

# Méthodes d'analyse des surfaces

## Méthodes physico-chimiques d'élaboration et de caractérisation des matériaux et des micro-systèmes en couches minces.

### Références :

- .*Analyse Structurale et Chimique des Matériaux* - J.-P. Eberhart - Dunod 1989,  
 .*Concepts in Surface Physics* - M.C. Desjonquères, D. Spanjaard - Springer Verlag Berlin Heidelberg 1996,  
 .*Fundamentals of Surface and Thin Film Analysis* - L.C. Feldman, J.W. Mayer - North-Holland 1986,  
 .*Surfaces and Interfaces of Solid Materials* - H. Lüth - Springer Verlag Berlin Heidelberg 1995,  
 .*Surface Science techniques* - J.M. Walls and R. Smith - Pergamon 1994,  
 .*Techniques de l'ingénieur* <http://www.techniques-ingenieur.fr>  
 .*Traité des Matériaux 4. Analyse et Technologie des Surfaces – Couches minces et tribologie* – H.-J. Mathieu, E. Bergmann et R. Gras – Presses Polytechniques et Universitaires Romandes 2003.

### Sigles et acronymes courants des méthodes d'analyse de surface :

- |                                                                     |                                                                             |
|---------------------------------------------------------------------|-----------------------------------------------------------------------------|
| AAS <i>atomic absorption spectrometry,</i>                          | ATR <i>attenuated total reflection,</i>                                     |
| ADES <i>angular dispersive electron spectrometry,</i>               | BEEM <i>ballistic electron emission microscopy,</i>                         |
| AEAPS <i>Auger electron appearance potential spectrometry,</i>      | BIS <i>bremsstrahlung isochromat spectrometry,</i>                          |
| AEM <i>Auger electron microscopy,</i>                               | CBED <i>convergent beam electron diffraction,</i>                           |
| AES <i>Auger electron spectrometry,</i>                             | CFM <i>chemical force microscopy,</i>                                       |
| AFM <i>atomic force microscopy,</i>                                 | CL <i>cathodo-luminescence,</i>                                             |
| AFS <i>atomic fluorescence spectrometry,</i>                        | CLSM <i>confocal laser scanning microscopy,</i>                             |
| AMEFS <i>Auger Monitored Extended fines structures,</i>             | CP <i>channeling pattern (Kikuchi),</i>                                     |
| APECS <i>Auger photoelectron coincidence spectrometry,</i>          | CPD <i>contact potential difference,</i>                                    |
| APFIM <i>atom probe field ion microscopy (FIM),</i>                 | DAFS <i>diffraction anomalous fine structure,</i>                           |
| APS <i>appearance potential spectrometry,</i>                       | DAPS <i>disappearance potential spectrometry,</i>                           |
| ARAES <i>angle-resolved AES,</i>                                    | DEL <i>diffraction d'électrons lents,</i>                                   |
| ARNPD <i>angle resolved normal photoelectron diffraction,</i>       | DFM <i>dynamic force microscopy,</i>                                        |
| ARPEFS <i>angle resolved photoemission extended fine structure,</i> | DNPA <i>diffusion des neutrons aux petits angles (SANS),</i>                |
| ARPES <i>angle resolved photoelectron spectroscopy,</i>             | DRIFTS <i>diffuse reflectance infra-red Fourier transform spectrometry,</i> |
| ARSES <i>angle resolved secondary electron spectroscopy,</i>        | DXPA <i>diffusion des rayons X aux petits angles (SAXS),</i>                |
| ARUPS <i>angle resolved UV photoelectron spectrometry,</i>          | EAPFS <i>extended appearance potential fine structure,</i>                  |
| ARXPD <i>angle resolved SPD,</i>                                    | EBIC <i>electron beam induced current,</i>                                  |
| AS <i>absorption spectrometry,</i>                                  | ED <i>electron diffraction,</i>                                             |
|                                                                     | EDS <i>energy dispersive X-ray spectrometry,</i>                            |
|                                                                     | EDAX <i>energy dispersive X-ray analysis,</i>                               |
|                                                                     | EDX <i>energy dispersive X-ray spectrometry,</i>                            |

