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RESEARCH

Ion Implantation of Kryptonite Into the Surface Layer of Tool Steels

Ion implantation of Kryptonite in tool steels was provided for the very first time respecting the information we could find by internet. Implantation was done using the cyclotron installation of Nikola Tesla center in Vinca. Two different ion energies were chosen for implantation into two different tool steels – cold working steel and high speed steel. Surface modifications were investigated by atomic force microscopy – AFM. Coeficient of friction was measured with continuose increase of load. Some of the preliminary results were analyzed and presented.

Key words: *kryptonite,ion implantation,*

1. INTRODUCTION

Ion implantation is a relatively new technology for improvement of the quality of tool steels. There could be found 188 papers related to ion implantation of tool steels during the period between 1960-2005, taking in consideration only the scientificly oriented papers. Since 1978 industrial items exposed to ion implantation are under evaluation in order to assess their performance under normal production conditions.

Interesting results were published in 1984 [1] about tribological properties of various tool steels implanted with nitrogen in order to investigate practical applications of nitrogen implantation for the improvement of durability for the injection molds for plastics. The nitrogen ion implantation was performed with doses of (1-5) multiplied by 10^{17} ions cm^{-2} at 150 keV. Some later investigations pointed out interesting results about the influence of temperature on the effects of ion implantation [2].

Ion implantation shows significant influence on tribological properties of steel surfaces using implantation of diferent types of ions including metallic elements [3]. It has been shown that hardness and friction coefficient are dependent on the type of implanted ions, doses, type of substrate and implantation conditions. It is concluded that the increase in hardness and/or the decrease in friction coefficient play(s) an important role in improving the wear resistance [4].

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In the 1990's ion implantation became a feasible technique for obtaining improved wear resistance of production tools. However, basic knowledge of how and in which cases ion implantation is working at its best is not clear enough. It was found that increasing the dose of carbon implatation untill $2x10^{18}$ions/cm^2 could increase wear resistance of steel dramatically.

However, at the same time the influence of the implantation dose of nitrogen or titanium show different results compared to implantation of carbon ions [5].Ion implantation has specific problems if the substrate is tool steel. Its appears because of the complex material structure related to presence the different types of primary carbides. In that sence, segnificant results are shown in paper [6], where the effects of implantation of N with low energy and high current density on M2 tool steel were investigated. It is shown that N implantation at 1 keV and 2 mA cm^{-2} can increase the hardness of the steel in either condition, but does not improve the wear resistance of the fully hardened material. Strengthening and hardening are induced through enrichment of the matrix that bonds hard $(Fe,Cr)_3(W,Mo)_3C$ and V_4C_3 particles with an iron nitride phase that appears to be predominantly ε-$Fe_{2+x}N$. In order for ions to be implanted their energy must be great enough to carry them through any barriers that may exist on a surface.

Advances in the last decade are oriented on industrial treatments using ion beams, but with new equipment designs and the development of new techniques. Simultaneously, much effort was focused on the search for new applications in order to exploit the possibilities of conventional high-energy (100-200 keV) ion bombardment.

Most papers deal with ion implantation of N, C, Ti but ion implantation of Krypton can be found in only a few papers. All four papers related to corrosion resistant steels and applications in medicine.

Based on the research findings set out above, Ion Implantation is a promising technology because it offers a wide number of parameters wich can be used to optimize the process of modification of surface layers for every specific use – biocompatible materials, food industry, stainless steels, and of most interest for us, tools and tool steels. Ion Implantation of Kr on tool steels has never been done before (according to the sources available to us) anywhere in the world as well as in our country.

The aim of this paper is to use Ion Implantation of Kr for the first time on two different tool steels . We hope that the results retreived from this paper will help the introduction of this technology into the up to date industrial use.

2. EXPERIMENTAL

Krypton ions have been implanted in steel substrates using mVINIS Ion Source. The mVINIS Ion Source shown in fig 1, is a part of the TESLA Accelerator Installation (AIT) at the VINČA Institute of Nuclear Sciences in Belgrade.

Basic characteristics of the mVINIS ECR ion source are: operating frequency: 14.5 GHz, total power consumption of ECR ion source: 68 kW, radial plasma confinement: permanent hexapole magnet NdFeB, B_r = 1.24 T, axial plasma confinement: electromagnet with two coils, max current 1000 A, mirror ratio: B_{max} / B_{min} = 1.29 T/ 0.46 T = 2.8, gas inlet system: fine flow control of main gas and supporting gas, solid substance inlet system: microoven inserted into the plasma chamber, T_{max} = 900° C, extraction system: simple two electrode system, plasma chamber at high voltage, U_{ex}=5 ÷ 25 kV, bias electrode: fixed position inside plasma chamber, U_{bias}= 0 ÷ - 500 V.

