Tribology Focus Topic
Room: Hall 3 - Session TR-ThP

Tribology Poster Session

TR-ThP1 Adhesion of Hard Coating on Neutral Nitrided Tool Steel Surfaces, *P. Abraha*, Meijo University, Japan, ***Takuma Matsuda***, Meijo UnUniversity, Japan

Hard thin films such as titanium nitride and titanium aluminum nitride films are widely used to improve the durability of cutting tools, punches, and dies that are extensively used in the manufacturing industries. In general, the hardness of hard coating films is about three to five times that of tool steel surfaces causing a remarkably high stress that would eventually lead to the detachment of the hard coating. One way of improving the adhesion of hard coatings is to increase the surface hardness of the tool steel, narrowing the gap, to maintain a reasonably stronger bondage.

In this research, neutral nitriding operation was performed on the SKH 51 tool steel surface before TiAlN coating. Neutral nitriding is a plasma process that allows only the neutral species to diffuse into the interstitial layer of the tool steel surface. The process delimits the formation of the undesirable brittle compound layer to a much higher treatment time while keeping the as-finished surface conditions. The scratch test was performed to provide a measure of coating/tool steel adhesion.

The results of our experiments show that in nitriding SKH 51 tool steel for 6 hours, the hardness of the tool steel surface was increased by about two times, 1400 Hv compared to the untreated sample (750 Hv). The scratch tests show that a well-defined failure of the coating occur at a higher critical load in tool steel samples that are neutral nitrided compared to samples without the pre-treatment. Our results demonstrate that neutral species based nitriding is effective for high adhesion of hard coating materials on tool steel surfaces.

TR-ThP2 Neutral Nitriding of Austenite Stainless Steel at Low Temperature, ***Jun Tamura***, *P. Abraha*, Meijo University, Japan

Stainless steels have very good corrosion resistance but the lower surface hardness poses marked limitation on the range of tribological applications that can be envisaged. Here plasma nitriding treatment was performed to improve the hardness without altering the corrosion resistance of austenitic AISI 304 stainless steels.

In nitriding the AISI 304 stainless steel, the passive Cr_2O_3 layer that protects the surface from corrosion is removed first as it hinders the diffusion of nitrogen species into the bulk of the stainless steel material. The removal of the passive layer was done by argon sputtering and the subsequent nitriding was performed in electron beam excited plasma apparatus under nitrogen and hydrogen atmosphere. The sample temperature was controlled at 400, 450, and 500 degree centigrade. Treated and untreated samples were characterized by means of morphological analysis, Vickers hardness measurements, optical microscope, and x-ray diffractometry.

The results of our experiments show that in neutral nitriding of stainless steel under low temperature, 400 degrees centigrade, the surface hardness increased to 780 Hv, more than two times, that of the untreated surface. Moreover, the cross sectional images show clear nitrogen expanded austenite layer without the formation of compound layer. Measurements of surface roughness and conditions of the surfaces were reasonably maintained. The above results indicate that stainless steels can be used as sliding or meshing mechanical parts in environments such as vacuum chambers and underwater machinery.

TR-ThP3 Non-Oxidized Metallic Transfer Film Formation Originated from Metallic Nanoparticles Embedded in Diamond-like Carbon under Sliding in Air, ***Takanori Takeno***, *H. Miki*, *T. Takagi*, *K. Adachi*, Tohoku University, Japan

This study clarifies the formation mechanisms of thin layer on the counter material when nanocompsite coatings consisted of nanoparticles and diamond-like carbon were sliding against steel ball in air. When low friction was obtained in such combination, thin metallic film was formed on the counter material. What we could find is that such metallic film does not contain oxygen less than the one coming from native oxidized surface.

Hybrid deposition system composed of CVD and PVD sources allows us to make nanocomposite structure based on diamond-like carbon (DLC) coatings. Thanks to magnetron sputtering system, target material in sputtering source is extracted as a form of nanoparticle, and its size varies depending on deposition condition and type of material. During sputtering process, hydrocarbon plasma is generated, and hydrogenated amorphous carbon phase is formed. Typical structure of the composite coatings is that nanometer-sized metallic particles are well dispersed in amorphous carbon host matrix. Friction tests are conducted under vacuum or dry conditions. Various analytical techniques including transmission electron microscope (TEM), secondary ion mass spectrometer (SIMS), Raman spectroscopy, Scanning Electron Microscope equipped with energy dispersive X-ray spectrometer (SEM-EDS), X-ray photoelectron spectroscopy (XPS) and Auger electron spectroscopy (AES).

Once iridium was selected as an inclusions in diamond-like carbon host matrix, Ir-containing DLC showed friction coefficient of less than 0.1 despite friction coefficients of Ir and DLC showed ~ 0.3. In-situ electrical contact resistance measurements revealed that such coating provides not only low friction coefficient but also low electrical contact resistance, several tens ohms. When low friction and electrical contact resistance was achieved, metallic thin film was formed on the counter material. EDS analyses revealed that chief material forming the metallic film is Ir. It could be understood that nanoparticles formed metallic thin film on the counter materials during friction. It is worth noting that such transfer film does not contain oxygen even friction tests were conducted under air. Same phenomena could be observed with Cu- and Ag-containing DLCs. Even for both cases, metallic transfer films were formed during friction tests, and we could not detect oxygen from the transfer by EDS. Possibly, tribochemical reaction occurred and oxygen from air reacts to carbon in DLC, then gas phase or wear particles of carbon-oxides were formed. Details on a possible chemical reaction between the coatings and air will be discussed at the conference.

