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Dynamic Mechanics

Neil Bourne

University of Manchester
Rutherford Appleton Laboratory
Didcot, Oxfordshire, OX11 0FA, United Kingdom.
neil.bourne@manchester.ac.uk

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Damage and hydrodynamic regime

Bourne, N. K. (2013). *Materials in Mechanical Extremes; Fundamentals and Applications*. Cambridge University Press

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Natural Extremes

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State stability, defects and scaling

Mechanisms and scale



Defects and scale



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Science in the modern age

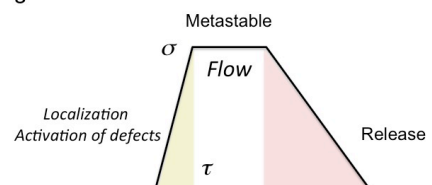
- **Discovery science**
Probing the bounds of natural science
- **Applied basic science**
Conducting accepted science in an applied context
- **Basic applied science**
Pursuing fundamental topics arising from the above

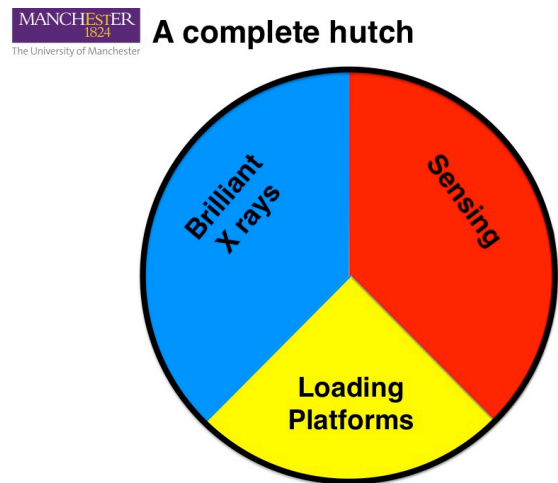
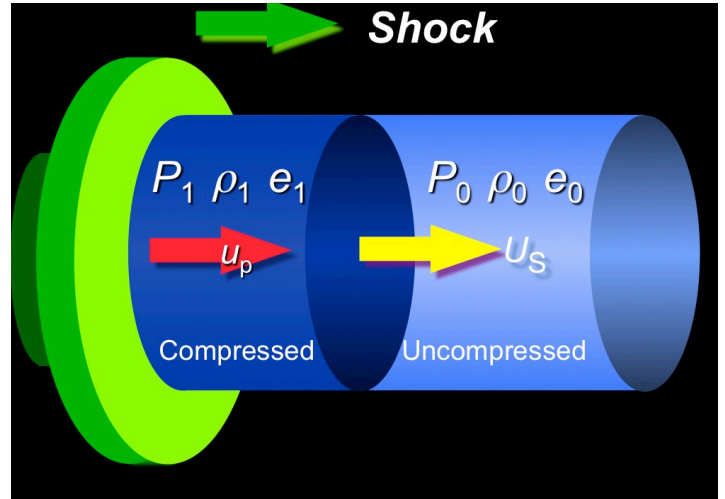
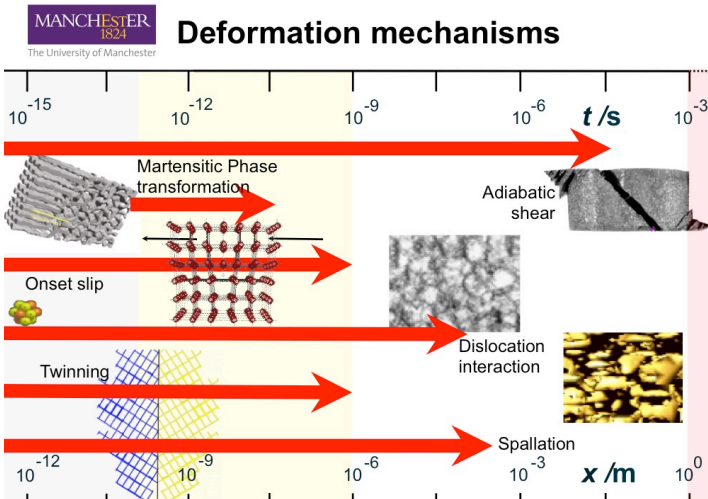
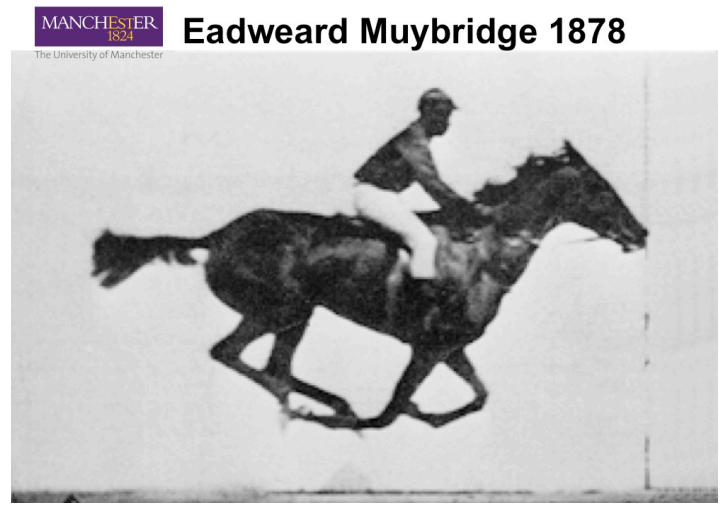
Alan Baddeley MRC

