H.Reuther, E.Richter
Academy of science of the GDR,
Central institute of nuclear
research, Rossendorf

SOME PARTICAL ASPECTS OF ION IMPLANTATION

The ion implantation is a high technology approach for changing the surface properties of materials. The method was first introduced in 1973 by Hartley and Dearneley from HARWELL and has been the focus of considerable interest in the last few jears. Concentrated effort has been devoted to laboratory and industrial evaluation of the implantation process. Over 600 articles on this subject have been published in the last ten years. The new technology will soon be adapted for many specific applications. To date industrial trials of this technology have been mainly directed at the wear reduction of steel and tundsten carbide tools by high dose nitrogen implantation. However, several other surface sensitive properties of metals such as fatique, corrosion, oxidation have been benefitted from either -direkt ion implantation of various ion species, e.g. Cr, Ti, C; - the use of ion beams for mixing of deposited thin films on steel substrates - deposition of material in conjunction with simmultanously ion bombardment.

This paper describes only the applications by high dose nitrogen implantation for reducing wear and improving the lifetime of steel and hard metal tools. This effects have been seen in both steel.as well as WC unter various applications /1/. It was found taht N implantation is ineffective for all applications involving high operating temperatures at the working surface area such as found in chip forming applications of metals for example. This is because in the instability of the N-defect and N-dislocation structure in the surface region formed during implantation that are thought to be responsible for improving wear resistance.

Rauschenbach have developed in his excellent studies the phase formation and the phase transformation after thermal annealing and his results are in a good aggrement with the fact of ineffectivity of nitrogen implantation at high operating temperatures /2/.
The efficacy of the ion implantation has been demonstrated by a great number of industrial tests. HARWELL has worked with over 100 companies and in the USA many companies are initiating industrial trials of nitrogen implanted tools or of tools implanted with other ion species /Ti, Cr, Y/ /9/. For example Spire is using the ion implantation for improving wear and corrosion resistance of precision air croft bearing elements /4/. We also work to date with some companies in the GDR. We think that ion implantation is an attractive technology for treating industrial tools where the following criteria are met:

- avoidance of dimensional changes of the tools
- the tool can not accomodate the elevated temperatures associated with other surface treatments such as PVD or CVD because of possible distorsion and decreasing of basic hardness
- conventional antiwear coatings have problems with delammination during use
- relatively expansive tools or high cost of lost throughput associated with downtime of a production line.

At now some examples for application of nitrogen implanted tools. All implantations for application tests were carried out with a selfmade simple implantation machine without mass separation. To date this implanter produces only nitrogen ions. The acceleration voltage was 50 kV and the usually used ion beam current density was in the range from 10 to 50 μa/cm^2. The effective beam area in the target chamber was about 100 cm^2 without scanning. The required implantation doses have been varied between 4 and 6 x 10^{17} ions/cm^2.

In the literature you will find in all cases only papers with high beneficial effects after implantation. That is nessecary for progagating the new technology and for using in the industry. But it is also nessecary to know and to publish the limits of this new technology. We have no one effects at chip forming tools for metals, for drilling in metals with HSS drills, for high speed woddcutting with WC-tools. In all these cases we have high temperatures at the operating area. Drilling in soft materials, e.g. in plastics gives very good results. In table 1 you find some of our lifetime factors for different investigated tools.

Some remarks to the cost of implantation treatments of tools. The cost of the improved tools are a very important factor for the industrial use of the new ion beam technology. Two factors are important for the cost of an implanted tool:

- cost of the equipment and
- the throughput of tools. The equipment costs are given by the design of the implanting system.

Smidt /5/ has published that for an implanter with a 10 mA ion beam and a goal fluence of 2.10^{17} ions/cm^2 the maximal throughput is 1125 cm^2 implanted area/h. However, it is only a theoretical value. In practice this can not be realized because of various considerations /sputtering, composition of basic material, heat sinking.../. An empirical expression given by Smidt for the throughput is

$$Tp = Tpo \cdot f_{th} f_b f_p$$

where is Tpo - theoretical maximal value

f_{th} - factor related to thermal constraints

f_b - to beam area utilization

f_p - to time for vacuum pumpdown

If the ion beam density must be reduced to permit adequate workpiece cooling f_{th} will be less than 1. If sputtering requires that the angle of incidence of the ion beam must

Table 1

Application of nitrogen implantation for industrial tools

Application	Material	Lifemite, Remarks
drilling		
- printed circuit boards	WC	lifetime x 2 ... 4, less frequent breakage better products
- dental burrs	WC	lower operating temperature, lower pains
punching, stamping		
- tubes	100 Cr 6	lifetime x 4
- electric contacts	210 Cr 46	lifetime x 4 ... 10
cutting		
- soft metals	100 W1	lifetime x 3 ... 6
- plastics	100 Cr 6 210 Cr 46 90 Mn V 8	lifetime x 4 ... 9 higher throughput

Other implanted tools are working to date.

be restricted -we must use masks- only a part of the ion beam can be used for the workpiece and this is reflected in the factor f_b - f_p showes how many time is spent pumping down the working chamber compared to the actual processing time. In example for a simple flat specimen using a cooling and a good pumping system $f_{th} = 1$ and $f_p = 0.9$ and $f_b = 0.9$ you have a proportion Tp/Tpo = 0.8. This is a optimal value. For balls e.g. f_b will be only 0.2 and respectively the cost for bearing ball implantation are about 5 x higher. Calculations in Spire and Zymet show that the cost of a implanted tool are in the same range like the cost of a tool with PVD treatment /5,6/. The aim of our investigation must be to get a similar factor of costs for our application trials.

In the summary we have seen that nitrogen implantation in steel and tungsten carbide tools improves the wear resistance and the lifetime of these tools significantly. The best results in application tests we will get at processes with lower operating temperature. For cutting of plastics and for punching of electrically contacts we found a lifetime increasing by a factor of 4 to 10. The results have shown that ion implantation is a practicable new technology for special tool treatment to reduce wear and tool downtime.

References

/1/ G.Dearneley, J. of Met. 1982, 18

/2/ B.Rauschenbach, A.Kolitsch, K.Hohmuth, phys. stat. sol. /a/ 80 /1983/ 471

/3/ S.T.Picraux, Physics today 1984 /11, 2

/4/ P.Sioshansi, Thin solid films 118 /1984/ 61

/5/ F.A.Smidt, B.D.Sartwell, Nucl. Inst. Meth. B6 /1985/ 70

/6/ J.K.Hirvonen, MRS Proc. 27 /1984/ 621