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Estimating the Speed of rotation of a rotating X-Ray window

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Introduction - rotating membrane is assumed to be a rotating disc and appropriate speed of rotation is a key consideration if the material in question must survive the heat flux imparted on it by impinging beam of electrons. 1μm hot spots are assumed to be distributed on the target material such that a circular pattern is formed according to figure 1 .

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Estimating the Speed of rotation of a rotating X-Ray window

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I. Introduction

A rotating membrane is assumed to be a rotating disc and appropriate speed of rotation is a key consideration if the material in question must survive the heat flux imparted on it by impinging beam of electrons. 1μm hot spots are assumed to be distributed on the target material such that a circular pattern is formed according to figure 1

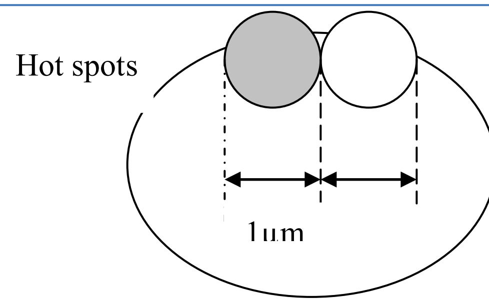

Figure 1 : Rotating disk with 1μm hotspots forming a circular pattern

II. Number of Hot Spots

Radii chosen varied from 1000μm to 50000μm. If we set speed of rotation as 825 *rev/s* (which is a realistically attainable speed)

$$825rev/s = \frac{44xR}{7T} \quad (1)$$

Where *R*=radius of rotating disc, and *T* is the time for 1 rev (period) Consider a circle of diameter 10mm; circumference, of the circle will be, $2\pi R = 2\pi\left(5\times10^{-3}\right)m = 3.142857\times10^{-2}m$

To arrive at the number of hot spots

We have $\frac{2\pi R}{d} = \frac{3.142857\times10^{-2}}{1\times10^{-6}} = 31428.57$

hot spots where *d* is the diameter of 1 hot spot.

If heat source will theoretically heat up $1\mu m$ hot spot to maximum allowable temperature in say 30ns and we rotate the disc by $1\mu m$ after this assumed time so that a new position is assumed on the circular path of the beam, the circle will make 1 revolution in a time expressed as

T=Number of spots x time per spot

$$=31428.57\times30\times10^{-9}s=942857.143\times10^{-9}s$$

$$\approx1\times10^{-3}s$$

$$w=\frac{2\pi R}{T}\div2\pi R\,(rev/s)$$

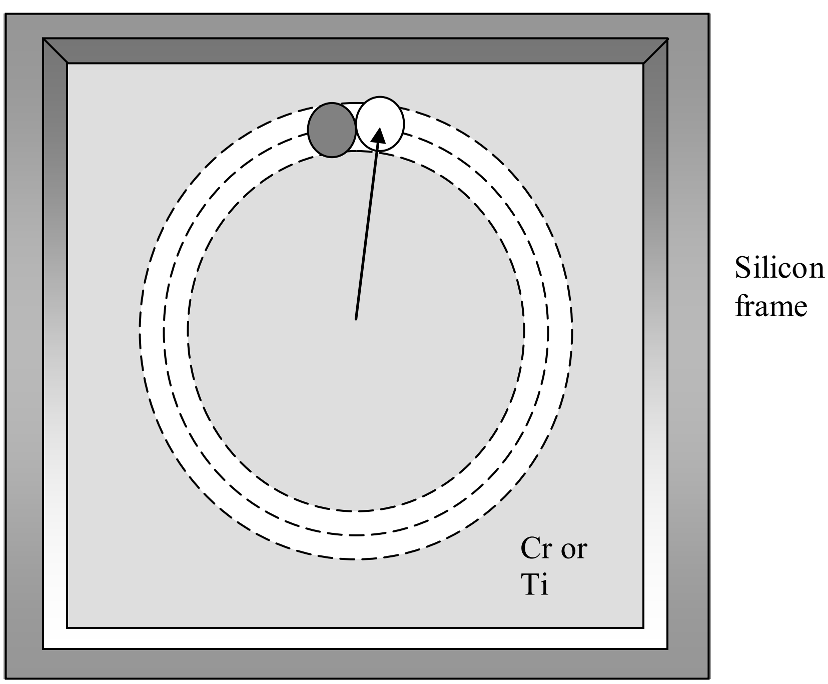

Figure 2 : Circular pattern showing the paths covered by heat flux on a square shaped X-ray window