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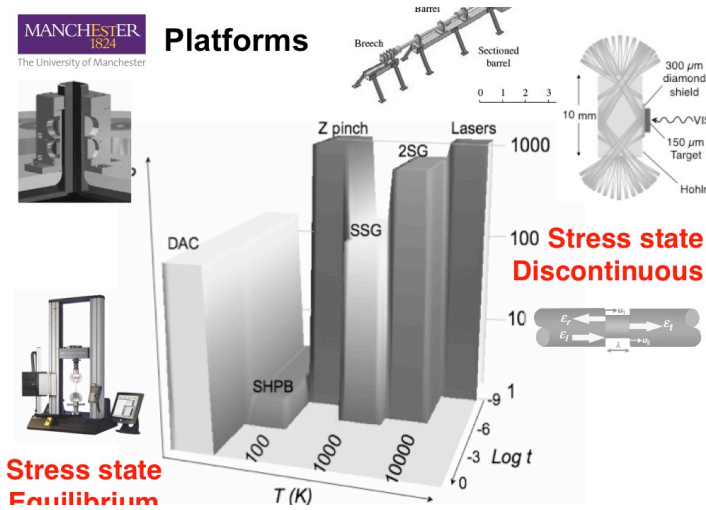
Probing deformation kinetics

- Use an impulse where one can specify
Pulse amplitude σ
Pulse duration τ
- Load in an idealised stress state
- Mechanism has a threshold and a duration
- Activated at CRSS (or defining P/T if chemistry occurs)
- All loading is finite

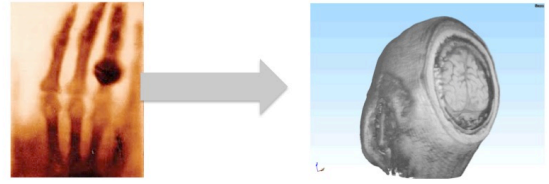




Platforms



Transforming light sources

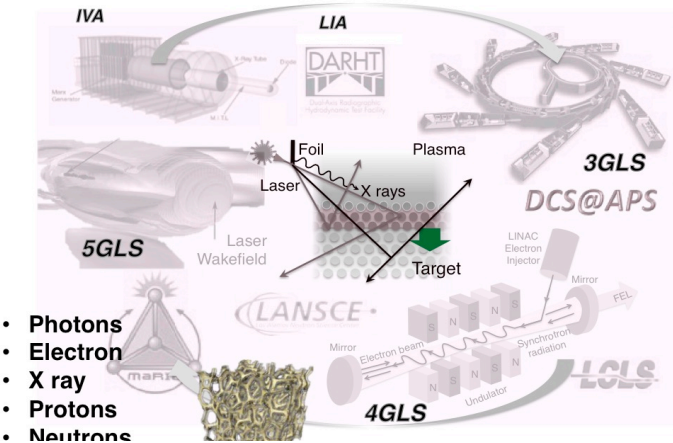


Röntgen 1895

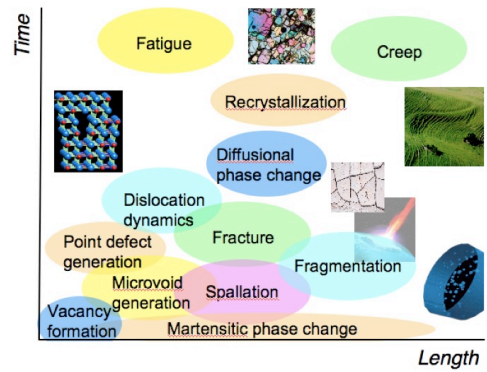
Non-invasive, label-free diffraction, imaging & spectroscopy
 Digital holographic microscopy
 Imaging; tomography & high-speed radiography
 Ptychography
 X ray absorption and emission spectroscopy
 But processes have kinetics

X ray diffraction
 X ray small and wide angle scattering
 X ray fluorescence
 Full-field TXM
et al...

