Alphabet Soup
An Overview of Diagnostic Techniques

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What we want to know

Crystalline cathodes (Diamond, GaAs, metals)

- Surface orientation, texture, grain size, defect density and type, strain, multilayer spacing and properties
- Surface chemistry, contamination, termination
- Bulk impurities, doping levels
- Surface morphology, spatial variation
- Electronic and emission characteristics: energy/momentum spread, QE, temporal response, carrier velocity, trapping, carrier lifetime/escape depth, scattering, density of states

Grown Cathodes (Cs_2Te, Cs_3Sb, CsK_2Sb)

- As above, plus film thickness and uniformity
- In situ diagnostics during growth

Diffraction

X ray diffraction (XRD) provides information on crystal structure, grain size and texture, strain

Grazing Incidence (GID) improves surface sensitivity

Topography provides strain and defect image

Electron diffraction (LEED, RHEED) provides surface orientation, including reconstruction

Electron Backscattered Diffraction (EBSD) provides spatially resolved grain maps

Photoemission Spectroscopy

- Ultraviolet Photoemission Spectroscopy (UPS)
  - Angle Resolved (ARPES) – valence band structure, momentum band structure, emission characteristics, electron/phonon coupling, scattering
  - Photoemission electron microscope (PEEM) - Spatially resolved electron emission
- X-ray Photoemission Spectroscopy (XPS)
  - Surface chemical composition, contamination

Absorption/Fluorescent Spectroscopy

X-ray Fluorescence (XRF) provides elemental analysis

- Can be stimulated with X-ray or Electron beams
- Energy Dispersive X-ray Spectroscopy (EDS) provides spatial resolved elemental composition

X-ray Absorption Spectroscopy (XAS)

- Measure electron yield or fluorescent yield for near edge analysis (NEXAFS/XANES) – provides surface or bulk chemical information, joint density of states
- Measure absorption or fluorescence for “extended” structure (>100 eV above edge, EXAFS) – provides information on local atomic environment due to photoelectron scattering

Other Spectroscopy

Infrared Spectroscopy (FTIR) – Vibrational modes, Impurity content, doping level, typically spatially resolved

Raman Spectroscopy – phonon/vibration modes, material identification

Photoluminescence (PL) – Impurities, intra band states in semiconductors, electronic impact of crystalline defects

Total Yield Spectroscopy (TYS) – QE vs photon energy, indirect information on density of states and scattering mechanisms

Imaging

- Scanning Electron Microscopy (SEM)
- Surface scanning
  - Atomic Force Microscopy (AFM) and Profilometry
  - Kelvin Probe Force Microscopy (KPFM)
    - Local work function
  - Scanning Tunneling Microscope (STM)
    - Local density of states
- Combined w/ other techniques (PEEM, XBIC, Topography)

Induced Current

Beam induced current (BIC) provides carrier dynamics (mobility, saturation velocity, lifetime, trapping sites, contact type) with spatial resolution determined by beam size and rastering capability

Electron, X-ray and Ion beams are used (EBIC, XBIC, IBIC)

XBIC provides the ability to probe depth

EBIC provides SEM spatial resolution

IBIC provides “delta function” temporal response

Diamond Science at BNL

Imaging

SEM	Scanning Electron Microscopy	Surface morphology
LEEM	Low Energy Electron Microscopy	Imaging of hydrogenated surface, spatially localized LEED, work function mapping
AFM	Atomic Force Microscopy	Surface morphology

Diffraction

XRD	X-ray diffraction, time resolved	Characterization of metal contacts, including temperature of formation and crystalline texture
XRD	X-ray diffraction	Diamond crystal quality; evaluation of stress caused by laser shaping
Topography		Diamond crystal quality, localization and identification of defects
LEED	Low Energy Electron Diffraction	Surface crystal analysis, evaluation of hydrogenated surface

Spectroscopy

UPS/ARPES	Ultraviolet Photoemission Spectroscopy	Electron affinity, energy & angular distribution of emitted electrons, lifetime of NEA surface
TYS	Total Yield Spectroscopy	Evaluation of hydrogenated surface, lifetime
NEXAFS	Near Edge X-ray Absorption Fine Structure	Surface elemental analysis, characterization of surface bonding, carbon formation
XAFS	X-ray absorption fine structure	Titanium/diamond surface chemistry
EDS	Energy Dispersive X-ray Spectroscopy	Surface elemental analysis
FTIR	Fourier Transform Infrared Spectroscopy	Impurities in diamond
Photoluminescence & Raman Spectroscopy		Impurity analysis, identification of carbon chemistry, mapping

Carrier Transport and Emission

Electron Generated	Carrier Transport vs Field, Emission, Gain, Thermal Emittance
Photo-electron Generated	Gain, Timing
Soft X-ray, Monochromatic	Charge collection distance, Charge trapping/detrapping effects
Hard X-ray, Monochromatic	Measurement of mean ionization energy (gain)
High Flux White beam	Current Limits, Contact requirements, Heat management
Micro-beam Mapping	Localization of electrically active sites