depositing a several ten microns thick boron carbide layer on a steel substrate using PLD. The as deposited film is subsequently used as the new target for the deposition process and results in boron carbide thin films with a significantly better surface quality. Comparing these B_4C films to the first deposited ones resulting from commonly used targets it can be shown that both number and size of the droplets decrease.

BP-4 In-situ Analysis of B-doped Diamond Synthesis using Hot Filament CVD, ***Ryo Tanaka (s16a3083gp@s.chibakoudai.jp)***, *M. Takuya,* Chiba Institute of Technology Graduate School, Japan*; Y. Sakamoto,* Chiba Institute of Technology, Japan

B-doped diamond (BDD) has excellent electrochemical properties, and its application for electrochemical electrodes is progressing. BDD is prepared in substrates such as Si by hot-filament chemical vapor deposition (HFCVD), microwave plasma CVD, etc. BDD synthesis using HFCVD apparatus, source gases are decomposed by filaments heated to 2273≦[K] in pressure of between molecular flow and viscous flow. Therefore, complicated convection occurs between filament-substrate, it's difficult to control the B source flow between filaments and the substrate. In addition to control the flow of gases supplied into the chamber, it is necessary to feedback control based on measurements of reaction gas states.

In this study, reaction gas states were measured with quadrupole mass spectrometer (QMS) during BDD synthesis, it was explored relationship of electrical resistance to peak intensity of fragments.

BDD films were synthesized on Si substrates using HFCVD apparatus. CH_4-H_2-$B(OCH_3)_3$ gas mixture was used, with CH_4/H_2 flow rate: 1/50 [SCCM], $B(OCH_3)_3$ flow rate: 0.025 to 0.150 [SCyCM]. Pressure was 4.0 [kPa]. Filament temperature was 2273≦ [K]. Synthesis time was 1 [h]. Reaction gas states were measured with QMS. Deposits were evaluated by Raman Spectroscopy. Electrical resistances were measured by four-probe method.

As a result of measuring reaction gas states with QMS, it was confirmed that $B(OCH_3)_3$ fragments of $(OCH_3)^+$, $BH(OCH_3)^+$ and $B(OCH_3)_2^+$. These peak intensities decreased during synthesis, so, it was recognized that can be measured the $B(OCH_3)_3$ with QMS. There was correlation between decreased electrical resistance and increased peak intensity of $(OCH_3)^+$ up to $B(OCH_3)_3$ flow rate 0.100 [SCCM]. In the case of $B(OCH_3)_3$ flow rate exceeded 0.100 [SCCM], electrical resistance indicated constant value. Supersaturated of B and O occurred on the surface of the substrate and electrical resistance of CVD diamond became constant value.

In conclusion, it was confirmed that controlling electrical resistance of BDD was suggested by in-situ analysis of reaction gas states with QMS.

BP-5 Behavior of Partially Oxidized Metal Targets, ***Jiri Houska (jhouska@kfy.zcu.cz)**, T. Kozak,* University of West Bohemia, Czech Republic

We investigate the oxidation of a wide range of metal surfaces by ab-initio calculations. The metals of interest span from transition metals (Sc, Y, La, Ti, Zr, Hf, V, Nb, Ta, Cr, Mo, W) through noble and post-transition metals (Cu, Ag, Au, Zn, Cd) to the main group (Al) [1,2]. We go through a wide range (up to 329 per metal) of distributions of O atoms on a partially oxidized metal surface. First, we focus on the qualitative information whether the preferred distribution of O atoms is heterogeneous (stoichiometric oxide + metal; e.g. Al or La), homogeneous (substoichiometric oxide; e.g. Ti or Zr), homogeneous at low surface oxygen coverage and heterogeneous at high surface oxygen coverage (e.g. Sc or Y), etc. This is of crucial importance for the quantities such as secondary electron emission coefficient, which correspond to a weighted average of those of stoichiometric oxide and metal only in the case of heterogeneous oxygen atom distribution. Second, we correlate these qualitative results with the known formation enthalpies of oxides of various compositions. Third, we provide the quantitative values of adsorption energies corresponding to the energetically preferred O atom distribution for various partial coverages of various metals by O. We find that the dependence of adsorption energy on the surface oxygen coverage can be decreasing (e.g. Al or La), increasing (e.g. Ti or Zr), concave (e.g. Sc or Y), etc. These data also include the information about the maximum stable surface oxygen coverage (nonzero but lower than 100% for Cu, Ag, Zn, Cd). Fourth, we demonstrate one use of these results by presenting Monte Carlo simulations of sputtering. Fifth, we utilize the theoretical results in order to explain the experimental results, such as the time dependence of the magnetron voltage during sputter cleaning of oxidized metal targets (monotonic e.g. for Al but non-monotonic e.g. for Ti).

