A BEGINNER'S GUIDE TO THE TRANSMISSION ELECTRON MICROSCOPE (TEM)

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While the Light Microscope (LM) has already had more than three centuries of development and refinement, the Electron Microscopy (EM) only started its development in the 1930s after it was discovered that the path of electrons can be deflected under a magnetic field. It then opened the door for another thousand fold increase in magnification over what LM could offer. As for resolving power, LM, (even augmented with "Super Resolution"), is still no match to that of a basic TEM, which has a native resolution measured in Angstroms. This presentation provides a quick introduction to the workings of the TEM, in as simple a way as possible, for those who are entering the field. These basic concepts can help them to be proficient users of the instrument and in turn achieving quality results for their research.

Properties of electrons making them suitable in high resolution imaging

- electrons have properties of waves.
- the path of electrons can be focused by magnetic lenses in the same way that light can be focused by optical lens.
- the wavelength of electrons are much shorter than that of photons ==> much better resolution

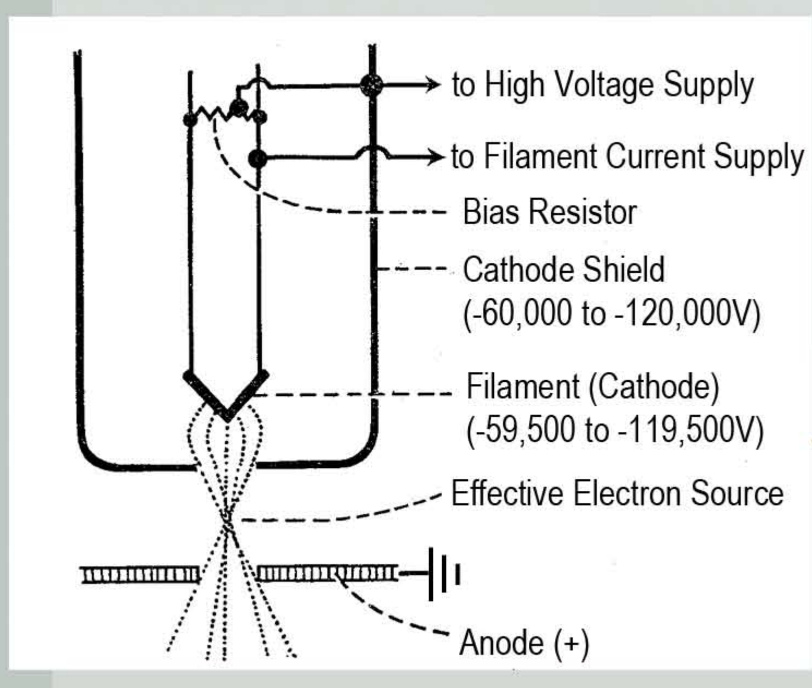
However, the theoretical maximum resolution cannot be achieved even in the best built EM

eg. at 100 KV, theorectical resolution = 0.039 Å (same formula as in ligtht microscopy); achieveable resolution is only ~ 2 - 3 Å.

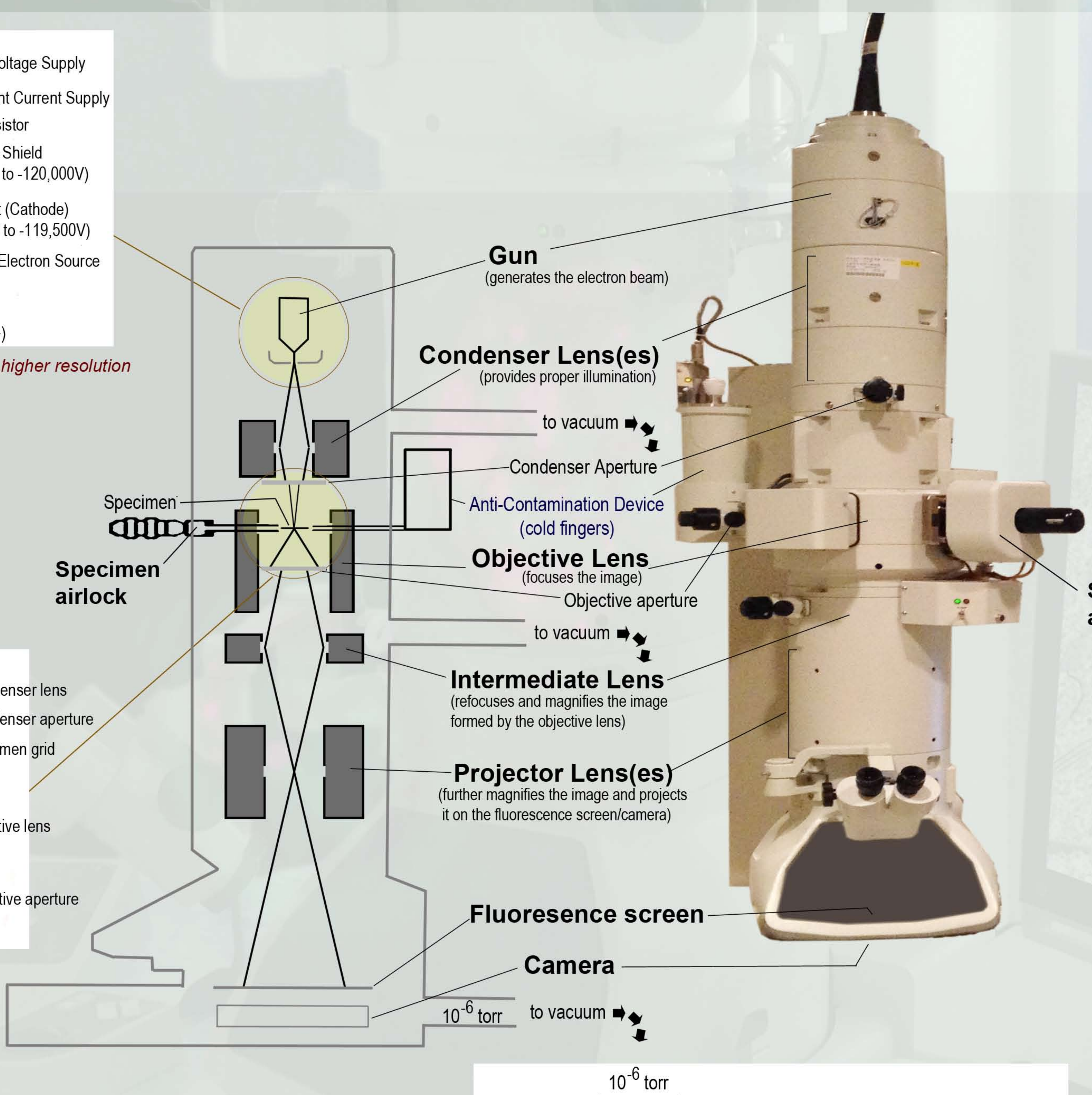
Reasons: inability to manufacture magnetic lenses to perfection; instability in HV and lens circuits; diffraction and various lens aberrations (spherical aberration, chromatic aberration, astigmatism, distortion, etc.)

