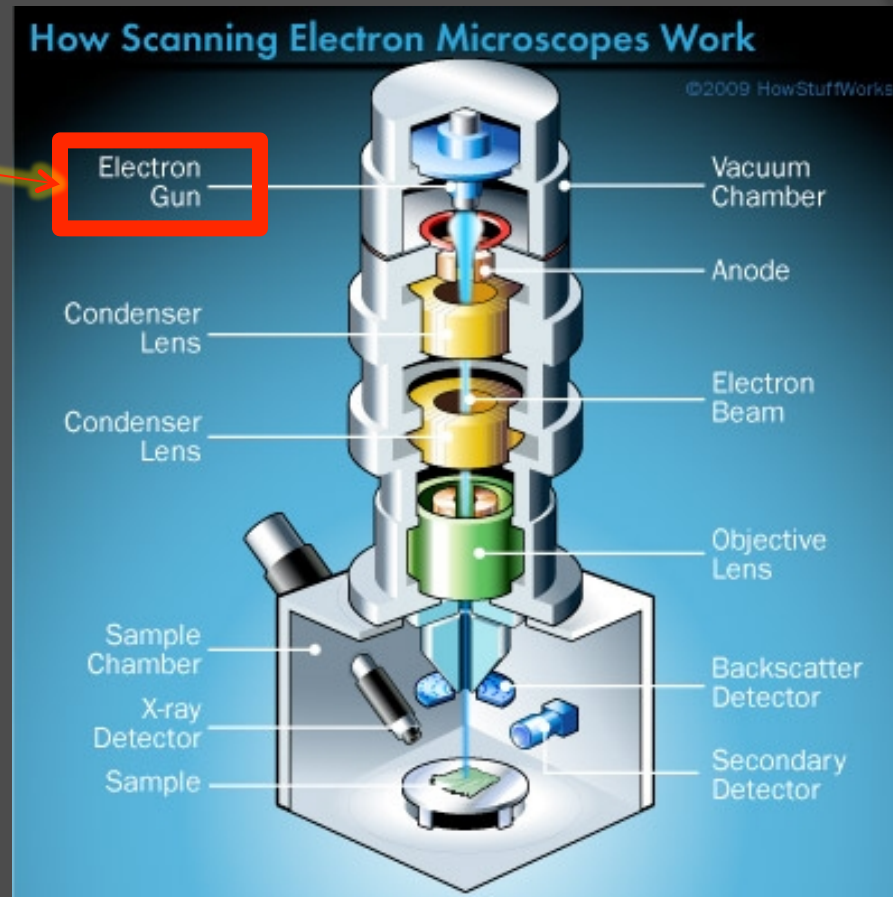


Ramin Jamnejad

ELECTRON GUNS



We are going to find what is going on here!



Electrons can be emitted from a solid surface if only they have equal or more energy than free electron in vacuum. So we should provide this energy:

- heating, irradiation with light (photoemission)



Solid



- bombardment with charged particles (secondary emission)
- using of a strong electric field (field, or cold, emission)



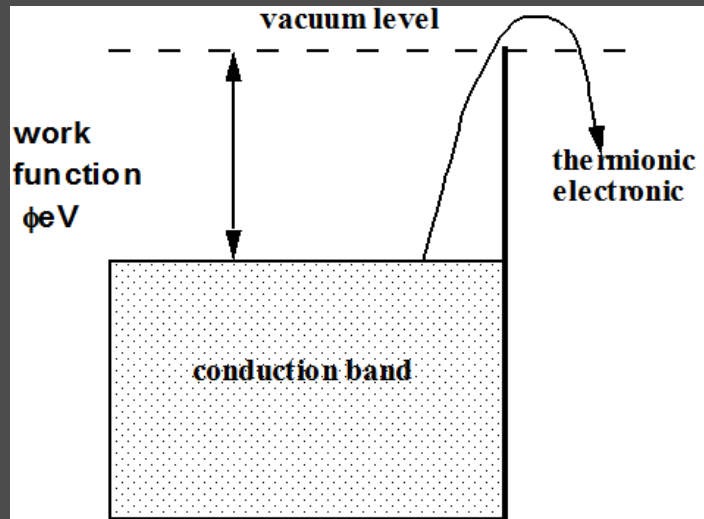
Tungsten Hairpin Filament

How does it work?