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BP-6 Phase Formation, Thermal Stability and Mechanical Properties of Nb-B-C Thin Films Prepared by Magnetron Sputtering Using a Combinatorial Approach, ***Stanislava Debnarova (408573@mail.muni.cz)**, P. Soucek, V. Bursikova,* Masaryk University, Czechia*; S. Mraz, M. Hans, J. Schneider, D. Holzapfel,* RWTH Aachen University, Germany*; P. Vasina,* Masaryk University, Czechia

The performance and lifetime of a tool can be significantly improved by the use of an appropriate protective coating. The most commonly used materials for these applications are ceramic-based coatings, favoured due to their high hardness. However, these coatings are inherently brittle which enables the spreading of cracks and coating failure. Therefore, new materials are being explored, which would combine the hardness of ceramics with a degree of ductility.

Ab-initio calculations have predicted that such a combination of properties could be present in a crystalline X_2BC material where X is a transition metal such as Mo, Ti, V, Zr, Nb, Hf, Ta or W [1]. Out of this group, only crystalline Mo_2BC has been successfully prepared and studied so far. There have been attempts to prepare a W2BC phase but these remain unsuccessful due to the near-zeroenthalpy of formation of this material. However, these studies have shown that the X-B-C system exhibits interesting mechanical properties even in an amorphous state [2, 3].

This study focuses on the Nb-B-C system as Nb_2BC is predicted to have a lower enthalpy of formation. The coatings have been prepared by magnetron sputtering from 3 targets using a combinatorial approach. A wide range of compositions has been studied and evaluated in regard to their structure and mechanical properties. As thermal and oxidation stability is a vital requirement for protective coatings, the studied coatings have been annealed up to 900°C in argon and up to 1000°C in an Ar/O_2 gas mixture. The study examines the effect of annealing on the structure and mechanical properties of the coatings.

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BP-7 Mechanical and Tribological Performance of V-C-N Coatings Deposited by RF Magnetron Sputtering, ***Akram Alhussein (akram.alhussein@utt.fr)**,* Universite de Technologie de Troyes (UTT), France*; L. Aissani,* Khenchela University, Larbi Ben M'Hidi University, Algeria*; C. Nouveau,* CER Arts et Metiers Paris Tech, France

Vanadium nitrides are known as hard and wear resistant materials widely used for cutting tools and other components. Vanadium carbides present excellent properties at high temperature, such as good wear resistance and high hardness. This work aims to evaluate the influence of the following deposition parameters on the structure, mechanical and tribological properties of V-C-N thin films deposited by RF magnetron sputtering: nitrogen partial pressure, $Ar-N_2$ deposition atmosphere and film thickness. VN, V–C-N coatings were deposited on silicon wafers and steel substrates and characterized with X-ray diffraction, XPS, EDS, SEM, nanoindentation and tribological tests.

Controlling the gas pressure in the deposition chamber is important to elaborate the desirable coatings (good adhesion and performance). It has been found that compared to the VN system, the VC-N films showed a smooth surface and the films deposited at 0.06 Pa presented the best mechanical and tribological properties: highest hardness of 26.1 GPa and lowest friction coefficient of 0.42 [1].

The Variation of nitrogen percentage in the deposition camber (10 - 20%) and the film thickness (0.26 – 2.5 µm) influenced significantly the film structure, hardness and wear resistance. Multiple phases of V2N and VN were formed and the thick films containing more nitrogen were slightly dense compared to the thinner ones [2].

