

## ALPHABET SOUP - AN OVERVIEW OF DIAGNOSTIC TECHNIQUES\*

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# 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 ( $\text{Cs}_2\text{Te}$ ,  $\text{Cs}_3\text{Sb}$ ,  $\text{CsK}_2\text{Sb}$ )

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

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

## Diffraction

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

## Spectroscopy

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

## Carrier Transport and Emission

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