By boiling electron to top of energy barrier

$$J_c = AT^2 \exp(-E_f/kT)$$

- Temperature
- Work function



Tungsten Hairpin Filament

Why Tungsten Hairpin Filament:

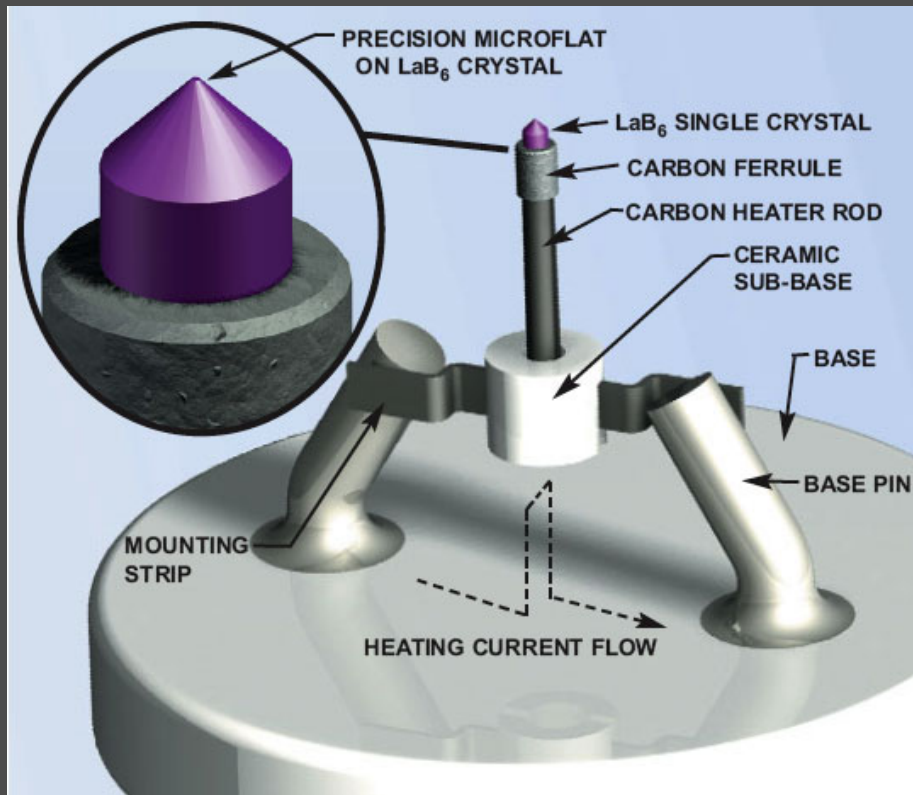
- Cheap to make and use
- Only needs modest-vacuum
- Last tens of hours

For operating in 100kV its brightness is $3 \times 10^5 \text{ A cm}^{-2} \text{ sr}^{-1}$



Lanthanum Hexa-Boride Crystal

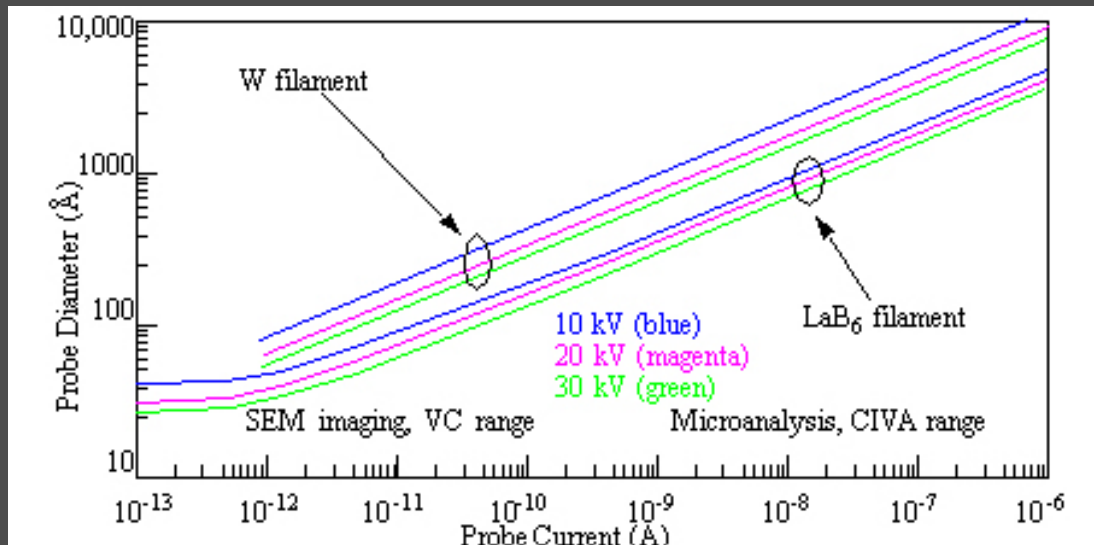
This filament is also a thermal filament. However, it has lower work function as tungsten, which results to better efficiency.