Keywords: *Vanadium carbonitride thin films, PVD, microstructure, mechanical properties, tribological performance.*

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BP-8 Radiation Stability of nc- ZrN/a-ZrCu Multilayered Films after He Implantation, ***Grégory Abadias (gregory.abadias@univ-poitiers.fr)**,* Institut Pprime - CNRS - ENSMA - Université de Poitiers, France*; V. Uglov, S. Zlotski, I. Saladukhin,* Belarusian State University, Belarus

The development of a new generation of nuclear reactors requires the use of materials and coatings with high radiation resistance. It's necessary to create materials with a large number of sinks for point defects, such as dislocations, grain boundaries, and interphase boundaries to achieve this goal [1-2]. One of the most promising materials with the large number of grain boundaries are nanocrystalline coatings, for example nc-ZrN, formed by vacuum arc deposition [3]. Nanocrystalline coatings with crystalline/amorphous interfaces (such as nanocomposite and multilayered nc-MeN/a-Si_3N_4 systems) exhibit a high radiation tolerance along with crystalline/crystalline systems, due to amorphous nanolayers associated with excellent defects absorption capability [4-5]. In this paper, the idea of replacing amorphous a-Si_3N_4 layers with amorphous a-ZrCu metal layers is proposed.

The work is devoted to the study of the elemental and phase composition, surface morphology and microstructure of the nc-ZrN/a-ZrCu multilayer systems and their evolution after He implantation. Nanoscale nc-ZrN/a-ZrCu multilayers with elementary layer thickness of 5 nm/5 nm and 5 nm/10 nm with different Cu concentration in a-ZrCu layer were grown by reactive magnetron sputter-deposition from Zr and Cu targets at substrate temperature of 300°C. XRD, EDX, SEM and AFM investigation of as-deposited and after He ion irradiation (40 keV and doses up to 1E17 cm^{-2}) of nc-ZrN/a-ZrCu multilayer systems were conducted.

XRD analysis confirms that multilayered films consist of nanocrystalline ZrN and amorphous ZrCu. It was found formation amorphous ZrCu in a wide range of Cu concentrations (up to 80 at.%).

The influence of the Cu composition (in the range of 20-80 at.%) in the ZrCu layers and thickness of individual layers (5 nm/5 nm and 5 nm/10 nm) of nc-ZrN/a-ZrCu multilayer on radiation stability of elemental and phase composition, surface morphology (blistering) and microstructure of films after He ion irradiation is discussed.

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BP-9 Physical and Mechanical Properties of Cr-Al-N and Cr-v-N Ternary Systems, ***Ahlam Belgroune (ahlam.belgroune@utt.fr)***, University of Technology of Troyes, France; *L. Aissani,* University of Abbes Laghrour, Algeria; *A. Alhussein,* University of Technology of Troyes, France

In the present work, ternary systems (Cr-Al-N and Cr-V-N) thin films were deposited on steel substrates by magnetron sputtering process. The effect of Al and V additions on the properties of the binary Cr–N system was evaluated. The morphology and surface topography of the coatings were investigated. The hardness and elastic modulus were measured by nanoindentation and the friction coefficient was determined by pin-on-disc tribometer.

We found that Al addition improved the mechanical properties of the Cr–N system (H= 27 GPa, E= 304 GPa) presenting a dense structure. Contrary, the V addition deteriorated the mechanical properties of films presenting rough surfaces (H= 10 GPa, E= 280 GPa). The friction coefficient of the CrAlN films slightly increased with rising Al percentage and varied between 0.42 and 0.61. For the Cr-V-N coatings, the friction coefficient was lower than those obtained for Cr-Al-N and Cr-N films. The wear resistance of Cr-Al-N and Cr-V-N coated steel substrates decreased with increasing Al and V contents.

Keyword: *Magnetron sputtering; Cr-Al-N; Cr-V-N; Cr-N; Hardness; Wear.*

BP-10 Understanding Residual Stress in Thin Films: Analyzing the Stress Evolution Using a Kinetic Model for Ag, Cu, Ni, Fe, Ti, and Cr, ***Zhaoxia Rao (Zhaoxia_Rao@brown.edu)***, *S. Berman,* Brown University, USA; *D. Depla ,* Ghent University, Belgium; *E. Chason ,* Brown University, USA

An analytical model for the evolution of residual stress in polycrystalline thin films is used to analyze numerous previously-reported wafer curvature measurements obtained for a variety of processing conditions and materials (Ag, Cu, Ni, Fe, Ti Cr). The model includes the effects of film growth kinetics by considering stress-generating mechanisms at the grain boundary that forms between adjacent grains as well as subsurface grain growth.Non-linear least-squares fitting is used to obtain a set of parameters for each material.Some of the parameters are material-dependent and are made to be the same for all the data for each material independent of the processing conditions; others are allowed to change with the processing conditions.The dependence of the fitting parameters on the material and processing conditions is compared with the behavior expected from the physical mechanisms in the model.