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III. SPEED AND SEAT UP TIME

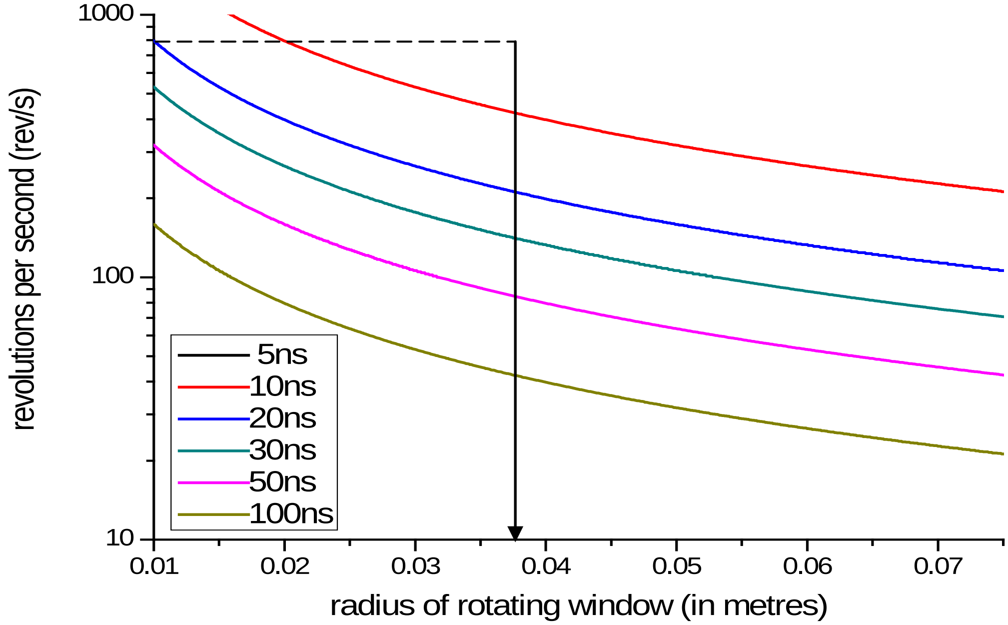

Figure 3 : Graph showing required rotation rate versus radius, for varying heat up times

Figure 2 Describes the rotation of the disk by the circular pattern showing the paths covered by heat flux on a square shaped X-ray window.

Figure 3 simply infers that at lower seating up times, the speed of rotation is greater and has an inverse relationship with radii of rotating window. Window of radius of about 32*mm* been impinged on, by a beam of electrons having heating up time of 5ns will be assumed to rotate at $1000 rev/s$. Rotating discs of radius of $\le 32mm$ will rotate at $\le 1000 rev/s$ for heating up times of 5, 10, 20, 30, 50 and 100ns according to figure 1. The graph shows that, assuming a maximum practical radius of 800*rev/s*, a range of heating up time s from 10ns to 100ns can be tolerated and rotating diameters of $\approx 20mm$ to $\approx 100mm$ can be used.

However the speed of an arbitrary hot spot travelling on a circular path in metres per seconds is unaffected by changing radii according to figure **

The maximum practically attainable rotation has 1650 *rev/s* or 100 000 *rev/min* and a more realistic and less problematic value of speed is approximately 825 *rev/s* or 50 000 rev/min. Maximum practical radius of rotation is taken as approximately 50mm. Radii larger than this critical value will cause centrifugal force to tear the rotating disk. Rotating disk of radii $R \le 28mm$ will rotate at speeds of $w \le 1100 rev/s$ at heating up times of 5ns, 10ns, 20ns, 30ns, 50ns and 100ns according to figure 3.

IV. CONCLUSION

A description on how to calculate the number of hot spots have been given; speed of rotation in revolutions per second and seat up time for each hot spot have been derived. In the course of microfabrication, radii of disks must not exceed 50mm, to avoid been torn apart by centrifugal force.

APPENDIX

Basic Thermal Properties of materials considered in the simulation (From CRC handbook)

TITANIUM

Thermal conductivity k = 0.219 W/ (cm. K) = 21.9 W/ (m. K) at 300K
Density r = 4500 kg/m3
Heat capacity Cp = 0.125cal/ (g. K) = 523 J/ (kg. K)

SILICON NITRIDE

Thermal conductivity k = 0.072 cal.cm-1.s-1.k-1 = 30.1 W/ (m. K) @300K
Density r = 3180 kg/m3
Heat capacity Cp = 0.17 cal/ (g. K) = 712 J/(kg. K)

ALUMINIUM

Thermal conductivity k = 2.37 W/ (cm. K) = 237 W/ (m. K) at 300K
Density r = 2700 kg/m3
Heat capacity Cp = 0.215 cal/ (g. K) = 900 J/ (kg. K)

CHROMIUM

Thermal conductivity k = 0.903 W/ (cm. K) = 90.3 W/ (m. K) at 300K
Density r = 7190 kg/m3
Heat capacity Cp = 0.107 cal/ (g. K) = 448 J/ (kg. K)

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