EELS *electron energy loss spectrometry*,  
 EFM *electrostatic force microscopy*,  
 EFOM *evanescent field optical microscopy (PSTM)*,  
 EID *electron impact desorption*,  
 ELNES *electron energy loss near edge structure*,  
 ELS *energy loss spectrometry*,  
 EM *electron microscopy*,  
 EMMA *electron microscope micro analyser*,  
 EMS *electron momentum spectrometry*,  
 ES *ellipsometry spectrometry*,  
 EPMA *electron probe micro analysis*,  
 ERDA *elastic recoil detection analysis*,  
 ESCA *electron spectroscopy for chemical analysis (AES + XPS + UPS)*,  
 ESD *electron stimulated desorption*,  
 ESDIAD *electron stimulated desorption of ion angular distribution*,  
 ESR *electron spin resonance*,  
 EXAFS *extended X-ray absorption fine structure*,  
 EXELFS *extended energy loss fine structure*,  
 EXEELFS *extended electron energy loss fine structure*,  
 FAB *fast atom bombardment*,  
 FDS *field desorption spectrometry*,  
 FEED *field emission energy distribution*,  
 FEM *field emission microscopy*,  
 FEEM *field electron emission microscopy*,  
 FEES *field electron energy spectrometry*,  
 FES *field emission spectrometry*,  
 FIM *field ion microscopy*,  
 FIS *field ion spectrometry*,  
 FS *fluorescence spectrometry*,  
 FTIR *Fourier transform infra-red*,  
 FTMS *Fourier transform mass spectrometry*,  
 FT RA-IR *Fourier transform reflectance-absorbtion infra-red*,  
 GDMS *glow-discharge mass spectrometry*,  
 GDOS *glow-discharge optical spectrometry*,  
 GDS *glow-discharge spectrometry (SDL)*,  
 HA *heat adsorption*,  
 HAS *helium atom scattering*,  
 HEED *high energy electron diffraction*,  
 HEIS *high energy ion scattering*,  
 HFS *hydrogen forward scattering*,  
 HREELS *high resolution electron energy loss spectrometry*,  
 HREM *high resolution electron microscopy*,  
 HVEM *high voltage electron microscopy*,  
 IAP *imaging atom probe*,  
 ICISS *impact collision ion scattering spectrometry*,  
 IETS *inelastic electron tunneling spectrometry*,  
 IFTS *infrared Fourier transform spectrometry*,  
 IIDS *ion-impact desorption spectrometry*,  
 IILE *ion-induced light emission*,  
 IIRS *ion-impact radiation spectrometry*,  
 IIXS *ion-induced X-ray spectrometry*,  
 ILS *ionisation loss spectrometry*,  
 IMMA *ion microprobe mass analysis*,  
 IMXA *ion microprobe X-ray analysis*,  
 INS *ion neutralization spectrometry*,  
 IPES *inverse photoemission spectrometry*,  
 IPM *ion probe microscopy*,  
 IRAS *infra-red absorbtion spectrometry*,  
 IRS *infra-red spectrometry*,  
 IRTF *infrarouge par transformée de Fourier (IFTS)*,  
 ISD *ion stimulated desorption*,  
 ISS *ion scattering spectrometry*,  
 KRIPES *k-resolved inverse photoemission spectrometry*,  
 LACBED *Large angle convergent beam electron diffraction*,  
 LAMA *laser microprobe analysis*,  
 LAMMA *laser microprobe mass analysis*,  
 LEED *low energy electron diffraction*,  
 LEELS *low energy electron loss spectrometry*,  
 LEEM *low energy electron microscopy*,  
 LEF *laser excited fluorescence*,  
 LEIS *low energy ion scattering*,  
 LEPD *Low energy positron diffraction*,  
 LFM *lateral force microscopy*,  
 LID *Lase-induced desorption*,  
 LIF *Laser-induced fluorescence*,  
 LIMS *laser ionization mass spectrometry*,  
 LOES *laser optical emission spectrometry*,  
 LRS *light Raman scattering*,  
 LS *light scattering*,  
 LMP *laser microprobe*,  
 MBRS *molecular beam surface reactive scattering*,  
 MBSS *molecular beam surface scattering*,  
 MCXD *magnetic circular X-ray dichroism*,  
 MDS *metastable deexcitation spectrometry*,  
 MEB *microscope électronique à balayage*,

