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HEAT PRODUCTION DURING ION IMPLANTATION

Hirvonen from Spire has published some viewpoints for technical implantation involving metallurgical and machine factors /1/. These factors are given in table 1. All of these factors are very important for the design of a technical implantation station in metals.

Tabel 1 Implantation factors for wear production

a/ Metallurgical factors
- bulk composition
- sputtering effects
- surface cleanlines and oxidation
- basic hardness, pre-implantation heat treatment
- ageing after implantation
- surface finishing

b/ Machine factors
- Ion species
- Ion dose
- Ion energy
- average temperature during implantation
- ion beam current density
- rest gas composition
- geometrical factors
- shadowing

In the following only about two factors will be written, about the average temperature and the ion beam current density. It is clear, the ion beam density directly influences the heat production during implantation. Heat input and the maintance of a low substrate temperature represented one of the most difficult problems for the high dose ion implantation, An typical implanter with a current density of 30 μA/cm^2 and an accelera ion voltage of 100 kV produces a heat load of 3W/cm^2 on the surface. Radiative cooling in a vacuum is below about 400°C totally inadequate for this high heat input and the aspired low workpiece temperature. But nitrogen implanted into steel or WC-hardmetal is not full retained in the material temperature exceeds 200-400°C. It diffuses to the surface and goes out /2/. In the other hand some beneficial effects of ion implantation anneal at this temperatures soon. The improvement of wear resistence is very small and not long lasting.

Grabowski had discussed in /3/ possible regimes of cooling by heat conduction: - heat diffusion limited
- heat capacity limited and
- steady state conduction to a heat sink.

For the most implantation doses and workpiece sizes considered heat capacity alone is insufficient to cool the target. The beam current density must maintained at an uneconomically low level if the target not will be overheated. Conduction to a heat sink will be essential. It has been published some different interface materials for workpieces cooling during implantation. Two system are usefull for practical applications:

- eleastomers with a high conductivity /4/ or
- eutectic metal alloys with a low melting point /5/.

We work too with an eutectic metal bath. In this case we have both a good cooling as well as for some workpieces a simple arrangement for holding during implantation.

For such cooling mode it is very important to know the temperature gradient between the cooled base of the workpieces and their parts standing out from the eutectic metal bath into the ion beam. The rise of the equilibrium temperature depends upon the thermal conductivity of the target material and the target geometry.

For 3 selected geometrical configurations which are mathematically simple to describe we have calculated the equilibrium tip temperature. The temperature distribution satisfy the laplace equation. The temperature is therefore assumed to be stationary. At first we consider a rectangular flat plate which is illustrated in Figure 1.

The ion beam treates the plate on the edge a and the other edges satisfy the following boundary conditions:

and . The equilibrium temperature T on the tip of the plate is given for $\frac{a}{l}$ 0,1 and $\frac{d}{l}$ 1 by

$T = T_o$ + -------------- /1/

with - thermal conductivity
- current density
- accelerating voltage
- object length
d - object thickness
- angl between the normal vektor of the plate and the incidence of beam

The final formula includes only geometrical parameters and gives the temperature at the point x + o, y = b /tip of the plate/. Assuming the following parameters:

$= 2\ W\ cm^{-2}$; $= o$; $l = 4\ cm$; $_{steel} = 0{,}5\ W\ cm^{-1} grd^{-1}$

$\frac{d}{l} = 0{,}5$ we find for $\frac{a}{l} = 0{,}25$ $/T - T_o/ = 8$ grd and for

$\frac{a}{l} = 0{,}5$ $/T - T_o\angle = 15$ grd.

The siring of the tip temperature is very small.
For the circular sector prism in Figure 2 we find for

this formula for the tip temperature:

$$T = T_o + \qquad /2/$$

with

= tip angel
= adge length

If we assume that = 2 W cm^{-2}; = 0; = 0,5 W cm^{-1} grd^{-1}, $R^{\hat{}} = 4$ cm and $= -\frac{}{4}$ we get a difference between basic temperature T_o and tip temperature T at about 20 grd. Third we consider a rectangular triangel /Figure 3/. In this case we find for the tip temperature the equation

$$T = T_o + \qquad /3/$$

Assuming the same parameters like in the other examples we got for the tip temperature about 22 grd.
All our calculations for the 3 different forms of tool tips show that the difference between the cooled tool basic and the irradiated tool tip is small only. The little higher tip temperature have not an influence on the properties of the implanted tools. However, it is very important to have a good heat sinking by an intensive cooling system for the target during implantation.