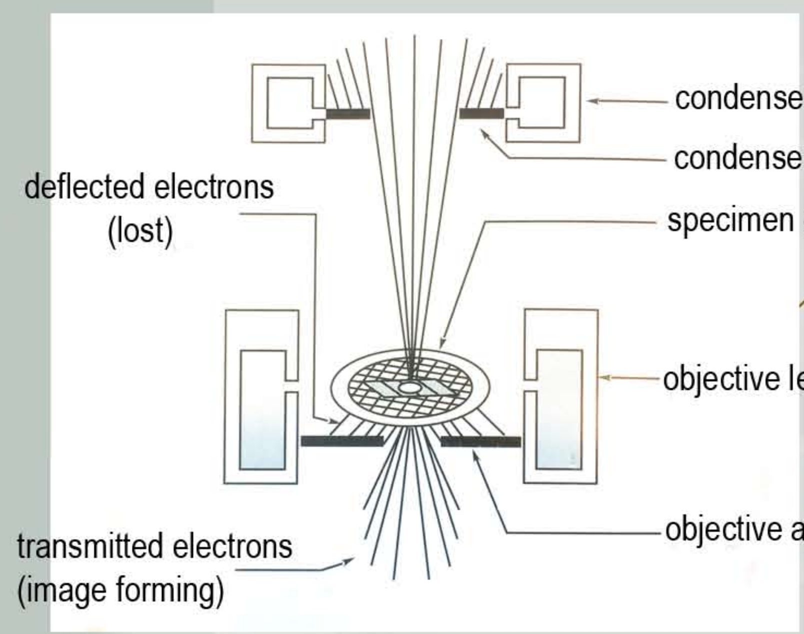
$$d = \frac{0.61\,\lambda}{n \sin\alpha}$$

d = minimum distance where two point objects can be resolved
λ = wavelength of illuminating light
n = refractive index of medium between lens and sample
α = half angle of the cone of illuminating light accepted by the lens
$n \sin\alpha$ is often expressed as NA (numerical aperture)



Note: higher voltage ==> shorter λ ==> higher resolution



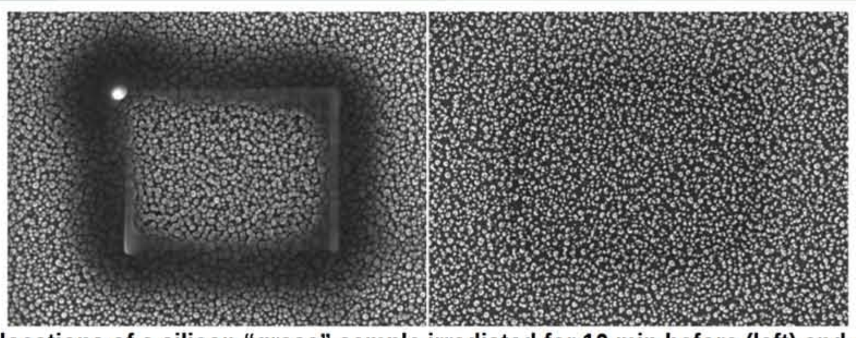


Apertures:

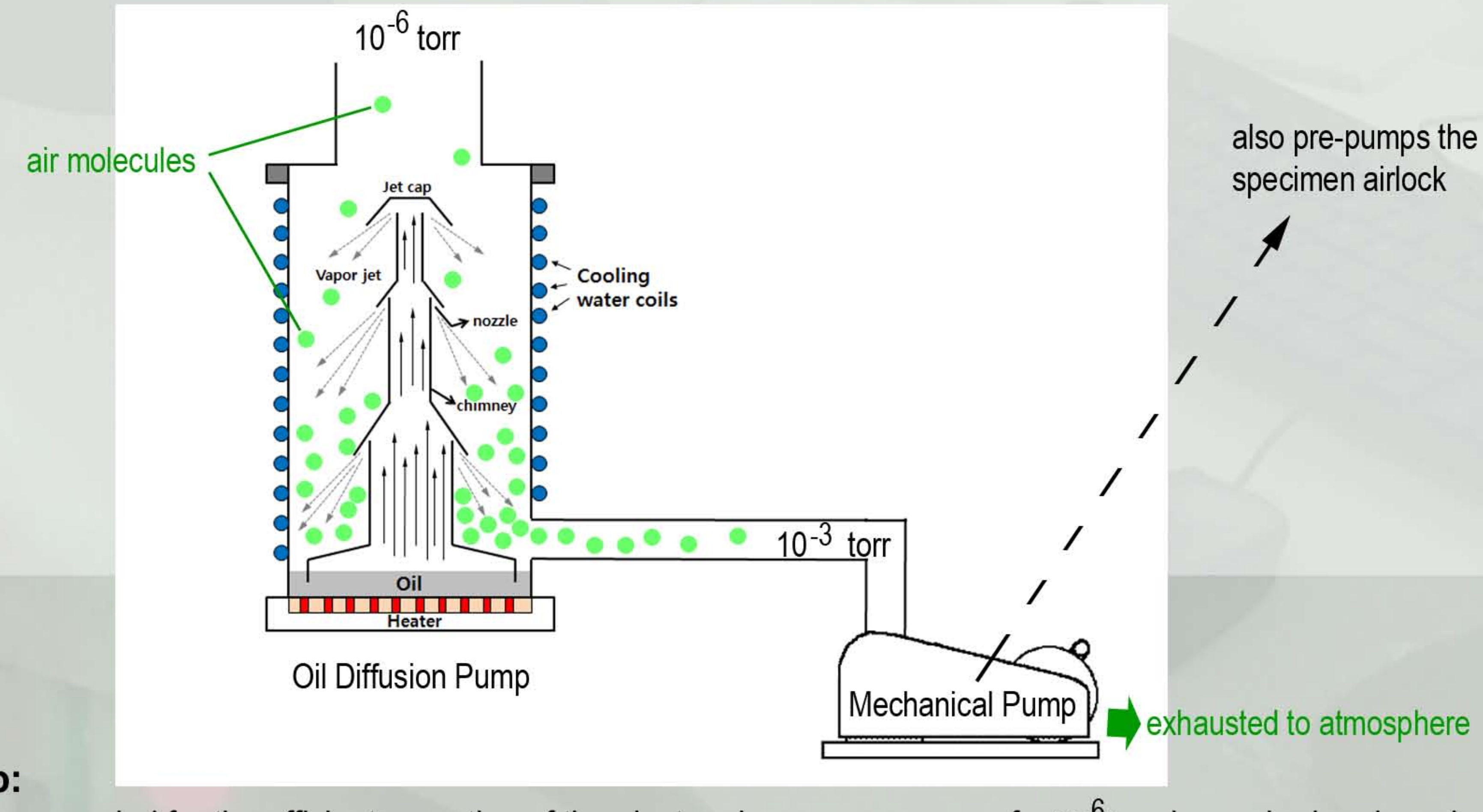
- ensure only the central portion of the beam is used .... minimizing various aberrations.
- block off scattered electrons ..... increasing contrast and resolution.

Anti-Contamination Device (Cold Fingers)**:**

- keeping the area around the specimen ultra-cold to trap hydrocarbon gas molecules (from diffusion pump back-streaming and/or human's finger grease) .... such contaimants can get polymerized under the beam and deposited onto the surface of the specimen.



Two locations of a silicon "grass" sample irradiated for 10 min before (left) and after (right) the use of Evactron anti-contamination device. 50 000x



Oil Diffusion Pump:

- provides the high vacuum needed for the efficient operation of the electron beam, a vacumm of ~10^{-6} torr is required and can be achieved with an oil Diffusion Pump (heated oil generates jet streams of vaporized oil, pulling air molecules towards the bottom of the pump and then evacuated by a Mechanican pump; oil vapor condenses to oil on the cooled wall, draining back to the heater to repeat the cycle.
- the Diffusion Pump cannot work from atmospheric pressure and must be "pre-pumped" by a Mechanical Pump to ~10^{-3} torr before it can operate. (the Mechanical Pump cannot pump further than 10^{-3} torr, so it works in tandem with the Diffusion Pump to reach the final vacuum.