MEBT <i>microscope électronique à balayage en transmission,</i>	REELS <i>reflection electron energy-loss spectroscopy,</i>
MEED <i>medium electron energy diffraction,</i>	REFLEXAFS <i>reflection extended X-ray absorption fine structure,</i>
MEHT <i>microscope électronique à haute tension,</i>	REM <i>reflection electron microscopy,</i>
MEIS <i>medium energy ion scattering,</i>	RHEED <i>reflection high energy electron diffraction,</i>
MET <i>microscope électronique à transmission,</i>	RIMS <i>resonant ionization mass spectrometry,</i>
MFM <i>magnetic force microscopy,</i>	RRS <i>resonant Raman scattering,</i>
MIES <i>metastable impact electron spectrometry,</i>	SAD <i>selected area electron diffraction,</i>
MFM <i>magnetic force microscopy,</i>	SAM <i>scanning Auger-electron microscopy,</i>
MOKE <i>magneto-optic Kerr effect,</i>	SAES <i>scanning AES,</i>
MOSS <i>Mössbauer spectrometry,</i>	SANS <i>small angle neutron scattering (DNPA),</i>
MPI <i>multi-photon ionization,</i>	SAXS <i>small angle X-ray scattering (DXPA),</i>
MS <i>mass spectrometry,</i>	SC <i>surface capacitance,</i>
NAA <i>neutron activation analysis,</i>	SDL <i>spectrométrie de décharge luminescente (GDS),</i>
NEXAFS <i>near edge X-ray absorption fine structures (XANES),</i>	SDMM <i>scanning desorption molecule microscopy,</i>
NIS <i>neutron inelastic scattering,</i>	SEAM <i>scanning electron acoustic microscopy,</i>
NIXSW <i>normal incidence X-ray standing wave,</i>	SEE <i>secondary electron emission,</i>
NMA <i>nuclear microanalysis,</i>	SEELFS <i>surface extended energy loss structures,</i>
NMR <i>nuclear magnetic resonance,</i>	SEELS <i>slow electron energy loss spectrometry (ou LEELS),</i>
NPD <i>normal photoelectron diffraction,</i>	SEM <i>scanning electron microscopy,</i>
NRA <i>nuclear reaction analysis,</i>	SEMPA <i>scanning electron microscopy with polarisation analysis,</i>
OPD <i>off-normal photoelectron diffraction,</i>	SERS <i>surface enhanced Raman scattering,</i>
PAES <i>positron annihilation Auger electron spectrometry,</i>	SEWS <i>surface electromagnetic wave spectrometry,</i>
PD <i>photodesorption,</i>	SEXAFS <i>surface EXAFS,</i>
PEELS <i>parallel energy loss spectrometry,</i>	SFG <i>surface frequency generation,</i>
PEEM <i>photoelectron emission microscopy,</i>	SFM <i>scanning force microscopy,</i>
PED <i>photoelectron diffraction,</i>	SHG <i>second harmonic generation,</i>
PES <i>photoelectron spectrometry,</i>	SH-MOKE <i>second harmonic magneto-optic Kerr effect,</i>
PhD <i>photoelectron diffraction,</i>	SI <i>surface ionization,</i>
PIES <i>Pennig ionization electron spectrometry,</i>	SIMS <i>secondary ion mass spectrometry,</i>
PIXE <i>particle induced X-ray emission,</i>	SIM <i>scanning ion microscopy,</i>
PL <i>photon luminescence</i>	SIS <i>surface infrared spectrometry,</i>
PLEED <i>polarized LEED,</i>	SLEEM <i>scanning low energy electron microscope,</i>
PSD <i>photon stimulated desorption,</i>	SM <i>spectrométrie de masse,</i>
PSDIAD <i>photon stimulated desorption ion angular distribution,</i>	SMOKE <i>surface magneto-optic Kerr effect,</i>
PSTM <i>photon scanning tunneling microscopy (EFOM),</i>	SNMS <i>secondary neutral mass spectrometry,</i>
RAIRS <i>reflection-absorption infrared spectrometry,</i>	SNOM <i>scanning near field optical microscopy,</i>
RAS <i>reflectance anisotropy spectrometry,</i>	
RBS <i>Rutherford backscattering spectrometry,</i>	
RDS <i>reflectance difference spectrometry,</i>	