BP-11 Effect of Target Poisoning Ratios on the Fabrication of TiO_x Coatings Using Superimposed HiPIMS and MF System, *W. Chen,* Ming Chi University of Technology, Taiwan; *B. Lou,* Chang Gung University, Taiwan; ***Jyh-Wei Lee (jefflee@mail.mcut.edu.tw)***, Ming Chi University of Technology, Taiwan

Titanium oxide film is characterized by its clean surface, sterilization, good abrasion resistance and good corrosion resistance, which make it become a functional coating with a wide range of applications.The superimposed high power impulse magnetron sputtering (HiPIMS) and mid-frequency (MF) system (superimposed HiPIMS-MF) is a relatively new deposition system, which adds MF pulses to the off-time of the HiPIMS for higher deposition rate.In this study, a superimposed HiPIMS-MF system was used to fabricate the titanium oxide films. During the deposition process, a plasma emission monitoring (PEM) system was used to feedback control the target poisoning ratio of Ti target. Titanium oxide (TiOx) films grown at five different target poisoning ratios were deposited on single crystal silicon wafer, glass slide and AISI304 stainless steel plate substrates. The microstructure of thin film was examined by a field emission scanning electron microscope. The crystalline structure of thin film was analyzed by an X-ray diffractometry. The optical transmittance measurement of thin films was performed with a UV–vis spectrophotometer. The hardness, adhesion and tribological properties of TiOx films were evaluated by nanoindenter, scratch test and pin-on-disk wear test, respectively. The corrosion resistance of TiOx films in 0.1 M H_2SO_4 aqueous solution was examined by an electrochemical workstation. The influence of target poisoning ratios on the deposition rate, microstructure, transmittance, hardness, adhesion, wear and corrosion resistance of TiOx films were studied in this work.

BP-12 The Role of Oxygen Flow Rate on the Structure and Stoichiometry of Cobalt Oxide Films Deposited by DC Reactive Sputtering, ***Nilton Francelosi Azevedo Neto (nilton.azevedo@unesp.br)***, *L. Affonco,* São Paulo State University, Brazil; *C. Stegemann, D. Marcel Gonçalves Leite ,* Aeronautics Institute of Technology, Brazil; *J. Humberto Dias da Silva ,* São Paulo State University, Brazil

The cobalt oxide films were grown on amorphous silica (a-SiO_2) in order to investigate the influence of the oxygen gas supply on the stoichiometry, structure and orientation texture of polycrystalline cobalt oxide films. The films were grown by direct current (DC) reactive magnetron sputtering using a metallic Co target and different oxygen partial pressures by controlling the inlet flow rate (0.5 to 5.0 sccm) over a dominant argon atmosphere (40 sccm) keeping constant the deposition power (80 W) and the total working pressure (0.67 Pa). X-ray diffraction results evidence a strong influence of the oxygen flow over the film's stoichiometry and structure, where low oxygen flows (< 2.0 sccm) favor the formation of the rocksalt CoO phase, while higher oxygen flows (>2.5 sccm) favor the spinel Co_3O_4 phase formation. The coexistence of monoxide and tetraoxide phases is observed only for 2.5 sccm oxygen flow condition. Strain and orientation texture effects related to the oxygen partial pressure are also observed and discussed. Computer simulations indicate that low oxygen flow (<2.0 sccm) occur in the metallic regime, while higher oxygen flow favor the poisoned regime. Consistent with the simulations, cobalt emission (Co^I = 340.5 nm) from the plasma show a significant decrease while the oxygen emission (O^I = 777.3 nm) is significantly increased when the oxygen flow is increased.