Brilliant Light Sources



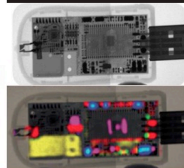
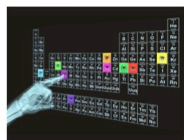
Micromechanics of failure



• **Fast and slow processes**
Chemistry: corrosion vs. Creep

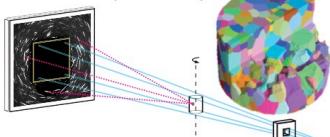
X ray/neutron imaging

- Labs in Turing building; Manchester, Diamond synchrotron
- Facilities and techniques including...



Diffraction Contrast Tomography (DCT)

- Non-destructive 3D grain mapping in lab
- Enables time dependent crystallographic evolution mapping
- Enables additional correlative microscopy workflows (XRM→EM)

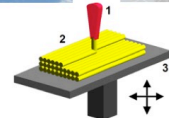
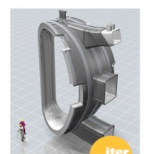
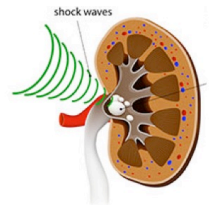


Colour Tomography

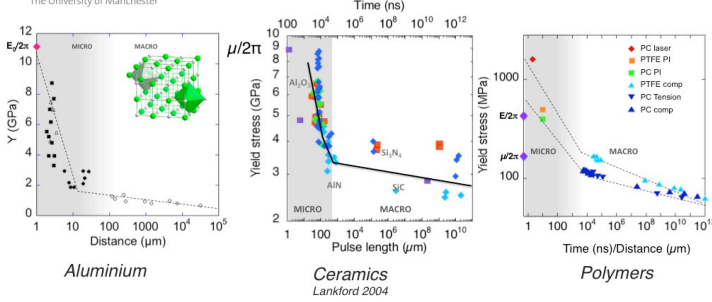
Cernik *et al.* see X-rays in colour (x-ray wavelengths)
 • Morphology and chemical structure
 • Identify structures 3D via X-ray fingerprint

Applications

- **Rock blasting**
 17 434 662 951 tonnes (2014)
 5 407 448 M\$
- **Medical physics**
- **Space engineering**
 5 250 M€
- **Protection**
- **Catalysis**
- **Energy**
 Fusion and fission
 Batteries
 Active and Irradiated materials
- **Advanced materials**
 Composites
 Graphenes, silicene
- **Advanced manufacturing**



Strength as a function of scale



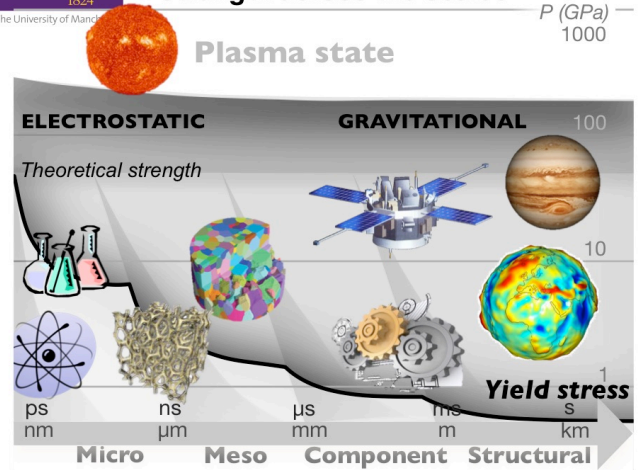
Strength has a direct correlation with volume element sampled

Bourne, N. K. (2015). "On strength at yield in condensed matter." Metallurgical and Materials Transactions A 46(10): 4491-4497.

Bourne, N. K. (2011). "Materials' Physics in Extremes: Akrology." Metallurgical and Materials Transactions A-Physical Metallurgy and Materials Science 42A(10): 2275-2284.

