Wavicle Theory

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1 Physical Principles

Optical microscopes use reflected or transmitted photons in the visible range (400 - 700 nm wavelength) to magnify specimens. The resolving power of a microscope is related to the wavelength of the particles it uses to produce images, therefore, optical systems are physically limited to around a 200 nm resolution [1]. Electrons, although not typically thought of as having a wavelength, are quantum mechanical objects and behave as waves and particles. The wavelength of an electron is called its de Broglie wavelength and is found as

$$\lambda = \frac{h}{p} \tag{1}$$

where λ is the de Broglie wavelength, h is the Planck constant $4.136{\cdot}10^{-15}$ eV·s, and p is the momentum of the particle. Neglecting relativistic effects which are less than 1% at the energies found inside an SEM, we can substitute the Newtonian kinetic energy formula $E = \frac{p^2}{2m}$ into equation 1 to find

$$\lambda = \frac{h}{\sqrt{2mE}} \tag{2}$$

where E is the energy of the electron in electronvolts and m is the electron mass, 510.9 keV/c^2. Assuming an electron is accelerated through a potential difference of 10 kV (giving it an energy of 10 keV), we can easily use equation 2 to find that its wavelength is on the order of 0.01 nm. In reality, the resolution of an SEM is two orders of magnitude greater than this due to various limiting factors, roughly 1 - 20 nm depending on the specific SEM machine and its configuration [2].

References

[1] "The diffraction barrier in optical microscopy." [Online]. Available: https://www.microscopyu.com/techniques/super-resolution/the-diffraction-barrier-in-optical-microscopy

[2] "Scanning electron microscopy," Aug 2020. [Online]. Available: https://www.nanoscience.com/techniques/scanning-electron-microscopy/