BP-13 e-Poster Presentation: Bipolar HiPIMS for Tailoring Ion Energies in Thin Film Deposition, ***Daniel Lundin (daniel.lundin@liu.se)***, *R. Viloan,* Linköping University, Sweden; *M. Zanáška,* Linköping University; *H. Du,* Guizhou University, China; *R. Boyd,* Linköping University, Sweden; *T. Shimizu,* Tokyo Metropolitan University, Japan; *U. Helmersson,* Linköping University, Sweden

Bipolar HiPIMS, where a reversed positive pulse is applied to the target following the negative pulse, has promised great potential to solve challenges in growth of insulating thin films or when insulating substrates are used. In this mode of operation, a significant fraction of the ion energy distribution functions (IEDFs) can be shifted with an energy proportional to the magnitude of the applied reversed potential, U_{rev}. This is a consequence of the fact that a limited region of the plasma, near the cathode, experiences an increased plasma potential with a value close to U_{rev}. However, the ion energy gain and the distribution of energy in the accelerated populations can be affected by the magnetic field arrangement, the anode position and shape as well as the HiPIMS pulse configuration. These aspects are of great interest in the present contribution, where time- and energy-resolved ion mass spectrometry was performed in different discharge configurations to further understand the physics in bipolar HiPIMS discharges. Based on the features of the recorded IEDFs, optimized bipolar HiPIMS deposition processes for relevant material systems, such as aluminum oxide, were investigated to observe the effect of ion acceleration on the tailoring of the phase constitution during film growth.

BP-14 Nb-C Thin Films Prepared by DC-MS and HiPIMS: Synthesis, Structure and Tribo-mechanical Properties, ***Neus Sala (neus.sala@iqs.url.edu)***, *M. Abad,* Institut Químic de Sarrià, Universitat Ramon Llull, Spain; *J. Sánchez-López,* Instituto de Ciencia de Materiales de Sevilla, CSIC-Universidad de Sevilla, Spain; *J. Caro,* Eurecat, Centre Tecnològic de Catalunya, Spain; *C. Colominas,* Institut Químic de Sarrià, Universitat Ramon Llull, Flubetech S.L. , Spain

Nanostructured Nb-C thin films were prepared by direct current magnetron sputtering (DC-MS) and via high power impulse magnetron sputtering (HiPIMS). The films have been characterized in depth by XRD, GIXRD, SEM, AFM, EPMA and Raman spectroscopy. The mechanical properties have been measured by means of nanoindentation and the tribological properties by pin-on-disk test in ambient air.The wear tracks and the ball scars were analyzed by Raman spectroscopy in order to elucidate the

tribochemical reactions appearing at the contact and to determine the wear mechanism present in each specimen type. The obtained DC samples were very dense with tunable mechanical and tribological properties depending on the amorphous carbon (a-C:H) content incorporated in the coatings. The crystal and phase composition changed from pure nanocrystalline (formed by Nb_2C and NbC phases) to nanocomposite structure (NbC/a-C:H). The samples prepared by HiPIMS developed a marked columnar morphology with a NbC/a-C:H nanocomposite structure. Hardness values range from 11 to 20 GPa depending on the deposition technique and the amount of a-C:H soft phase present in the samples. The tribological properties of all the coatings were remarkably good when the carbon content was around 50 at. %. The formation of alubricant sp^2-rich C tribofilm between the ball and the coating during the pin on disk tests was observed by Raman spectroscopy, preferentially in the samples prepared by HiPIMS technique with higher C content.

BP-15 Impact of Stacking Sequence with InWZnOx/InWZnOy Bilayer Conductive Bridge Random Access Memory, ***Chih-Chieh Hsu (cchsu.06g@g2.nctu.edu.tw)***, *P. Liu, K. Gan, D. Ruan, Y. Chiu,* National Chiao Tung University, Taiwan*; S. Sze,* Naitonal Chiao Tung University, Taiwan

This work investigates the hybrid oxide devices with different stacking sequence of Cu/TiW/IWZOx/IWZOy/Pt memristor. Typical bipolar resistive switching can be observed in all CBRAM devices. The hybrid oxide device shows good non-volatile memory characteristics, such as endurance cycle, low operation voltage, data retention time and stable on/off ratio. The oxide stacking sequence can improve the endurance cycles to 104, retention time to 104s and more resistance state uniformity. These results have given a prospect for simple and fast method to optimize the oxide-based memory device.

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