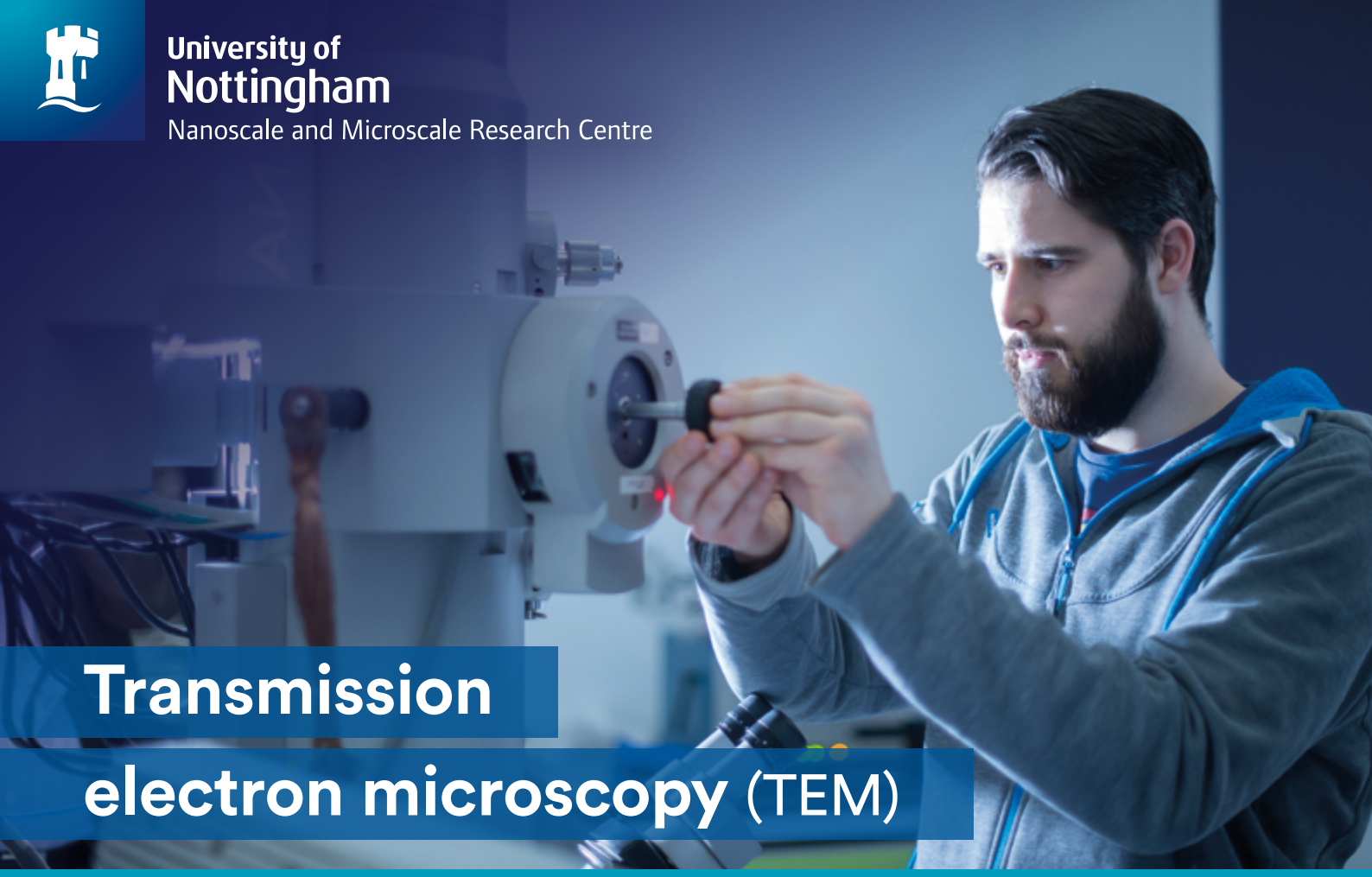
University of Nottingham
Nanoscale and Microscale Research Centre



Transmission electron microscopy (TEM)

Transmission electron microscopy is an electron microscopy technique capable of imaging with a resolution down to an Ångstrom scale (~0.19 nm). It uses the spatial contrast generated by variations in electron transmission as they pass through specially prepared ultra-thin specimens to generate an image.

TEM can also provide advanced structural, crystallographic and chemical characterisation of samples on the nanoscale.

Capabilities

- Ultra-high magnification and resolution imaging.
- Micro- and nano-structural characterisation.
- Simultaneous elemental and compositional analysis.
- Thickness, pressure and process measurements.
- Nanotomograhy (3D profiling).

