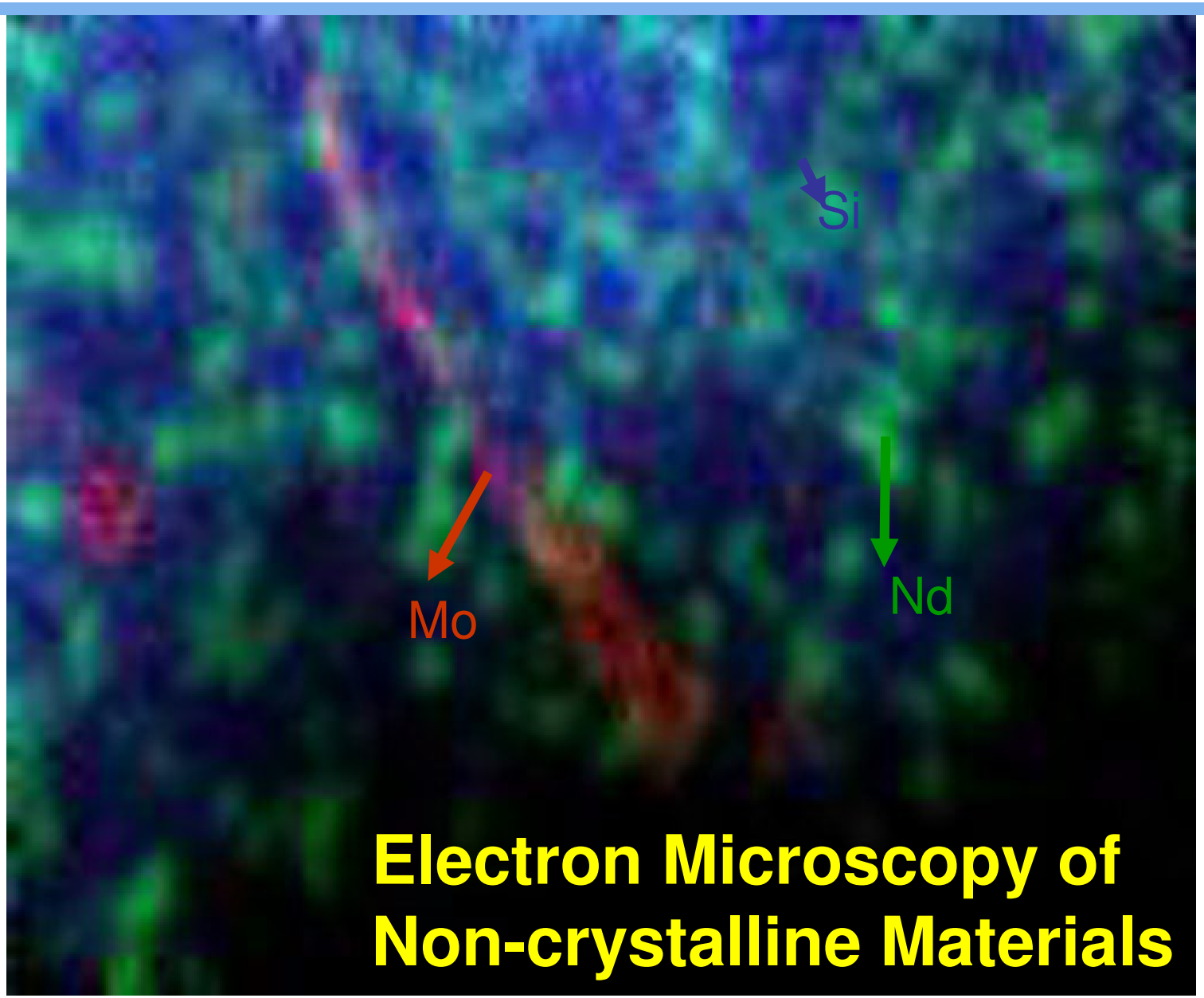

Electron Microscopy of Non-crystalline Materials

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1. **Overview: (T)EM for glasses, why?**
   - SEM versus TEM; imaging modes; electron diffraction;
   - specimen preparation;