TR-ThP4 Achieving Very Low Friction with Molybdenum Disulfide Nanoparticles Embedded into Hydrogenated Amorphous Carbon Coatings, ***Kazuki Ikoma***, *K. Adachi*, *T. Takeno*, Tohoku University, Japan

Solid lubricants are usually used at severe environment (ex. vacuum). Among these lubricants, MoS_2 is widely used for many mechanical systems and shows low friction by forming transferred layer with MoS_2 lamellar structure. However, one of the drawbacks of MoS_2 is that it must be kept in dry nitrogen condition to avoid oxidation of molybdenum-disulfide.

We have proposed amorphous carbon coatings containing Molybdenum disulfide (MoS_2-DLC) as a new solid lubricant. It is well known that amorphous carbon coating is used for a gas barrier coating decreasing gas permeability. So, we have made the coatings with nanocomposite structure that MoS_2 clusters with several nm in diameter are embedded in hydrogenated amorphous carbon (a-C:H) host matrix. It was reported that friction coefficient obtained by MoS_2 sliding against SiC ball decreased with increasing MoS_2 concentration It is worth noting that MoS_2-DLC with proper MoS_2 concentration showed lower friction than MoS_2 coatings. Further reduction of friction could be obtained by changing a deposition parameter leading to a modification of host matrix of amorphous carbon. Therefore, not only concentration of MoS_2 but also properties of amorphous carbon host matrix are very important for achieving low friction.

This study focuses on hydrogenated amorphous carbon host matrix to achieve low friction. Especially, deposition parameter that controls properties of carbon host matrix was changed to produce various amorphous hydrogenated carbon host matrix containing MoS_2 nano-clusters. After the friction tests, a thin transferred layer proving low friction is well analyzed by various analytical techniques including transmission electron microscope (TEM), secondary ion mass spectrometer (SIMS) and Auger electron spectroscopy (AES). It was clarified that thin transferred layer was composed of two phases. Dominant one contains mainly MoS_2 with lamellar structure. It is worth noting that there is very thin carbon-rich layer with ~ 5 nm between MoS_2-rich layer and the counter material of SiC, and carbon at thin carbon layer comes from carbon host matrix. Taking into account the selective transfer of carbon from the coating and the possibility that such carbon-rich layer becomes a kind of support for forming lubricious MoS_2 layer, friction properties could be controlled by the properties of carbon. In this study, formation mechanisms of such two-phase thin layer are clarified, first. Then, we try to achieve very low friction with low MoS_2 concentration with optimized phase of carbon phase in the coating. Finally, design guideline for achieving low friction utilizing MoS_2-DLC coatings is proposed.

TR-ThP5 Study of Wear-corrosion Mechanisms of CoCrMo Alloys Alone and Coated with TiAlN Coatings, ***Martin Flores***, *O. Jimenez*, Universidad de Guadalajara, Mexico, *E. Andrade*, Universidad Nacional Autonoma de México

The wear-corrosion phenomenon is present in biomedical alloys that are used in artificial implants to replace natural joints. This damage limit the service life of such implants, the hard coatings can improve the resistance to wear and corrosion. The coatings of TiAlN were deposited on CoCrMo alloys by magnetron sputtering. In this work we study the wear mechanism of the samples coated and alone in a simulated body fluid with an ion concentration similar to that in the human blood. The structure of coatings was studied by means of XRD and the composition by RBS and EDS techniques. The tribocorrosion behavior of CoCrMo alloys alone and coated with TiAlN coatings was studied in simulated body fluid. The tribocorrosion was performed using a ball on plate reciprocating tribometer, the tests were conducted at 37 °C of temperature. The loads used were between 0.5 N to 2N, the oscillating frequencies was 1Hz. The corrosion and tribocorrosion were studied using open circuit potential (OCP) and potentiodynamic polarizations. In order to study the wear mechanisms, the debris, the topography and composition of worn surfaces were analyzed by means of SEM and Raman spectrocopy. The coatings improve the corrosion and tribocorrosion resistance of CoCrMo alloys and change the wear mechanisms of the substrate.

TR-ThP6 Frictional Property Optimization of Metal Oxide Thin Films by a Combinatorial Optimization of Crystal Orientation for Tribology (COCOT) Technique, ***Michiko Sasaki***, *M. Goto, A. Kasahara, M. Tosa*, National Institute for Materials Science, Japan

Combinatorial technology has much attention as the effective method for the development of novel functional materials. Also, the combinatorial technique have been used as one of the analysis methods in tribology research.

In this study, we were performed crystal structure analysis by combinatorial optimization of crystal orientation for tribology (COCOT) technique at the sliding surface of after the friction measurement (while changing the load continuously) of metal oxide thin film such as ZnO and Cr_2O_3.

As a result, it is a correlation in the crystal optimization of the sliding surface and the counter ball materials had an effect on the friction coefficient of the thin films.

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