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Advantages and Disadvantages of Low-voltage TEM for the Imaging and Spectroscopy of Organic and Inorganic Materials

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The correction of TEM-lens aberrations has made atomic resolution possible even at low accelerating voltages. However, the image resolution for most organic and some inorganic specimens is limited by radiation damage, and can be a factor of 10 or 100 worse than the electron-optical resolution. Radiolysis, electrostatic charging and thermal effects are the main damage mechanisms in insulating materials, whereas knock-on displacement predominates in metals and semiconductors. The influence of radiolysis can be reduced by lowering the specimen temperature and by coating the specimen or increasing its thickness. Charging and thermal effects can be controlled by reducing the incident-beam current, at the expense of data-recording time. Knock-on displacement can sometimes be avoided by reducing the incident-electron energy below some threshold value, which is typically exceeds 200kV for atom displacement within a crystal but is considerably lower for displacement from the surface (electron-induced sputtering) or along the surface (beam-induced atom motion). The dose-limited resolution also depends on the contrast and electron-collection efficiency of the imaging or spectroscopy mode employed in the TEM or STEM. It is potentially better for phase-contrast imaging, compared to bright-field or dark-field scattering-contrast methods. Resolution also depends on the detective quantum efficiency (DQE) of the electron detector, and an improvement by a factor of two is possible by using an electron-counting detector rather than regular CCD recording.