John de Laeter Centre

• Major research infrastructure hub at Curtin University, Perth, W.A.
• ~$30M worth of microscopes, spectrometers, diffractometers and experimental facilities
• AuScope partner, Microscopy Australia link node
Microscopy & Microanalysis Facility (MMF)

The facility provides a broad range of advanced microanalysis instrumentation as well as expertise in materials and earth science to enable high impact research and provide relevant services to industry. 

Primary capabilities;
- High resolution imaging (SEM, TEM)
- Spatially resolved Elemental analysis (EDS)
- Phase & orientation analysis (EBSD)
- Quantitative mineral analysis (Q-XRD)
- Ion beam sample manipulation including TEM & T-EBSD lamella preparation (FIB)
- Automated mineralogy (TIMA)
- Light microscopy
MMF; John de Laeter building (301.020)
Electron microscope Vs light microscope

<table>
<thead>
<tr>
<th>1m</th>
<th>10cm</th>
<th>1cm</th>
<th>1mm</th>
<th>100μm</th>
<th>10μm</th>
<th>1μm</th>
<th>100nm</th>
<th>10nm</th>
<th>1nm</th>
<th>0.1nm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1m</td>
<td>10⁻¹m</td>
<td>10⁻²m</td>
<td>10⁻³m</td>
<td>10⁻⁴m</td>
<td>10⁻⁵m</td>
<td>10⁻⁶m</td>
<td>10⁻⁷m</td>
<td>10⁻⁸m</td>
<td>10⁻⁹m</td>
<td>10⁻¹⁰m</td>
</tr>
</tbody>
</table>

Eye

Light Microscope

Electron Microscope

child  hand  finger  hair  blood cell  bacteria  virus  DNA  glucose  atom
## Electron microscope Vs light microscope

<table>
<thead>
<tr>
<th>Feature</th>
<th>Light Microscope</th>
<th>Electron Microscope</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highest practical magnification</td>
<td>About 1000-1500</td>
<td>Over 100,000</td>
</tr>
<tr>
<td>Best resolution</td>
<td>0.2 μm</td>
<td>0.5 nm</td>
</tr>
<tr>
<td>Radiation source</td>
<td>Visible light</td>
<td>Electron beam</td>
</tr>
<tr>
<td>Medium of travel</td>
<td>Air</td>
<td>High vacuum</td>
</tr>
<tr>
<td>Type of lens</td>
<td>Glass</td>
<td>Electromagnet</td>
</tr>
<tr>
<td>Source of contrast</td>
<td>Differential light absorption</td>
<td>Scattering of electrons</td>
</tr>
<tr>
<td>Focusing mechanism</td>
<td>Adjust lens position mechanically</td>
<td>Adjust current to the magnetic lens</td>
</tr>
<tr>
<td>Method of changing magnification</td>
<td>Switch the objective lens or eye piece</td>
<td>Adjust current to the magnetic lens</td>
</tr>
<tr>
<td>Specimen mount</td>
<td>Glass slide</td>
<td>Metal grid (usually copper)</td>
</tr>
</tbody>
</table>
Electron - specimen interactions

Primary electron beam

- Backscattered Electrons
- Secondary Electrons
- Auger Electrons
- Thermal
- Inelastically Scattered Electrons

- Elastically Scattered Electrons
- Cathodoluminescence
- X-rays

SEM

TEM
More that just pretty pictures
Microanalysis

Mineral sample: Pattern Quality + Phase Map
Px: 1.66 µm Map Size: 1000 x 750
Scanning Electron Microscopes

Zeiss Neon 40ESB dual beam field emission SEM and focussed ion beam (FIB)
Tescan MIRA3 field emission SEM
Zeiss EVO SEM
Tescan TIMA (installed this week)
Second FIB-SEM (coming soon)
Zeiss Neon 40ESB (FIB-SEM)

A dual column, field emission SEM and focussed ion beam (FIB) microscope.

The NEON is capable of high resolution electron imaging and can use the ion beam for precision milling of samples to observe subsurface features or prepare thin sections for TEM and T-EBSD analysis.
Tescan LYRA FIB-SEM with ToF-SIMS

**Model:** Tescan LYRA3 GM

**Ion column:** Cobra (monoisotopic $^{69}$Ga$^+$)

**FIB resolution:** <2.5 nm at 30 kV

**Accelerating voltage:** 0.5 kV – 30 kV

**Probe current:** 1 pA – 50 nA

**Deposition:** MonoGIS with Pt reservoir

**Nanomanipulator:** SmarAct

**Electron column:** MIRA (field emission)

**SEM resolution:** 1 nm at 30 kV (In-Beam SE)

**Additional detectors:** Tofwerk ToF-SIMS, Oxford EDS, Oxford EBSD

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**XRD, XRF, ICP**

**Slice & view, 3D TOF-SIMS**

**APT, TEM tomography**

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**Bulk**

**Surface**

**Sub-surface**

**2D atomic scale**

**3D atomic scale**

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**Imaging, EDS, EBSD, TOF-SIMS**

**TKD, TEM on site specific lamellae**

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**Millimeter → 10s µm → µm → 10s nm → nm → sub-nm**
TEM Lamella Preparation on the Curtin FIB-SEM

Area Selection
Cutting the trenches
Cutting the U-cut
Removing the lamella
Mounting the lamella
Thinning and polishing the lamella

Sample: Fly ash particle containing freecalc. Images courtesy of William Rickard
Figure 4. EBSD phase map (left) and an all-ruler orientation map (right) from a meteorite. The colours in the phase map represent quartz (blue), anorthite (yellow), augite (green), enstatite (brown), olivine (aqua), ilmenite (fushia); chromite (red) and zircon (orange). Number of points (diffraction patterns) = 113,208. Collection time ~50mins.
Transmission electron microscopy (TEM)

- Transmission Electron Microscope is capable of producing images at very high magnifications with ultimate resolution of almost 0.1 nm (less than one millionth of a millimetre!).

Jeol 2100 TEM decommissioned in July 2016

FEI Talos TEM commissioned in 2017
TEM in nano-material research

Elemental mapping in nano-scale

Elemental mapping in grain boundaries

Core-shell structures
HR TEM and diffraction in nano-particle research

TEM analysis on coherent particles and FIB milled multilayer samples

Dark field TEM of nano particle

Ref. MZ Quadir et al
Acta Mat 55(2007)5438

FIB milled multi layered pillars

Ref. Pranesh Dowal and Zakaria Quadir et al.
Thin solid film 519(2011) 3213

TEM: before deformation

TEM: after deformation
Atom probe tip

TEM image
Electron microscopy training

User category A: Trainee
Learn to operate under constant supervision

User category B: Independent user
Operate while support staff members are around

User category C: Expert user
Operate independently with some maintenance skills

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Our people (instrument specialists and scientists)

Ms. Veronica Avery: Bruker D8A and D8D XRD instrument specialist

Ms. Kelly Merigot: FEI TEM, Tescan TIMA specialist

Ms. Elaine Miller: Zeiss Evo, Zeiss Neon, and Tescan Mira specialist

Dr. Zakaria Quadir: Physical metallurgist (Fe, Al, Ni, Ti and composite metals) and electron microscopist

Dr. Mark Aylmore: Mineralogist with specialisation in Digital mineralogy

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Dr. Will Rickard: Material scientist and Tescan Lyra, FIB SEM and ToF SIMs specialist

Dr. Matthew Rowles: Physicist and Bruker SAXS and in-situ diffraction specialist.

Dr. David Saxey: Material scientist and Atom Probe Tomography (ATP) specialist