2. **Analytical electron microscopy**
   - EDX; EELS; ELNES; chemical mapping

3. **Special Topics:** Irradiation Damage; Latest Developments

4. **Question Time and/or EELS+HREM Software Demo**

Recommended Literature

Literature List:

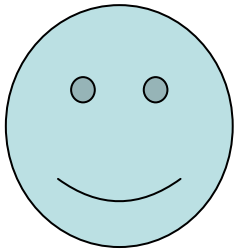
D.B. Williams, C.B. Carter, Transmission Electron Microscopy, Paperback, vol 1-4. TEM only, comprehensive and easy to read.

P. Goodhew, J. Humphreys, R. Beanland, Electron Microscopy and Analysis. SEM and TEM + EDX, very simple introductory level.

R Egerton, Electron Energy Loss Spectroscopy in the Electron Microscope. EELS only monograph, very comprehensive.

R Brydson, Electron Energy Loss Spectroscopy. Paperback, Introduction to EELS, short but still enough details.

W Vogel, Glass Chemistry, Springer; Detailed chapter on TEM specific to glasses and phase separation (currently out of print)

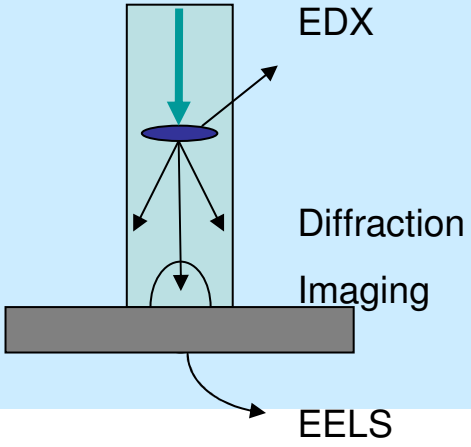


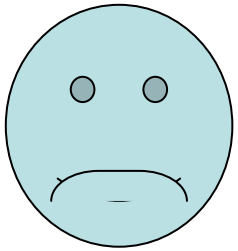
Advantages of (T)EM:

- Many techniques in one tool:

- High Spatial Resolution: 0.1 – 2nm

- Good counting statistics (little volume of material needed for clean signal)



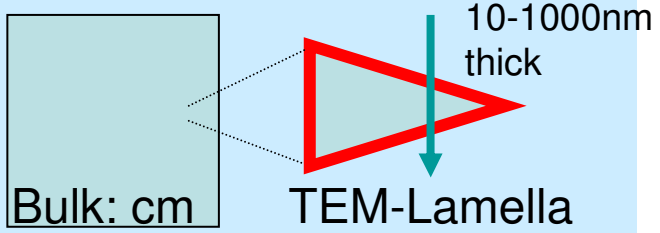


Disadvantages of (T)EM:

- "Near-surface" sensitivity (neither true surface nor true bulk)

- Irradiation damage by electrons

- Effort of specimen preparation



(red: surface area
for SPM: 0.5nm thick)

Comparison of

SEM

Typical Resolution: 3-5nm (W gun); 1nm (Field emission gun)

Typical Specimen: (polished) surface of glass block < 1cm diameter

Imaging Modes: Secondary electrons, backscattered, EDX

Main applications: crystals in glass, glass-ceramics, homogeneity testing, chemical mapping, surface roughness, fracture and cracks

Main limitations: Irradiation damage, beam interaction volume

and

TEM

Typical Resolution: 0.15 – 0.25 nm {0.1nm with aberration corrector}

Typical Specimen: sub-μm glass fragments on carbon film or ion milled glass disk (3mm diameter, perforated in centre).

Imaging Modes: Bright/ Dark-field, STEM, EELS, EDX, Diffraction

Main applications: crystallites and nanoparticles, nano-homogeneity and phase separation, fine scale chemical mapping, coordination and valence of ions, radial distribution functions from diffraction

Main limitations: Irradiation damage, preparation artefacts