SOM *scanning optical microscopy,*  
 SP-LEEM *spin polarized low energy electron microscopy,*  
 SPA-LEED *spot profile analysis low energy electron diffraction,*  
 SPC *surface photoconductivity spectrometry,*  
 SP-EELS *spin polarised electron energy loss spectrometry,*  
 SPEEM *scanning photoelectron emission microscopy,*  
 SPEM *scanning photoelectron microscopy,*  
 SPI *surface Pennig ionization,*  
 SPIES *surface Pennig ionization electron spectrometry,*  
 SPIPES *spin polarised inverse photoemission spectrometry,*  
 SPLEED *spin polarised low energy electron diffraction,*  
 SPLEEM *spin polarised low energy electron microscopy,*  
 SPM *scanning probe microscopy,*  
 SPUPS *spin polarised ultraviolet photoelectron spectrometry,*  
 SPV *surface photovoltage spectrometry,*  
 SPXPS *spin polarised X-ray photoelectron spectrometry,*  
 SRS *surface reflectance spectrometry,*  
 SREM *scanning reflection electron microscope,*  
 SSIMS *static SIMS,*  
 STEM *scanning transmission electron microscopy,*  
 STIPE *scanning tunneling inverse photoemission,*  
 STM *scanning tunneling microscopy,*  
 STOM *scanning tunneling optical microscopy,*  
 STP *scanning thermal probe,*  
 STS *scanning tunneling spectrometry,*  
 SXAPS *soft X-ray appearance potential spectrometry,*  
 SXES *soft X-ray emission spectrometry,*  
 SXPS *soft X-ray photoelectron spectrometry,*  
 SXRD *surface X-ray diffraction,*  
 TDMS *thermal desorption mass spectrometry*  
 TDS *thermal desorption spectrometry,*  
 TEAS *thermal energy atom scattering,*  
 TED *transmission electron diffraction,*  
 TES *thermionic emission spectrometry,*  
 TEM *transmission electron microscopy,*  
 THEED *transmission high energy electron diffraction,*  
 TL *thermoluminescence,*  
 TLM *transmission light microscopy,*  
 TOF *time of flight (mass spectrometer),*  
 TPD *temperature programmed desorption,*  
 TPRS *temperature programmed reaction spectrometry,*  
 TREELS *time resolved EELS,*  
 TSM *tandem optical microscopy,*  
 TXRF *total reflection X-ray fluorescence,*  
 UPS *ultraviolet photoelectron spectrometry,*  
 VLEED *very low energy electron diffraction,*  
 XANES *X-ray absorption near edge structure,*  
 XAES *X-ray stimulated AES,*  
 XAS *X-ray absorption spectrometry,*  
 XPD *X-ray photoelectron diffraction,*  
 XPS *X-ray photoelectron spectrometry,*  
 XRD *X-ray diffraction,*  
 XRFA (XRF) *X-ray fluorescence analysis*  
 XRR *X-ray reflectometry,*  
 XSW *X-ray standing wave.*

# Méthodes d'analyse des surfaces

## Méthodes physico-chimiques d'élaboration et de caractérisation des matériaux et des micro-systèmes en couches minces.

1. *Introduction aux méthodes d'analyse des surfaces, Spectrométrie de photoélectrons – XPS, UPS, ESCA, PEEM, Spectrométrie des électrons Auger – AES, SAM.*
2. *Spectrométrie d'émission d'ions secondaires - SIMS, SIM, Diffraction d'électrons lents – DEL (LEED), Diffraction d'électrons rapides – RHEED.*
3. *Spectrométrie de perte d'énergie des électrons – HREELS, EELS, EXELFS, Spectrométrie par faisceau d'ions – ISS, LEIS, MEIS, HEIS, RBS.*
4. *Spectrométrie d'absorption des rayons X - XAS, XANES, EXAFS, Microscopies à effet tunnel, à force atomique - STM, AFM.*
5. *Spectrométrie d'absorption des rayons X - XAS, XANES, EXAFS (1/2),*
6. *Spectrométrie d'absorption des rayons X - XANES, EXAFS (2/2),*
7. *Microscopies à force atomique - AFM, DFM, LFM, MFM, EFM,*
8. *Diffraction d'électrons lents - DEL/LEED, LEEM (1/2),*
9. *Diffraction d'électrons lents - DEL/LEED, LEEM (2/2),*
10. *Spectrométrie de diffraction de photoélectrons - XPD, PhD, ARPEFS, ARUPS.*
11. *Visite Laboratoire CEA Saclay DSM/IRAMIS/SPCSI (STM, AFM, ESCA, XPS, UPS, AES, DEL, PEEM, LEEM, HREELS...).*

*italique introduction*

**Gras approfondissement**

1 séance = 2heures

**Supports de cours**

<http://iramis.cea.fr/Pisp/ludovic.douillard/>