Materials Science Research – An Overview

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Introduction

- AWE has developed dedicated capabilities in
  - New/replacement materials development and qualification
  - Materials ageing and lifetime prediction and compatibility
  - Materials characterisation

- AWE provides chemistry and materials science expertise in the following areas:
  - High explosives research and analysis
  - Plutonium and uranium chemistry & metallurgy research
  - Non-metallic materials (organic and inorganic) research
  - Tritium science and technology
  - Radiochemistry, mass spectrometry and spectroscopy capability
Materials Science Research Division

Characterisation, Materials Life Assessment, New Materials Synthesis/Development

Actinide Chemistry and Metallurgy
Tritium Science, Handling and Storage
High Explosives Synthesis and Characterisation
Organic and Inorganic Materials R&D
Materials Modelling, Ageing and Compatibility
Spectroscopy and Sensors Development
Analytical Chemistry, Radiochemistry
Nuclear Forensic Science/Micro-Analysis

Slide 3
Materials Science Research Division

- Materials Life Assessment
- New Materials Synthesis / Development
- Characterisation

- Actinide Materials Group
  - Actinide Chemistry and Metallurgy
- Actinide Analysis Group
  - Gloveboxed Actinide Analysis
- Materials Systems Group
  - Organic and Inorganic Materials R&D
  - Spectroscopy and Sensors Development
- Tritium Technology Group
  - Tritium Science, Handling and Storage
- Explosives & Initiation Systems
  - Detonator Development & Design
- Explosive Materials Group
  - High Explosives Synthesis and R&D
- Analytical & Nuclear Chemistry
  - Nuclear Micro-Analysis/Forensics (CTBTO Lab)
Materials Systems

- **Organic Materials**
  - Ageing & Lifetime Assessment – *Multi-Material trials*
  - New Materials Synthesis and Development
  - New Characterisation and Analysis Methods

- **Metallic Materials**
  - Accelerated Ageing
  - Mechanical and Fracture Testing
  - Continuum Modelling of Manufacturing and Corrosion Processes

- **System Monitoring**
  - Sensor development
  - Materials Compatibility & Ageing
Multi-Material Trials

- Accelerated ageing experiments for multiple material combinations
- The atmosphere provides information regarding the degradation and interactions of materials within the vessel
- Designed to study the interactions between materials
- Provides data for system/sub-system life prediction models
New Characterisation and Analysis Methods

- Laser absorption spectroscopy
- Laser-induced breakdown spectroscopy
- Fibre optic sensors
- Micro-structured gas cells
- Logistics condition monitoring devices
- Embedded sensing

LIBS analysis of material samples
New Characterisation and Analysis Methods
Inorganic Surface Science Capability
- X-ray & UV photoelectron spectroscopy
- Auger electron spectroscopy
- Low energy electron diffraction
- Secondary ion mass spectrometry
- Molecular beam (O₂, H₂, H₂O, CO₂ and H₃CCOOH)
- Sputter source and gas-atomiser
- Metal vapour deposition
- Secondary Electron Multiplier
- Dedicated glovebox for sample handling
- Thermal desorption studies
- Mass spectrometer
- Vacuum transfer vessel
Metallic Materials-Mechanical and Fracture Testing

- Mechanical Testing
  - Compression and tension, quasi static to $10^3 \text{ s}^{-1}$
  - Fatigue and fracture mechanics testing
  - Environmentally assisted cracking testing
  - Indentation and impact excitation testing

- Electron Microscopy
  - FEG-SEM with EDS, EBSD, STEM
  - TEM with EDS

- Raman Spectroscopy
  - Raman for analysis of corrosion products

- Electrochemistry
  - Standard electrochemical polarisation equipment

- NDE
  - Robot mounted eddy current and conductivity systems for automated scanning of components
Ageing Models and Life Prediction

**Computational Chemistry**

Fundamental calculations to:
- Provide parameters often unavailable from experiment.
- Provide 'mechanistic' information.

**System Modelling**

Constitutive – to simulate the ‘kinetics’ of ageing

- Diffusion Coefficients
- Arrhenius Factors
- Solubility Values

**Engineering Level**

Finite Element Component Response

Slide 10
Example: Simulation of Uranium Dioxide
Analytical And Nuclear Chemistry

Radiochemical Sciences
- Radiochemistry & Radiometry
- UGT Rad-chem Data
- Fissile Particle Detection/Analysis

CTBTO GB15 Laboratory

Mass Spectrometry
- Gas & Organics
- Warhead Isotopes
- Trace Actinide Isotopes
- SIMS & Organics

Nuclear Forensic Capability
- Conventional Samples Laboratory
Explosive Materials

- Ageing and Life Prediction
- New Materials
  - Synthesis of Novel Energetic Ingredients
- Chemical Characterisation
  - Explosive Chemical Analysis
  - Trace Explosives Analysis
  - Compatibility
- Physical Characterisation
  - Explosive Hazard Testing
  - Mechanical Properties
  - Particle Characterisation
- Formulations
  - Future Plastic Bonded Formulations
Actinides Analysis

Operations
- Glovebox Facility
- Component Certification
- Process Control
- Ageing
- Actinide Material Recycle [INRM]
- Inter-lab Comparison Exercises

Development
- Decrease Risks
- Reduce Wastes
- Reduce Wet Chemistry
Tritium Technology

- Purpose built tritium laboratory with Modern Standards Safety Case
- Tritium ‘Loading’
  - Hydrogen storage beds
  - Accelerator Targets
- Hydrogen Adsorption Studies
  - Thermodynamics and Exchange Kinetics
  - Ageing – tritium and helium release studies
- Tritium Analysis
  - Gas assay – High resolution tritium and Helium
Actinide Materials

Metallurgy and Materials Microstructure
- Modern set of in-box equipments
  - DSC, FEG-SEM, EPMA etc
- Materials characterisation and stability studies
- Casting Development – inc modelling

Chemistry
- Hydriding – testing and characterisation
- Oxidation Characterisation
  - XPS, ellipsometry, FTIR
- Computational Chemistry
  - Mathematical and Molecular modelling
Plutonium Research

- Pu Corrosion Research Facility
- XPS/UPS
- Hardness/tensile test facilities
- Ellipsometry
- XRD
- Heat treatment furnaces
- EPMA
- SIMS
- DSC & TMA
- Density measurement
- Casting furnaces
- FEGSEM
Summary

- AWE supports the UK’s National Nuclear Security by providing materials science expertise in the following areas:
  - High explosives research and analysis
  - Plutonium and uranium chemistry & metallurgy research
  - Non-metallic materials (organic and inorganic) research
  - Tritium science and technology
  - Radiochemistry, mass spectrometry and spectroscopy capability
- Materials that are sustainable, well-characterised, with controlled manufacturing processes and consistent properties.