The mVINIS Ion Source can produce multiply charged ions from gases using a specially designed gas inlet system. This system is crucial for the stable and reproducible operation of the complete ion source.

In this paper, two kinds of steels were used. The reason why these steels have different machinability is due to the difference in steel structure caused by the different percentage of carbon and alloying elements present. Since the structure is not the same, the effects of the implantation will also not be the same. The matrix of the 100Cr6 steel is consisted of uniform martensite, while the matrix of the M2 steel is consisted of mixture primary carbides and martensite. The stopping of ions in a material as uniform as steel 100Cr6 will be on a different depth comparing to the material with a nonuniforme structure as present in M2 steel.

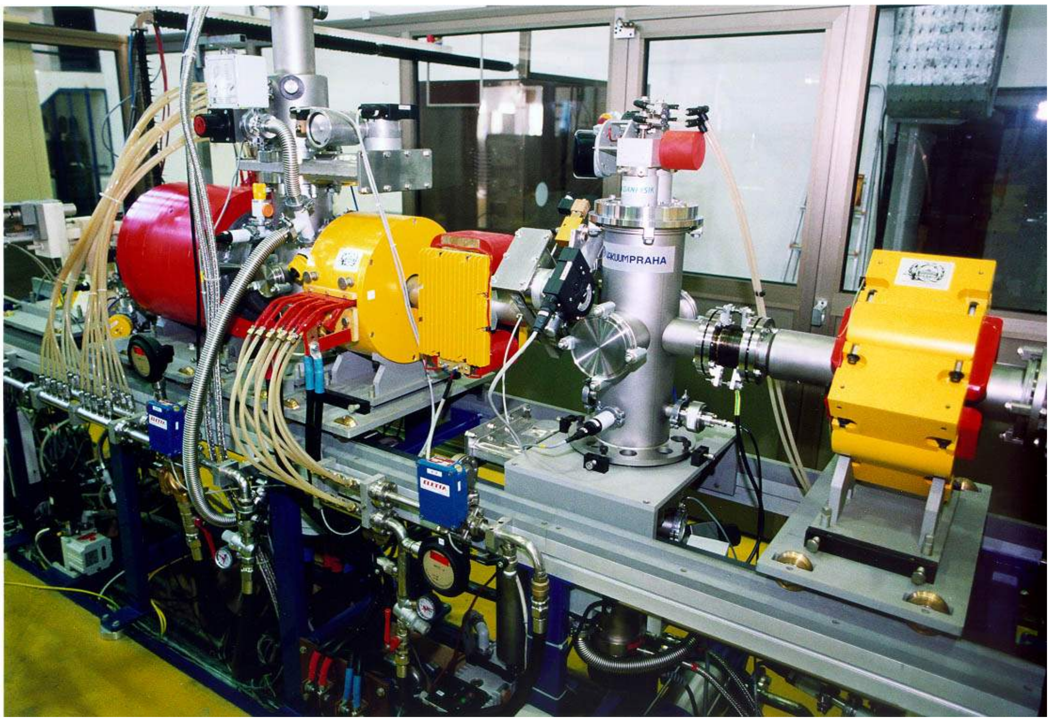

Figure1: mVINIS Ion Source

In this paper Kr^{8+} ions with the energy of 120 keV and Kr^{11+} ions with the energy of 180keV were used.

The Krypton spectrum is shown in fig 2.

Main parameters of ion implantation:

Parameters for Kr8+ - U_{ex}=15kV ; I_{ex}=3.2µm ; D=10^{16} ions/cm^2 ; W=120keV ; t=295min

Parameters for Kr11+ - U_{ex}=16.4kV ; I_{ex}=4.14µm ; D=10^{16} ions/cm^2 ; W=180keV ; t=280min

