Jake Blanchard June 20, 2002

Addendum to Surface Roughening Document

Non-Surface Heating

Most surface heating actually deposits heat as volumetric heating within a thin layer near the surface. A typical model for volumetric heating resulting from energy impinging on a surface is

$$Q''' = Ae^{-\gamma x}$$

Where A is a constant, γ is the attenuation coefficient and x is the distance from the surface. To provide the same total heat input as a true surface heating flux q, we must enforce $A=q\gamma$. The temperature distribution resulting from volumetric heating of this type is

$$T = \frac{2q}{k\gamma}\left[z\ ierfc\left(\frac{\eta}{2z}\right) - e^{-\eta} + e^{z^2-\eta} erfc\left(z - \frac{\eta}{2z}\right) + e^{z^2+\eta} erfc\left(z + \frac{\eta}{2z}\right)\right]$$

where $\eta=x\gamma$ and $z = \gamma\sqrt{\kappa t_p}$, representing the ratio of the diffusion length in time t to the characteristic deposition length. The surface temperature resulting from this solution is

$$T_{surface} = \frac{q}{k\gamma}\left[\frac{2z}{\sqrt{\pi}} - 1 + e^{z^2} erfc(z)\right]$$

The ratio of the surface temperature from this equation to the surface temperature due to surface heating is

$$R = 1 - \frac{\sqrt{\pi}}{2z}\left[1 - e^{z^2} erfc(z)\right]$$

Figure 1 provides a plot of this ratio as a function of z. The corresponding stresses would follow the same curve. From this curve one can see that the effect is less than 10% for z>8. The effect is less than 1% for z>60. This latter result was determined using the asymptotic result:

$$R \sim 1 - \frac{\sqrt{\pi}}{2z} + \frac{1}{2z^2}$$

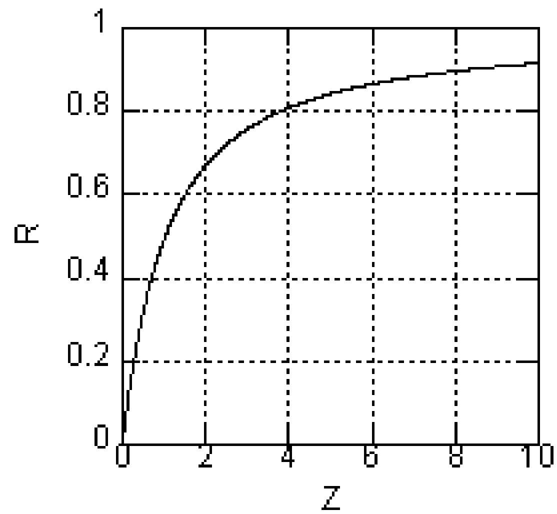


Figure 1: Ratio of surface temperatures due to volumetric heating and equivalent surface heating as a function of dimensionless time z.

Using the surface temperature derived above, the fluence to just yield the surface is given by

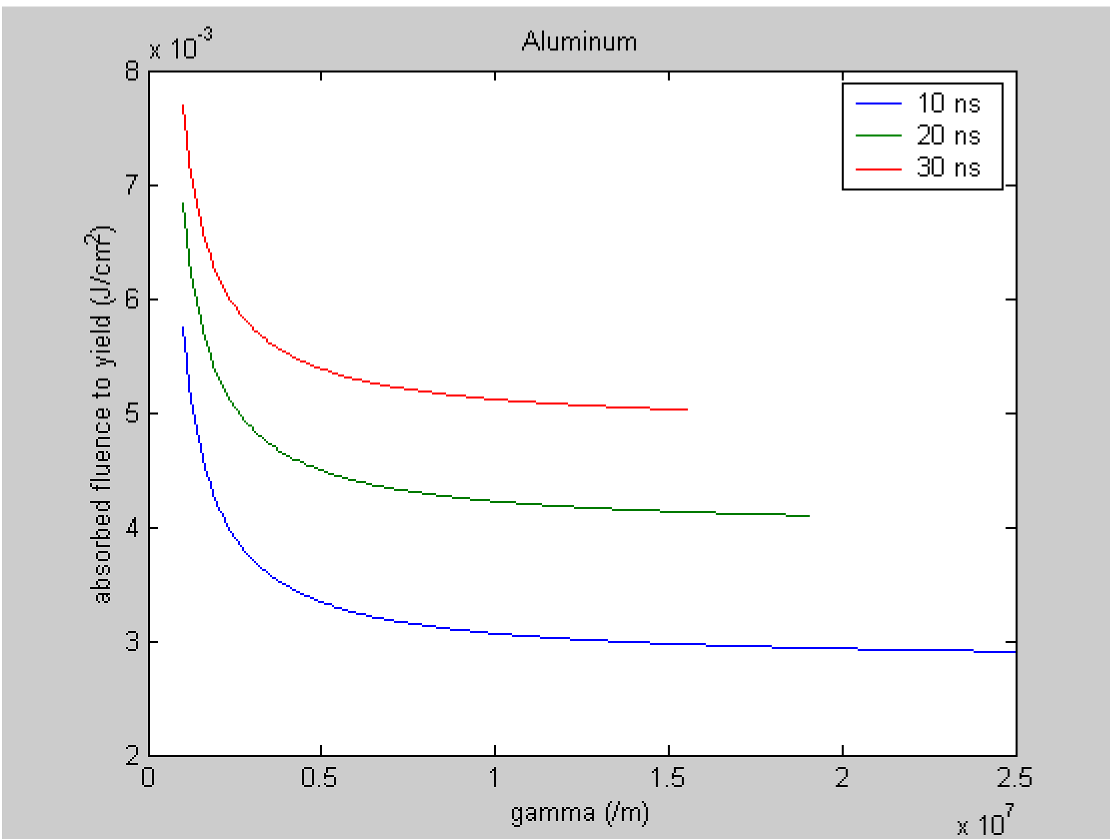
$$\Gamma_y = \frac{Y(1-\nu)k\gamma t_p}{E\alpha\left[\frac{2z}{\sqrt{\pi}} - 1 + e^{z^2} erfc(z)\right]}$$

