

Experimental Methods in Nanotechnology

Homework 2
Due 23 Jan 2008

1. The Richardson-Dushman equation for the electron flux (J_z) during thermionic emission can be written as:

$$J_z = A T^2 \exp(-\phi/k_B T)$$

where A is a grouping of constants, T is temperature, ϕ is the work function, and k_B is Boltzmann's constant. Write the terms down constituting A and calculate them to find the "universal" constant. Comment from results in the literature whether A is in fact a universal constant. How much does it vary? Please write down references to values of the universal constant, these may be books or journal articles. DO NOT USE WIKIPEDIA AS A REFERENCE SINCE IT MAY BE INCORRECT. I will not accept references to Wikipedia.

Below is a nomograph developed by Smith and Breiwieser (J. App. Phys. 41 (1970) 436). Assume a couple of temperatures for a Tungsten and LaB₆ thermionic electron gun, at their typical operating temperatures, and compare what you get from the nomograph to calculation with the equation you developed.

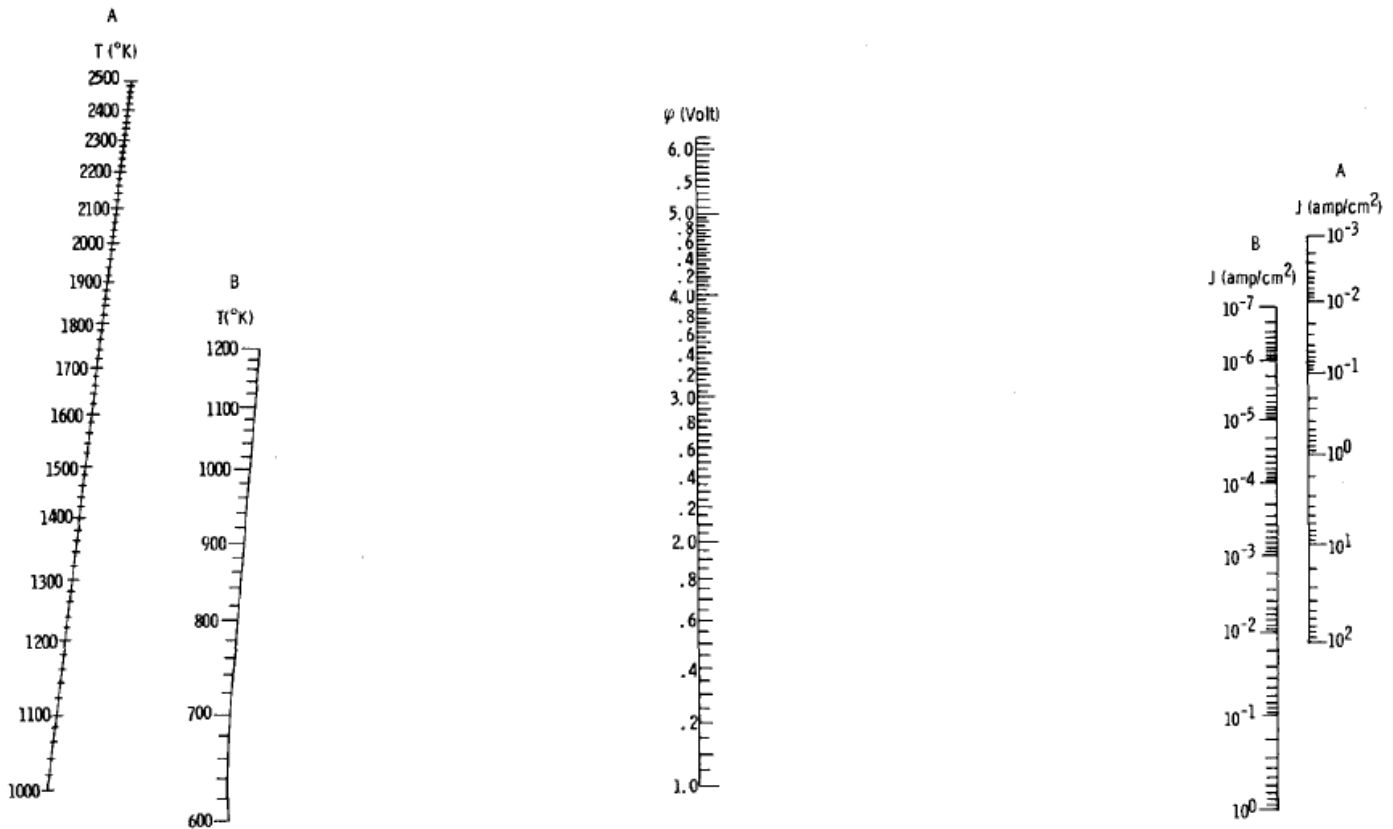


FIG. 1. Emission current density based on the solution of the Richardson–Dushman equation for various effective work functions (ϕ) and electrode temperatures (T).

2. Fowler and Nordheim considered field assisted emission of electrons from a metal (Proc. Roy. Soc. A **119** (1928) 173). Write down their electron flux relation with all the constants in it, then evaluate the constants to arrive at a relation like this:

$$J_z = A \sqrt{(E_f/\phi)} |\mathbf{E}|/[E_f + \phi] \exp(-B \phi^{3/2}/|\mathbf{E}|)$$

where A and B are constants, E_f is the Fermi level and $|\mathbf{E}|$ is the magnitude of the electric field. Report the values for A and B. Also, give a reference which also evaluates the Fowler-Nordheim relation and compare to their results.

3. Determine what Bremsstrahlung radiation is, how it is formed and comment on its importance to Scanning electron Microscopy. Does it occur in a typical SEM experiment? Is it harmful?

4. Find out what type of "lenses" are used in a typical SEM. Are they a permanent magnet or an electric field? Is the electric or magnetic field the principle focusing mechanism? Give references to your comments and do not use Wikipedia.