Lanthanum Hexa-Boride Crystal

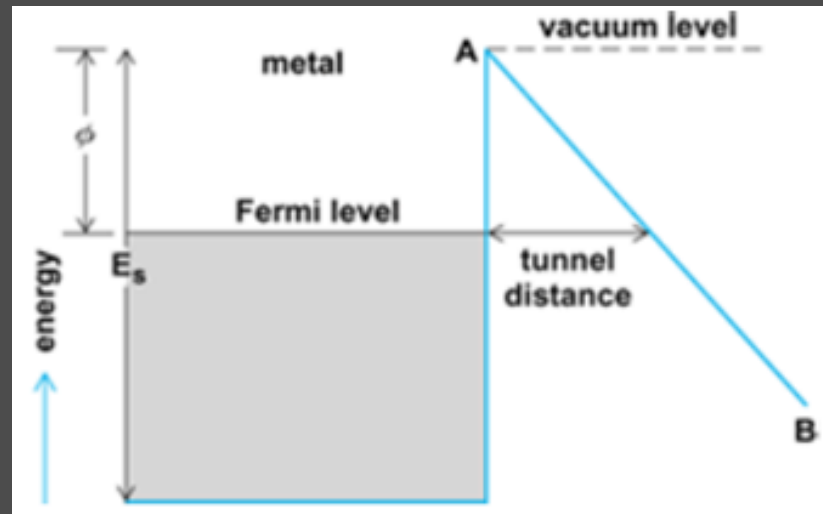
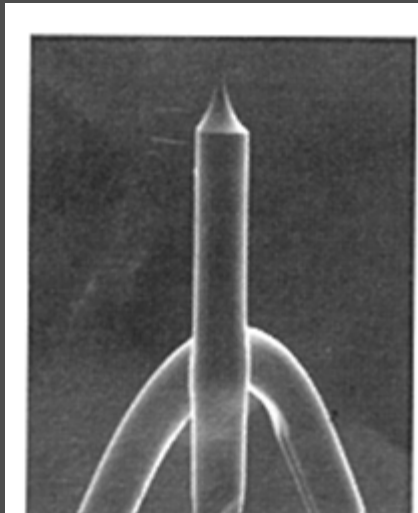
What are the differences of LaB6 filaments and Tungsten ones?

- Higher current in small probes
- More Brightness as high as $10^7 \text{ A cm}^{-2} \text{ sr}^{-1}$ at 100kV



Cold Field Emission

- Electrons 'tunnel out' from a tungsten wire because of the high field obtained by using a sharp tip (100nm) and a high voltage (3-4kV).
- The tip is usually a $\langle 111 \rangle$ orientation crystal of Tungsten.



Cold Field Emission

The resulted current density is described by the Fowler-Nordheim equation:

$$J_{the} = A_{FN} \cdot E_{FN}^2 \cdot e^{-B_{FN}/E_{FN}}$$

A and B are constants and E is the applied electric field. Surprisingly this equation is independent of temperature. (So **cold** is not a completely right term here!)



Cold Field Emission

Cold Field Emission Guns:

- Need Ultra High Vacuum
- Have a very long life
- Give very high performance
- The resulted brightness can be as high as 10000 times of conventional Tungsten filaments.

 **Hitachi High Technologies America, Inc.**

&

JEOL

are companies who use Cold Field Emission Guns in their products



Cold Field Emission

- Cleanness of the tip is very important in these electron guns.
- Even at 10^{-6} Torr a monolayer of gas deposit on the tip in every second.
- Flashing is the name of cleaning process in these instruments.
- Flashing means heating the tip to white heat for a few second. It will burns off the deposited gas.
- On Hitachi S4700, S4800 (Ours!) and S5500 the tip must be re-flashed every 8-12 hours of operation. (The machine will warn you automatically.)

