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Long-range effect of ion-implanted materials in tribological investigations

Budzyński P.[1)], Kamiński M.[1)], Pyszniak K.[2)], Wiertel M.[2)]

[1)] *Faculty of Mechanical Engineering, Lublin University of Technology, Nadbystrzycka 36, 20-618 Lublin, Poland*

[2)] *Institute of Physics, Maria Curie-Skłodowska University, Pl. M. Curie-Skłodowskiej 1, 20-031 Lublin, Poland*

Obtained microhardness results and the presence of radiation effects at a depth higher than the predicted range of implanted ions pointed to the presence of a so-called long-range effect. An attempt is made to determine the thickness of a layer with modified tribological properties by measuring the friction and wear factors. The authors of this study decided to explain the mechanism of the long-range effect. Tribological tests were performed on a pin-on-disc stand. The real thickness of a layer with implantation-modified tribological properties can be determined via tribological testing by measuring the wear trace depth when the value of friction factor and/or wear of the implanted sample is close to the value characteristic of the unimplanted sample. The prediction range of implanted ions RSRIM [μm] was estimated by SRIM. The presence of the long-range effect was confirmed for the steel grades AISI 316L, H11, Raex 400, Hardox 450 as well as for the alloys Stellite 6 and Ti6Al4V. The modified layer thickness determined by tribological testing is much higher (by 4.7÷16.7 times) than the initial range of the implanted nitrogen ions. The depth of changes in the tribological properties of the surface layer (due to the long-range effect) agrees with the nanohardness measurement result obtained for the steel grades AISI 316 and H11.

An analysis of the content of elements on the sample surface as well as in its wear trace and wear products was performed by X-ray spectroscopy (EDS and WDXS). Obtained results demonstrate that one of the causes of the long-range effect is the dislocation of nitrogen and carbon atoms in the zone of friction during the tribological test. The long-range effect was also be observed in Ti6Al4V alloy implanted with carbon atoms by ion beam assisted deposition (IBAD) using a beam of nitrogen ions with an energy of 120 keV.

The tribological test results demonstrate that the thickness of a layer with lower friction and wear factors is much higher than the initial range of implanted ions (atoms). Apart from the diffusion of radiation effects inside the sample, one can also observe the diffusion of the implanted ions of nitrogen and carbon, the latter being an alloying component of the tested steel. The dislocation of nitrogen and carbon atoms is caused by accelerated radiation diffusion and a higher diffusion coefficient resulting from a local temperature increase in the friction pair during the tribological test. The thickness of the modified surface layer depends on the applied test conditions such as the load exerted on the sample by the countersample.

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