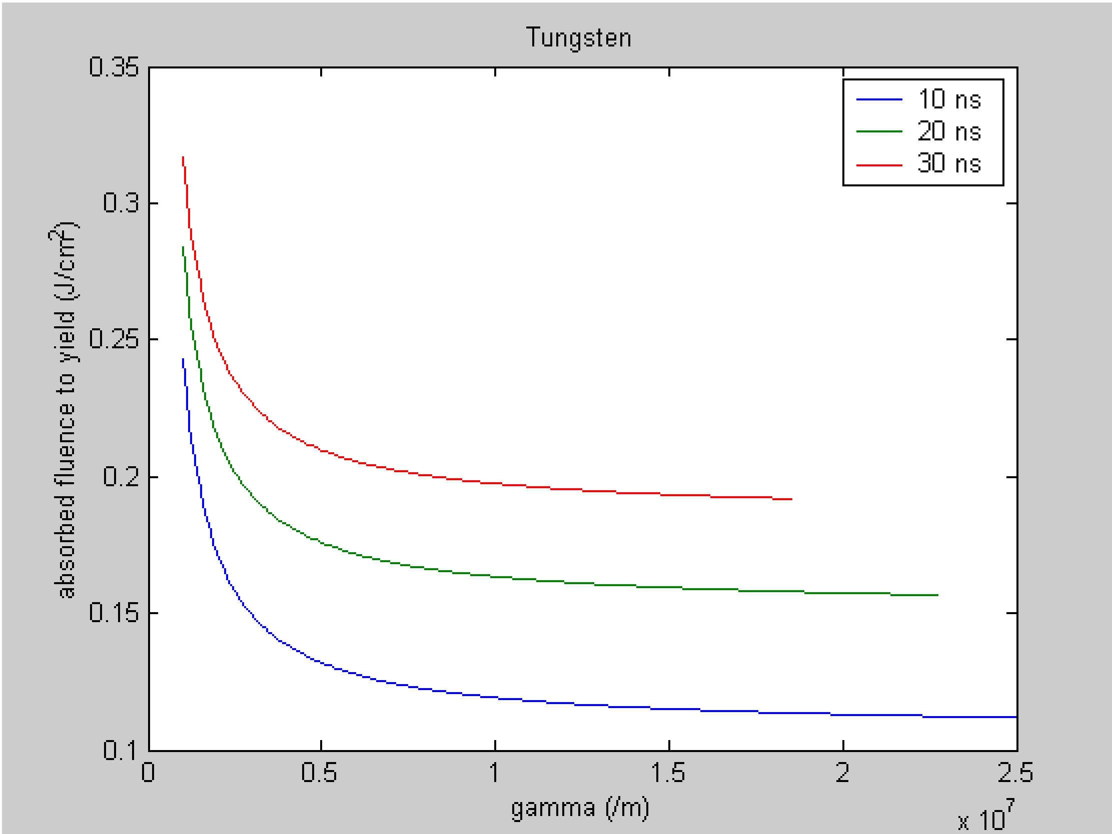
The fluence to cause yielding in aluminum is given in the following table for several values of pulse length and γ.

pulse time	gamma	Z	fluence to just yield surface	ratio of fluence to result from surface heatng
ns	/m		J/cm^2	
10	1E6	0.985	0.0057	2.05
10	5E6	4.93	0.0033	1.19
10	1E7	9.85	0.0031	1.10
20	1E6	1.39	0.0068	1.72
20	5E6	6.97	0.0045	1.15
20	1E7	13.9	0.0042	1.07

Table 1: Fluence to just yield aluminum.

Results are plotted in the following two figures for aluminum and tungsten.




Tungsten
absorbed fluence to yield (J/cm2)
gamma (/m)
x 10^7
10 ns
20 ns
30 ns
0.35
0.3
0.25
0.2
0.15
0.1
0
0.5
1
1.5
2
2.5