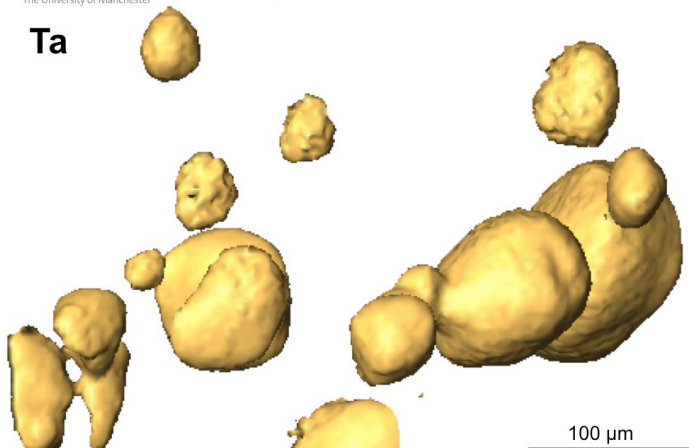
Strength across the scales

P (GPa) —
1000

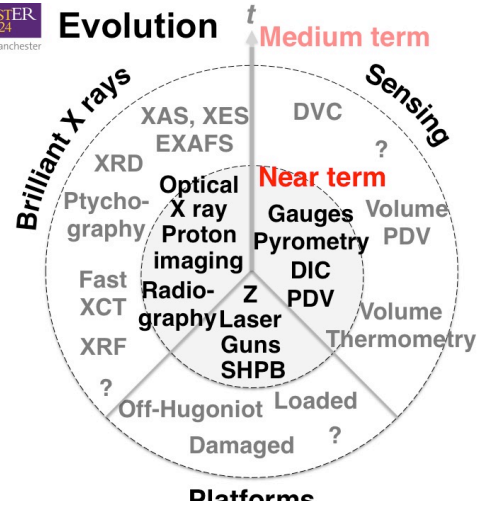


Damage quantification in spall

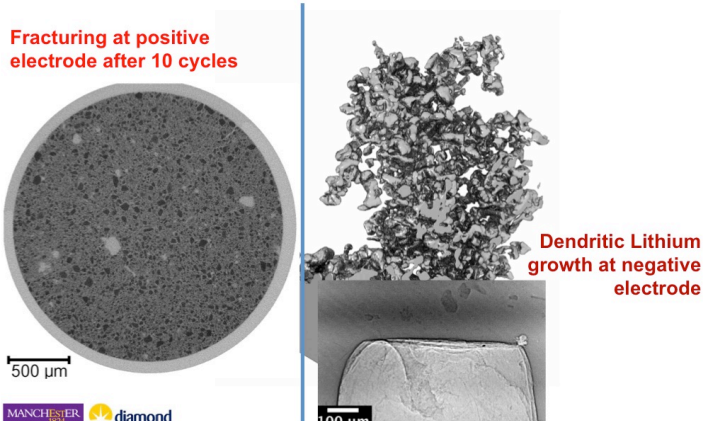
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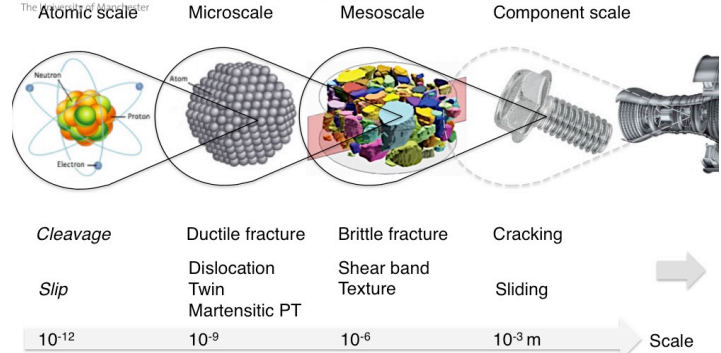
Evolution



Understanding lithium battery failure



Failure at different scales



- Defects significant at length scale of interaction *ca.* tenth of RVE for structure in *compression*; at largest defect in *tension*
- Populations and statistics of defects and damage



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• **Defects**

- Stacking defects
- Chemical defects
- Microcracks
- Second phases
- Joints

• **Accident investigation and safe regulation**

- Critical defects?
- Code V&V for design
- Regulation
- Qualification

Risk drives dynamic mechanics

Scale boundar: electronic & aravity bound: meso-



MANCHESTER 1824 **Light sources transform safety?**