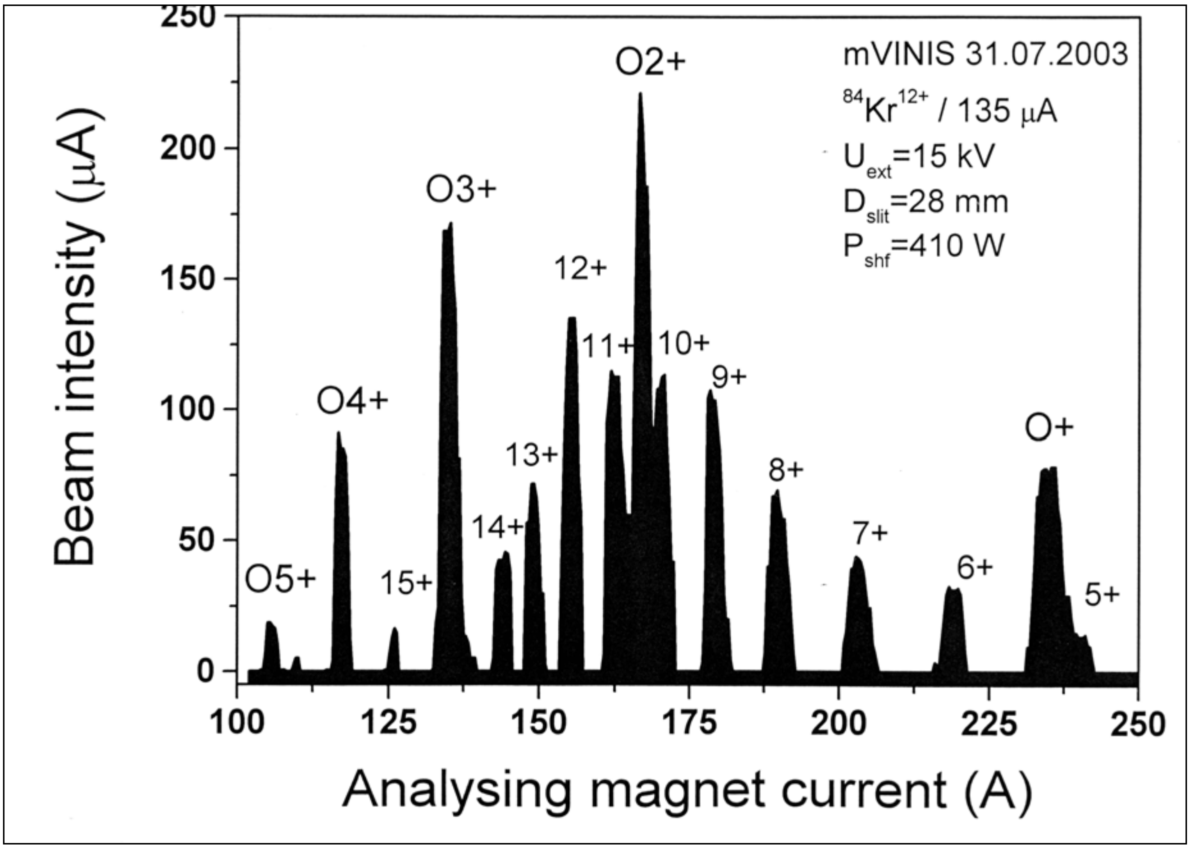

Figure 2: Krypton spectrum

3. RESULTS AND DISCUSION

Surface roughness was measured by AFM SOLVER-P47 at BIONT a.s., Department of Nanotechnologies, Bratislava. Before implantation sample surface were grinded and polished. In fig.3 and 4. the uper and lower value of measuring are shown. It is obvious that samples made of M2 steel posses a higher dispersion of results – fig 4.. It could be explained with the presence of primary carbide at surface of polished samples. More uniform microstructure of 100Cr6 steel results with a smaller dispersion of AFM roughness results – fig.3.

Using Monte Carlo system for simulation it could be calculated that the depth of surface implantation for 100Cr6 and M2 steels reaches about 70nm for Kr8+ and about 90nm for Kr11+. Calculation for high speed steel was more complicated because of the high alloying effect but also becouse very complex microstructure.

Friction coeficient was measured with different load and type of prism – hard metal and diamond. Fig5 shows the influence of implanted ion energy on the friction coefficient for cold work tool steel 100Cr6. It could be concluded that ion implantation can decrease friction coeficient for both energies of Kr ions.

Ion implantation influence for modification M2 steel surface shows different results. The increase of Kr ion energy realise with increase of coeficient of friction. It could be explained by increase in surface nanoroughness (fig. 4) but also with presence of very hard primary carbide in microstructure. This carbide could produce local picks in roughness (fig 7.) what normaly significantly increase friction coeficient.