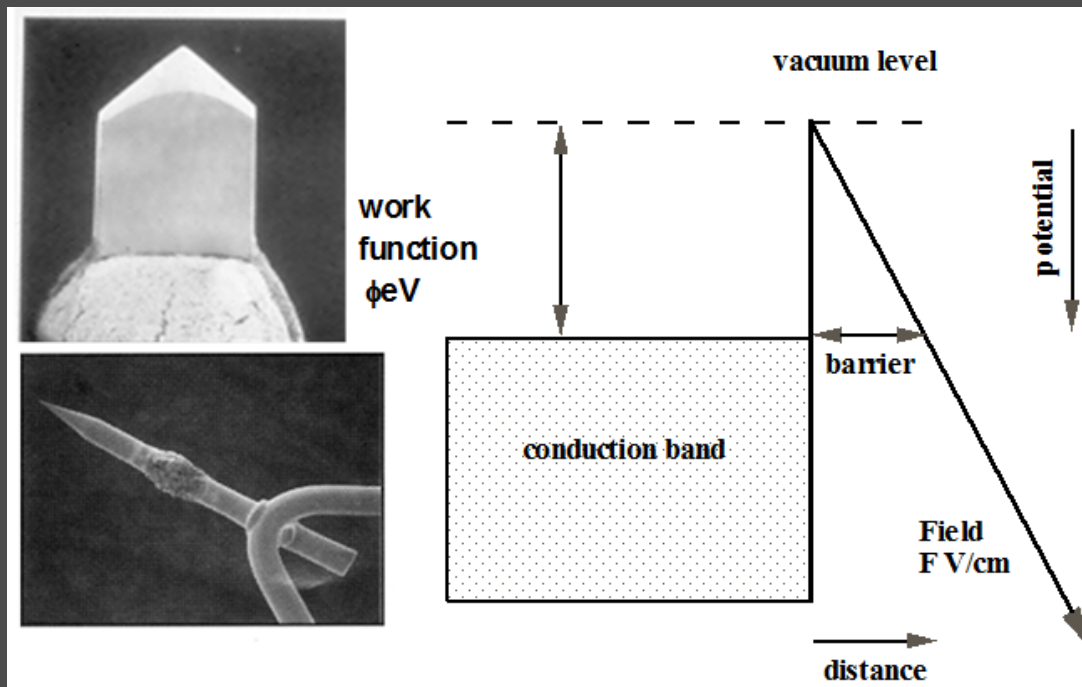


S4800



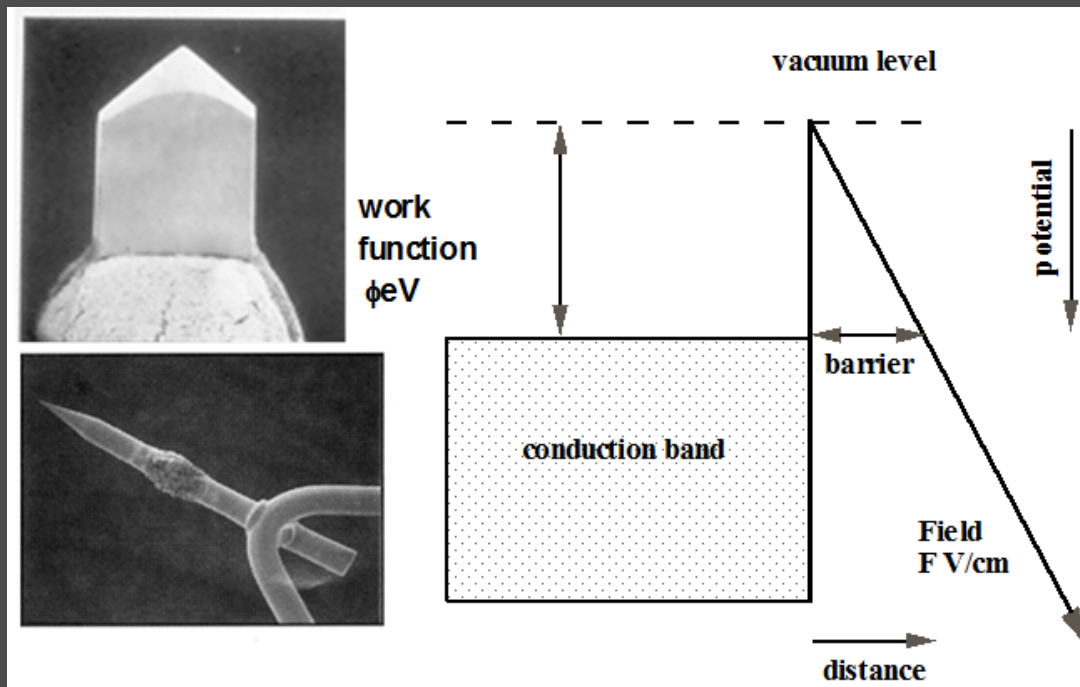
Schotky

Same as Cold Field Emission guns, a voltage is applied to the emitter in order to reduce the barrier height.