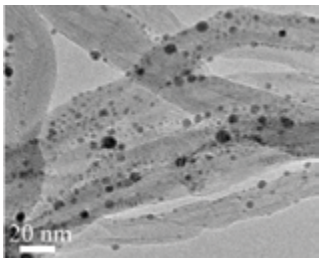
Typical applications

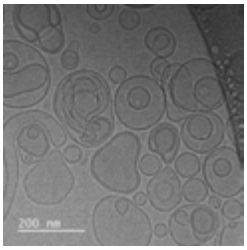
- Nanostructural analysis and component identification.
- Interrogation of coating, multi-phase alloy, fibre (and other) ultrastructures.
- Tissue and cellular imaging of with full-structure visualisation.
- Cryogenic visualisation of solution or suspension based nano-structures, such as liposomes.
- Small structure electron crystallography.

Imaging molecular assemblies

TEM offers nanoscale, high magnification imaging and chemical analysis. The smallest structural systems down to the atomic scale can be imaged and characterised in real time. Here silver nanoparticles can be visualised as having been successfully encapsulated in multi-walled carbon nanotube. Such capability ensures complex physicochemical processes to produce novel materials with bespoke characteristics can be validated for example size control, electron transport, heat transfer and others.

JA Watts, MW Fay, GA Rance, PD Brown, AN Khlobystovbc. *Carbon* 139 (2018), 538-544.





Electron transfer across biological membranes

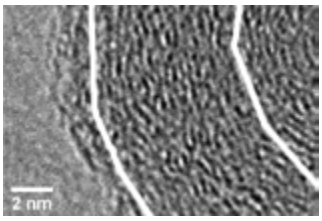
TEM was used to investigate the use of carbon nanotube porins (CNTPs) as wireless bipolar electrodes and artificial voltage-dependent anion-selective channels (switchable porins within the membrane) within biological systems. CNTPs were self-inserted into giant unilamellar vesicles and the fine-details of subsequent CNTP presence within the membrane was visualised with use of a cryogenic-TEM method.

JM Hicks, YC Yao, S Barber, N Neate, JA Watts, A Noy, FJ Rawson. *Small* 17 (2021), 2102517.

Quantifying soot nanostructures

TEM offers unique system diagnostics by combining molecular level structural and chemical information, such as particle morphology, size distribution, elemental presence/absence and others. One such example is soot-nanostructures. TEM analysis revealed the atomic structuring of the nano-sized soot-in-oil particulates and agglomerates from a gasoline direct injection deposit. This morphological information was used to evaluate image processing parameters, relevant for lattice fringe analysis, a common method to quantify soot nanostructures. White lines indicate the region of interest in this investigation.

SA Pfau, A La Rocca, MW Fay. *Combustion and Flame* 211 (2020), 430-444.



Our facilities

JEOL 2100F FEG-TEM

- Field emission electron gun (FEG) instrument, for use at 100kV and 200kV.
- A point resolution of 0.19nm.
- Bright field STEM detector.
- High angle annular dark field (HAADF) STEM detector.
- Gatan K3 IS 23.6 megapixel, electron counting direct detection (DDE) camera. Capable of 150 frames per second at full view, or >3500fps at 256×256 pixels.
- Gatan Tridiem Filter Spectrometer and 2K x 2K CCD camera, configured for use at 100kV and 200kV. Enables elemental mapping via electron energy loss spectroscopy (EELS) and energy filtered TEM (EFTEM).
- Oxford Instruments 80mm X-Max system for energy dispersive X-ray spectroscopy (EDS) analysis.
- Room temperature tomography: Gatan 916 room temperature tomography holder with up to 80 degrees tilt.
- Cryo-tomography and cryo transfer: Gatan 914 and Gatan Elsa Cryo-tomography holders including cold controller/cryo-workstation.
- Electrical holder. Gatan 936 DT analytical LN2 holder with temperature controller with EBIC stage option (four electrical connections) plus Smart EBIC.
- Gatan 4004 heating and gas exchange holder. Allows samples to be heated up to 800 °C, or air sensitive sample analysis.

JEOL 2100+ TEM

- LaB6 TEM for high throughput, high versatility analysis at 80kV or 160kV.
- Gatan OneView camera. High-resolution, 16-megapixel CMOS camera. Capable of 25 full frames per second or 300fps at 512×512 pixels.
- Bright field STEM detector.
- Oxford Instruments X-MaxN 80 TLE EDS detector.
- Gatan Enfinium EELS detector.
- HADDF detector.
- Range of specialised sample rods including heating and cryogenic stages.
- MEMS Heating holder. DENSsolutions Wildfire S3 capable of analyses up to 1300°C with millisecond heat and quench speed, and nanoscale sample drift with step changes of hundreds of degrees. Enables EELS and EDS mapping at elevated temperatures.

FEI Tecnai G2 12 Biotwin

- 120 kV LaB6 TEM for high contrast imaging.
- Gatan SIS Megaview IV digital camera.
- Tomography compustage for tomographic characterisation.
- Cryo-stage for low temperature observation of temperature dependent or hydrated samples.
- Ideal for low-contrast, beam-sensitive biological specimens, or other soft materials such as polymers.
- Gatan Orius (4k x 2.6k) Camera with digital streaming video for high-resolution and TV rate imaging.

Find out how TEM could help with your applications, designs or solutions:

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nottingham.ac.uk/nmrc