ABSTRACT

In the modern technology, tribologically suitable components and devices are important to increase the energy efficiency. It is possible when one can reduce the friction coefficient and wear of sliding components. The economic effectiveness can be achieved by better tribological system and therefore research in tribology is aimed at minimizing the energy losses resulting from friction and wear. In this view, hard coatings deposited by physical vapor deposition (PVD) are adequate solutions for increasing the work efficiency, lifetime of tools and components.

The present thesis deals with hard tribological materials γ-TiAl and coatings such as TiAlN, CrN/NbN superlattice, diamond like carbon (DLC) and nanocrystalline diamond nanowire (DNW) films. Various characterization techniques were used to study morphology, microstructure and chemical state of the materials. The thesis describes tribological properties of above mentioned hard coatings sliding against 100Cr6 steel, Al_2O_3 and SiC balls. It also describes friction and wear based on classified mechanisms and outlines material properties that influence the performance of sliding surfaces. Traditionally wear is associated with friction and wear mechanisms are classified as adhesion, abrasion, erosion, fatigue and oxidational.

Mechanical and tribological properties of γ-TiAl alloy, TiAlN, CrN, carbon based coatings of DLC and nanocrystalline DNW were reviewed. The importance of such hard coatings and critical application in machine and industries are highlighted. Moreover, tribological properties and evaluation of wear mechanism is introduced in the respect of microstructure and chemical behavior of the sliding interfaces. Various wear mechanism with different combination of sliding surfaces such as hard coating/soft ball and soft ball/hard coating is reviewed in order to understand the wear mechanism. The fundamentals of some of the characterization techniques used to study the mechanical, tribological, morphological, structural, and chemical properties of the coating and wear track is introduced.

Instrumented micro-indentation technique have been used to characterize the mechanical properties namely hardness and elastic modulus of γ-TiAl alloy. The recorded indentation curves and the related energetic properties were analysed in order to compare the Attaf energetic approach and Oliver-Pharr method. Moreover, tribological behavior of γ-TiAl alloy was studied by sliding against 100Cr6 steel, SiC and Al_2O_3 balls as counterbodies for friction pairs. The friction coefficient and wear rate was found to high when γ-TiAl alloy slides against Al_2O_3 and SiC balls. However, these values were less while sliding against steel ball. The wear mechanism is explained by the sliding combination of harder/harder system such as SiC/γ-TiAl, and Al_2O_3/γ-TiAl alloy. However, steel/γ-TiAl alloy acts as softer/harder sliding combination.

Tribological behavior of TiAlN coating were studied by sliding against 100Cr6 steel, SiC and Al_2O_3 as counterbodies for friction pairs. Two distinct types of wear modes such as oxidational and plastic deformation are investigated. It is shown that wear of metal debris tribochemically reacted with moisture available in ambient atmosphere and metal oxide formation which leads oxidational wear in TiAlN/steel sliding pair. In TiAlN/SiC sliding pair, low friction coefficient is measured and this is attributed to the formation of lubricious composite tribofilm. In contrast, TiAlN/Al_2O_3 pair shows high friction coefficient and wear mechanism is governed by plastic deformation.

CrN/NbN superlattice coating sliding against 100Cr6 steel, SiC and Al_2O_3 ball as counterbodies for friction pairs was investigated. The value of friction coefficient and wear rate was lowest ~0.01 and 2.6×10^{-7} mm^3/Nm, respectively, when coating slides against Al_2O_3 ball. In contrast, friction coefficient and wear rate is increased while sliding with steel and SiC balls. It is observed that the deviation in friction coefficient is described by mechanical and chemical properties of these balls. In this respect, hardness of Al_2O_3 and SiC ball is comparable but significant deviation in friction coefficient is observed. This is related to oxidation resistance of balls which is high for Al_2O_3 compared to SiC as evident by Raman analysis of the wear track. However, steel ball shows oxidational wear mechanism against CrN/NbN superlattice coating.

The tribological properties of DLC and nanocrystalline DNW films were investigated. A friction mechanism based on surface chemistry and mechanical properties of sliding interfaces such as DLC/100Cr6 steel, DLC/SiC and DLC/Al_2O_3 is studied. In DLC film, the high friction coefficient is governed by surface roughness of the sliding interfaces during initial sliding passes. However, for longer sliding cycles, the sliding interfaces get smoothened and magnitude of friction coefficient is reduced. Under these experimental conditions, carbonaceous transferlayer forms on the ball sliding surface.

Nanocrystalline DNW films was deposited in N_2 enriched microwave plasma enhanced chemical vapor deposition (MPECVD) system. As-deposited DNW film was treated in O_2 plasma which resulted in chemical and microstructural modification. The sheath of the nanocrystalline DNW is chemically constituted by amorphous carbon (a-C) and graphite (sp^2C-C) like bondings. However, nanowires transformed into ultra- small spherical grains after the O_2 plasma treatments. In this condition, a-C and sp^2C-C fraction get significantly reduced due to plasma etching. Oxidation and formation of functional groups increases on the surface and inside the wear track. The friction coefficient of O_2 plasma treated film showed super low value of ~0.002 with exceeding high wear resistance of 2×10^{-12}mm^3/Nm. Such an advance tribological properties is explained by passivation of covalent carbon bonding and transformation of sliding surfaces by van der Waals and hydrogen bondings. High surface energy and the consequent superhydrophilic behavior of film attributed to the formation of an adsorbate layer of above mentioned functional groups which acts as a lubricant.