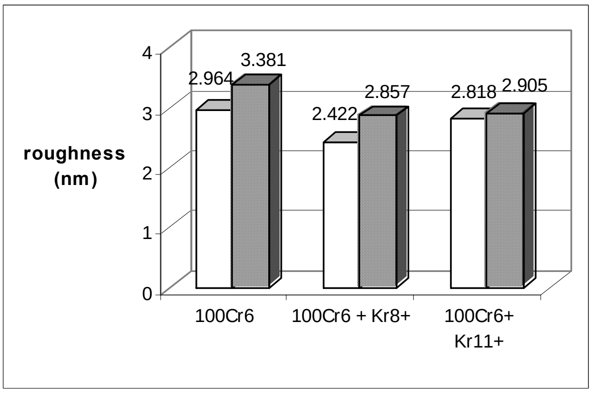

Figure 3: AFM surface raughness – 100Cr 6 steel

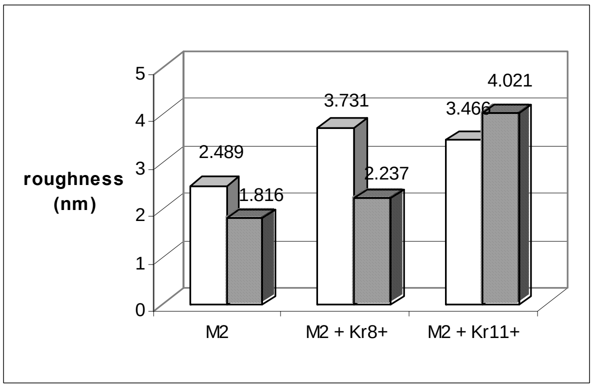

Figure 4: AFM surface raughness – M2 steel

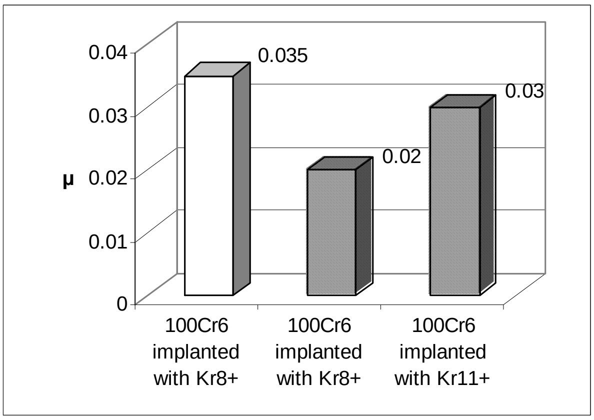

Figure 5: Friction coefficient μ - steel 100Cr 6, F=10N.

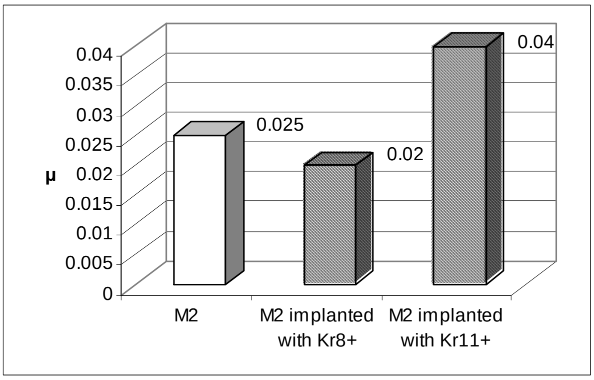

Figure 6: Friction coefficient μ - steel M2, F=10N.

