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Update on RF Breakdown Theory Since AAC06

Effect of backscattering

A fraction of the electrons incident on a metal surface are backscattered. The backscattering coefficient b depends only on the atomic number Z and is given by

$$B = A + BZ + CZ^2 + DZ^3$$

where A = –5.23791 x 10^{-3}, B = 1.5048371 x 10^{-2}, C = –1.67373 x 10^{-4}, and D = 7.16 x 10^{-7}. The fraction of electrons transmitted into the metal is 1–b.

For a metal surface bombarded by electrons with a power density per unit area P_A, the temperature rise at time t_0 is

$$T = \frac{P_A}{X_0 C_S \rho} \int_0^{t_0} erf\left\{ \frac{X_0}{\left[4D\left(t_0 - t\right)\right]^{1/2}} \right\} dt$$

To take backscattering into account, P_A must be multiplied by 1–b.

Without backscattering, the surface field at breakdown scales as (AAC06 paper)

$$E_b \sim \left[\frac{T_m C_s}{(I/t_0)} + H\right]^{1/2}$$

To take backscattering into account, this expression must be multiplied by the factor $1/(1-b)^{1/2}$. The table below shows the effect of taking backscattering into account for selected metals.

Element Z	Breakdown Field– No backscattering	Transmission Factor 1–b	Breakdown Field– with backscattering
Cu 29	1.0	0.69	1.0
W 74	1.20	0.52	1.39
SS 26	1.21	0.72	1.19
Nb 41	1.21	0.62	1.28
Mo 42	1.28	0.62	1.36
Ti 22	1.32	0.7	1.27
Cr 24	1.39	0.73	1.37
Be 4	2.53	0.95	1.88
C 6	~4	0.92	~3.5

TABLE 2. Breakdown Fields Normalized to Copper for Various Metals

1.00 –1.09	1.10–1.19	1.20–1.29	1.30–1.39	> 1.4
Cu 1.00	Al 1.10	Co 1.22	Re 1.31	Be 1.88
Ca 1.06	Mn 1.10	Os 1.27	Ru 1.31	
Tc 1.08	Zr 1.12	Ti 1.27	Mo 1.36	*Non-metals*
	Y 1.14	Nb 1.28	Cr 1.37	B 2.17
	Rh 1.15	Sc 1.29	V 1.37	C 3.55
	Ta 1.16		W 1.39	
	Mg 1.16			
	Fe 1.17			
	Ni 1.18			
	SS 1.19			
	Ir 1.19			

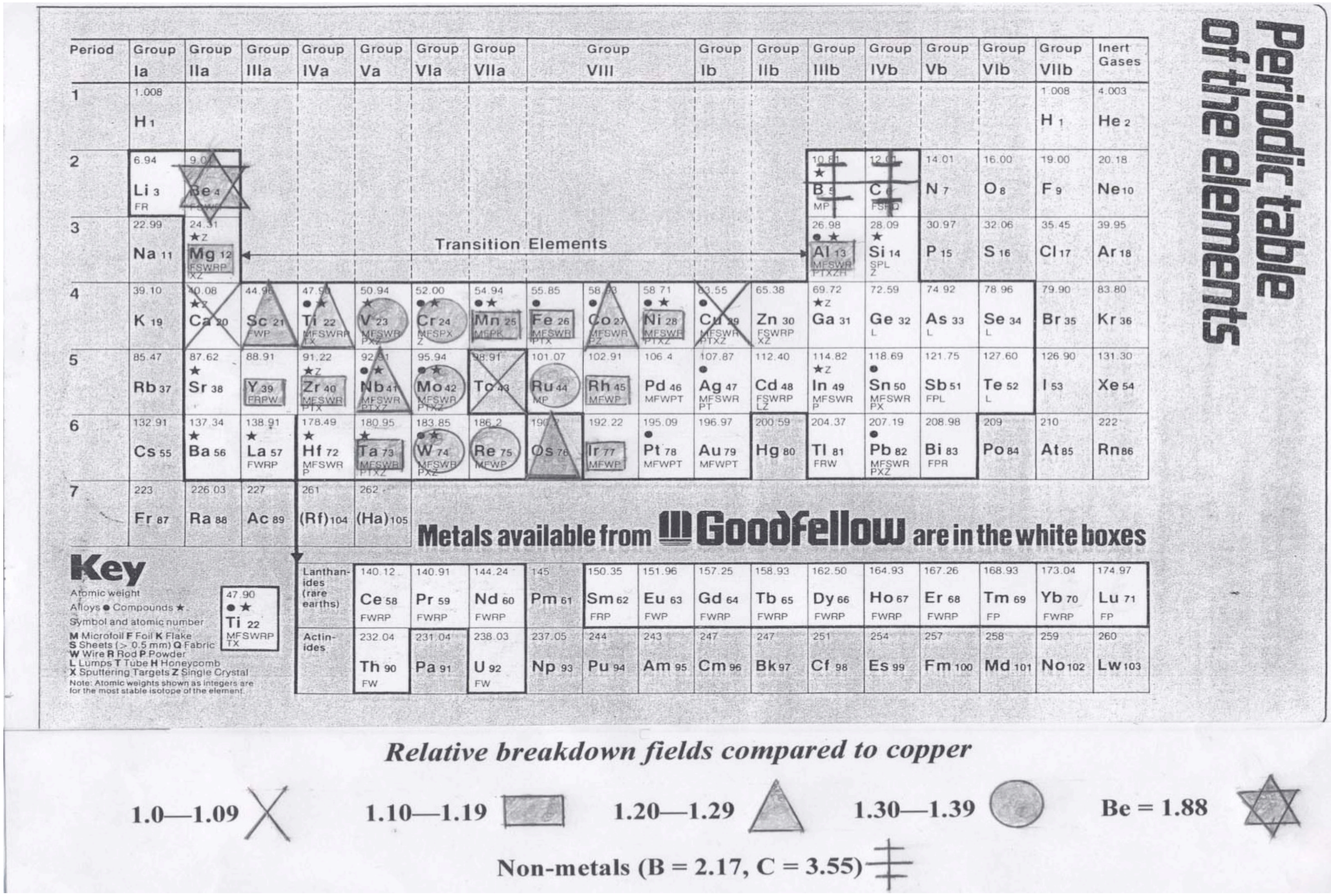

FIGURE 4. The breakdown field groups in Table 2 plotted on a periodic table of the elements

Taylor Cones

From Jon Orloff, *High Resolution Focused Ion Beams*, RSI **64**, 1105 (1993):

“A LMIS (liquid metal ion source) consists of a liquid metal held in some suitable way to which an electric field is applied strong enough to cause the metal to assume a conical shape---”.

“The cone apex is believed to have a radius of only about 5nm”