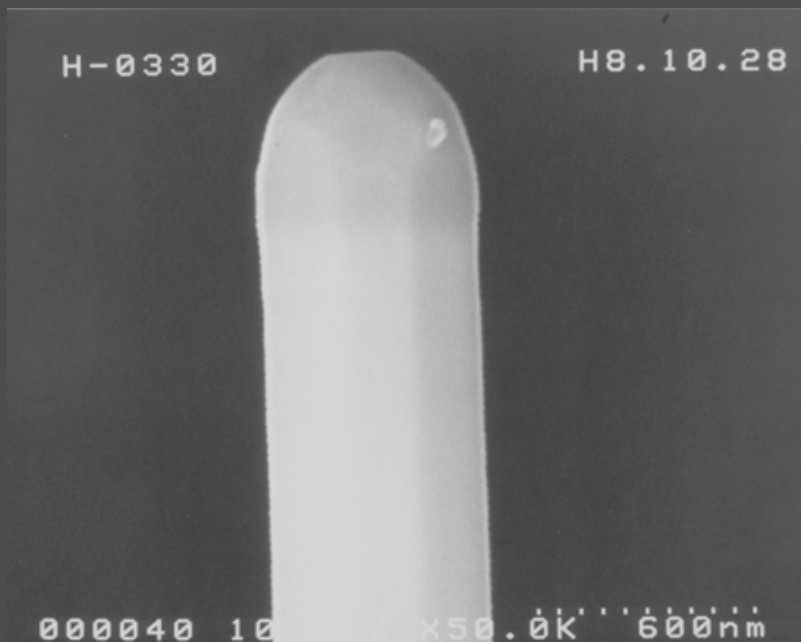
Schotky

As you can see in the picture, ZrO₂ is also added to the emitter in order to reduce the work function.



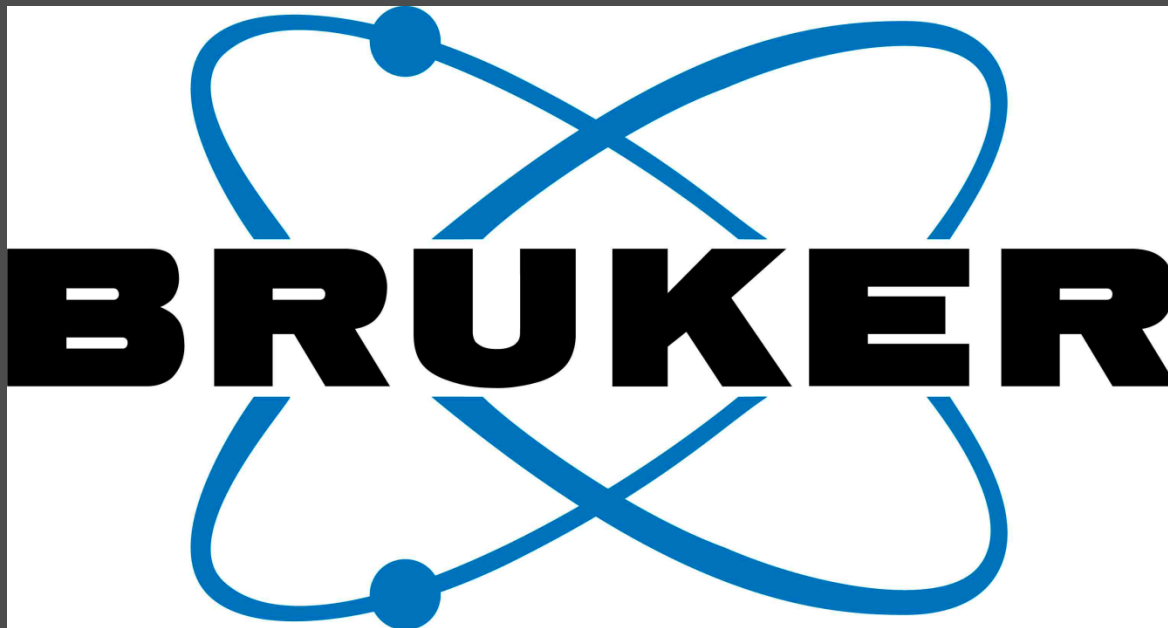
Schotky

- These guns runs at 1750K.
- These guns are NOT field emission guns, because if you turn off the heat, there will be no emission. Furthermore, the tip is not sharp at all.
- Actually these are Field Assisted Thermionic Source.
- They can work 24/7 for one to two years. It is determined by depleting the ZrO_2 coat.



Schotky

Emission rate for these guns are very high. Cold Field Emission guns are less useful for EDS systems, and completely useless for e-beam lithography.



Thank you for your time