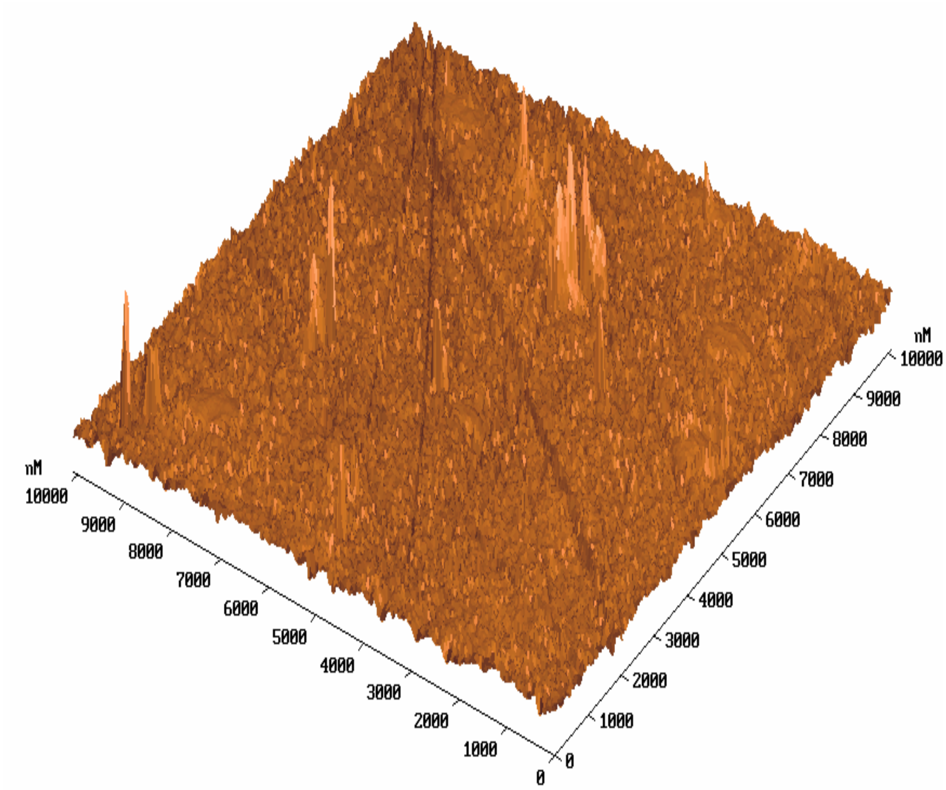

Figure 7: AFM image of surface raughness – M2 steel after Kr 8^+ implantation.

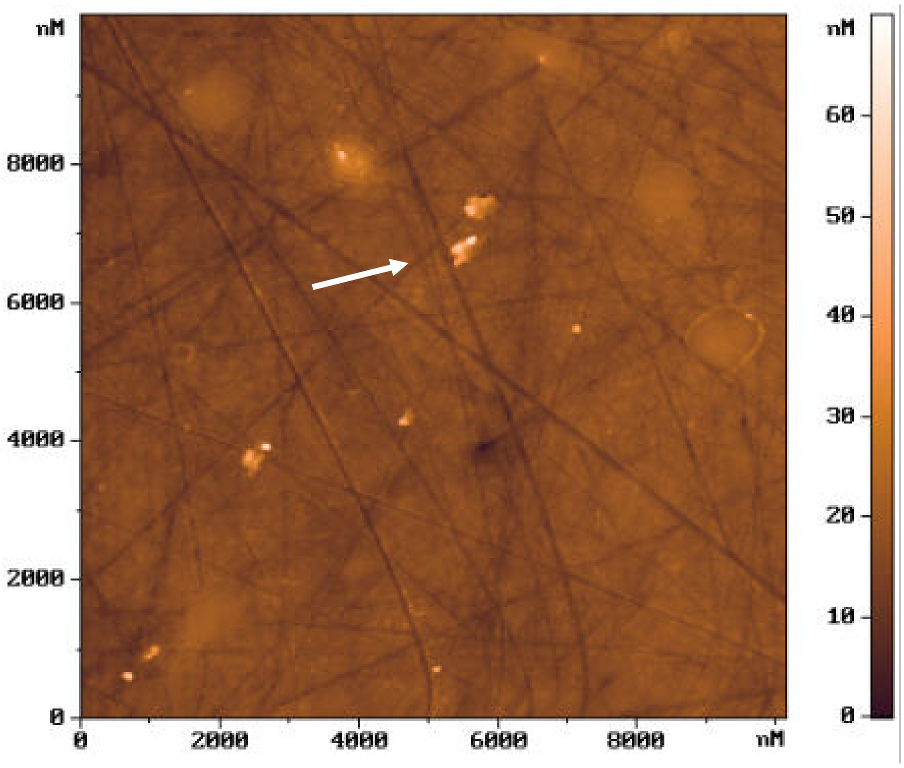

Figure 8: AFM 2D image of the same sample

AFM enables the observation of the sample using the angle of observation of 90 degrees fig8. A light zone can be seen and it is related to the presence of primary carbide particles like buckling (see the arrow). In this picture, shallow traces of grinding wich were not removed during the process of polishing can also be seen.

4. CONCLUSION

Ion implantation is very interesting methodology for surface modification of steel. It offer meny parameters for adjusting the property of steel surface, what could be very useful for improvement the tool quolity.

Ion implantation of Kr could decrease surface nanoroughness for cold working steel 100 Cr 6 , but results depend of Kr ion energy. Surface nanoraughness for high speed steel M2 increase after ion implantation with significant dispersion in results. It could be explained with presence of primary carbide in martensitic matrix, so microstructure are very unhomogenious from point to point.

Friction coefficient shows some correlation to surface hardnes for cold workin steel 100Cr 6 which posses very unuform microstructure. High sped steel could reach lower friction coeficient after Kr ion implantation althou the surface roughness little increase (compare fig 4 and fig. 6.). This phenomenons need further investigation to be explained.

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