Objective of the project

The main goal of the proposed project is the wear resistance properties increase of amorphous carbon (a-C:H) coatings by introducing metallic nano- particles (Cu, Nb, Ta, Zr, AgPt, and Ag) into their structure, simultaneously maintaining its very good biological properties.

Describe the basic research to be carried out

Pure amorphous carbon coatings are characterized by low friction coefficient as well as low-specific wear rates. However, the disadvantage are high compressive residual stress and inherent thermal stability what would limit the potential application of these type of coatings. Recently, in order to improve mechanical properties of coatings based on amorphous carbon, metallic nano-particles: Ti, W, Ag, Cr etc. are inserted.

In the frame of the proposed project a new group of metallic nano-particles will be introduced (Cu, Nb, Ta, Zr, AgPt, and Ag). Nano- particles will be applied to reduce residual stress as well as improve quality of adhesion of the coating to the substrate, maintaining high biocompatibility properties (by which pure a-C:H is characterized). Tribological and biological properties will be connected.

Coatings will be deposited using a novel hybrid PLD technique. It is a pulsed laser deposition method supported by a magnetron sputtering. The deposition will be done in the frame of the cooperation with foreign partner from Austria.

Detailed diagnostics of new coatings based on amorphous carbon will be carried out in the proposed project. Coatings will be subjected to mechanical tests (tribological, strength/ fatigue) and biological analysis. The tribological tests will include micro-hardness measurements, scratch adhesion test and ball-on-disc wear tests in ambient and elevated temperatures. The strength/fatigue tests will be based on cyclic applying of strength in tensile test. X-ray technique will be used in order to residual stress measurements of nano- composite coatings.

The biological analysis will consist in determining the quality of adhesion of eukaryotic cells, cytotoxicity, activation of the clotting and immune surface, together with confocal microscopy characterization.

The as deposited coatings, as well as after mechanical and biological tests will be subjected to complex microstructure characterization using scanning (SEM) and transmission electron microscopy (TEM). Analysis will be performed using a scanning microscope QUANTA 200 3D DualBeam and TECNAI G2 SuperTWIN FEG (200kV) Transmission Electron Microscope. Thin foils for TEM analysis will be prepared directly from places of interest (namely from the wear track or from crack), using focused ion beam technique (FIB; QUANTA 200 3D DualBeam), what is crucial in such type of analysis. The investigations will allow to determine bio-tribological wear mechanisms in nano and atom scale.

Present reasons for choosing the research topic

Nano- composite, amorphous carbon (a-C:H) based coatings have very good mechanical properties, such as low coefficient of friction, high wear resistance, and it is a biologically inert material (very good bio- material). Therefore, the properties of this material allow to be widely used in various branches of industry: in medicine, in aircrafts, in electronics.

However, the disadvantage of this material is high residual stresses. It is associated with low adhesive strength of the coating to the substrate, what limits their use.

Recently, in order to reduce residual stress and to increase the mechanical properties of the a-C:H coatings, metallic nanoparticles are implanted into their structure. Till now, much attention was mainly paid to improve mechanical properties of these type of coatings. However, amorphous carbon is also a very good bio-material.

In project, in order to improve properties of the coating, metallic nano-particles (Cu, Nb, Ta, Zr, AgPt and Ag) will be inserted into the a-C:H structure. Implanting by metallic nano- particles is an effective method to reduce residual stress and enhance adhesion of coating to substrate. Type of metallic nano- particles was selected not only to increase mechanical properties of a-C:H coatings, however also to maintain a sufficiently high bio- compatibility properties. The bio- compatibility aspect will be equally controlled with mechanical properties.

The elaborated in the frame of the proposed project coatings will be subjected to complex mechanical and biological diagnosis as well as detailed microstructure characterization by the use of X-ray diffraction and electron microscopy techniques. In case of positive project results, the subject connected with bio- tribological coatings basis on amorphous carbon implanted by metallic nano- particles, will be continued in the frame of application projects, what is in a good agreement with the National Science Center and National Center of Science and Development politic.