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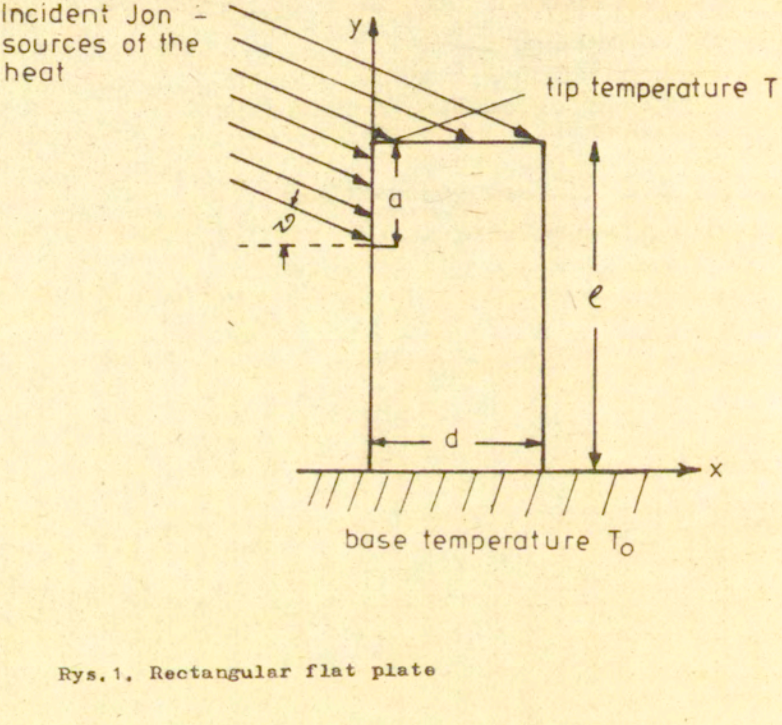
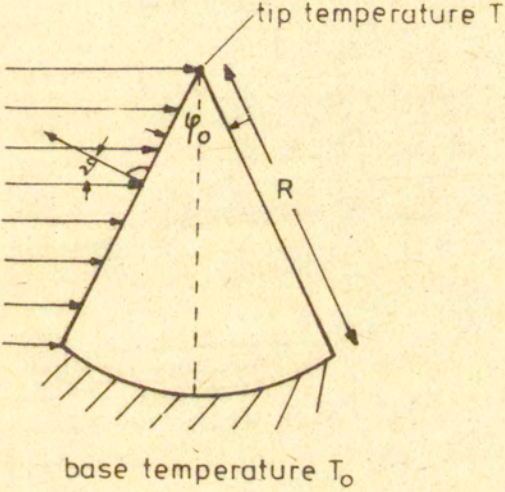
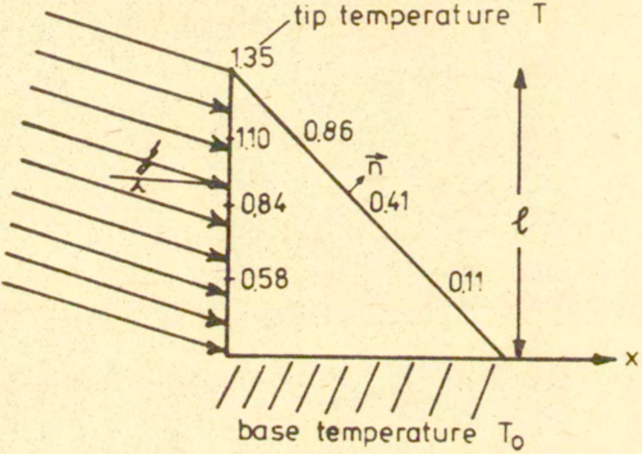


Rys. 1. Rectangular flat plate



Rys. 2. Circular sector prism



Rys. 3. Rectanfular triangel