De la physique de l'émission des électrons secondaires au contraste de l'image en microscopie électronique.

Un hommage à Jacques Cazaux

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Faculté des Sciences Jean Perrin
Lens

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UNIVERSITÉ D'ARTOIS

Introduction

Jacques Cazaux est décédé le 4 décembre 2014 à l'âge de 80 ans

conférences est susceptible d'être modifié : il sera tenu à jour sur site web

La basse énergie en MEB et microanalyse

Jeudi 4 décembre 2014

09h00 - 09h30	*Accueil*
09h30 - 10h30	Pourquoi vouloir absolument travailler à basse tension? Intérêts et limitations (Jacky Ruste, GN-MEBA)
10h30 - 14h00	**Exposition Constructeurs** *avec pause-café et repas de midi (buffet froid) offerts aux adhérents du groupement par le GN-MEBA et les constructeurs - Stand EDP Sciences*
14h00 - 14h15	Assemblée Générale
14h15 - 14h30	Présentation du forum du site GN-MEBA (Fabrice Gaslain, Mines ParisTech, PSL - Research University, Centre des Matériaux, Evry 91)
14h30 - 15h00	Qu'est-ce qu'une surface ? (Evelyne Darque-Ceretti, Mines ParisTech, PSL - Research University, CEMEF, Sophia Antipolis 06)
15h00 - 15h30	Préparation des échantillons pour analyse à basse énergie. (Patrice Lehuédé, C2RMF, Paris 75)
15h30 - 16h00	Emission d'électrons secondaires à très basse énergie (Mohamed Belhaj, Onera, Toulouse, 31)
16h00 - 16h30	*Pause*
16h30 - 17h00	Les émissions X caractéristiques de basse énergie (Philippe Jonnard, UPMC, Paris 75)
17h00 - 17h45	De la physique des émissions électroniques aux contrastes des images en MEB. (Jacques Cazaux, Université de Reims, Reims 51)

Par une étrange coincidence

Réunion GNMEBA Paris

UNIVERSITÉ D'ARTOIS

Bref résumé de sa carrière académique

- Maitrise en physique en physique à l’Université Paris Sorbonne -
- Doctorat en 1970 au laboratoire de physique théorique du collége de France
- Professeur de physique à l’ Université de Reims
- Il reste actif même en retraite, sa dernière publication en 2014

Journal of Electron Spectroscopy and Related Phenomena 192 (2014) 40–51

Contents lists available at ScienceDirect

Journal of Electron Spectroscopy and Related Phenomena

journal homepage: www.elsevier.com/locate/elspec

ELSEVIER

Work function effects on the positive charging of supported insulating samples exposed to X-rays (as in XPS) and other irradiations

CrossMark

J. Cazaux*

UNIVERSITÉ D’ARTOIS

Ses contributions scientifiques

- 150 publications
- Conférencier Invité dans plus de 50 congrès internationaux
- Cours durant des écoles thématiques (SFmu, GN MEBA, EMAS).
- Membre du bureau de nombreuse sociétés savantes

EMAS membre honoraire de l'EMAS

Ecole d'été du GNMEBA
Jacques Cazaux – François Grillon
2006
Saint Martin d'Hères

La première…….

460 — Série B C. R. Acad. Sc. Paris, t. 263 (8 août 1966).

PHYSIQUE DES SOLIDES. — *Influence de l'anisotropie du milieu cristallin sur les énergies perdues par les électrons qui traversent un cristal.* Note (*) de MM. Jacques Cazaux et Roger [illegible], transmise par M. Jean Laval.

48 ans

Journal of Electron Spectroscopy and Related Phenomena 192 (2014) 40–51

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ELSEVIER

Work function effects on the positive charging of supported insulating samples exposed to X-rays (as in XPS) and other irradiations

CrossMark

J. Cazaux*

et la dernière contribution

UNIVERSITÉ D'ARTOIS

Ses Contributions scientifiques

- La physique de l'émission des électrons secondaires
- L'effet AUGER
- Les effets de charge dans les isolants
- Le contraste en microscopie électronique

→ Le point de vue de l'échantillon

- La spectroscopie et microscopie AUGER
- La spectroscopie de photoelectrons
- Le MEB

→ le point de vue de l'instrument

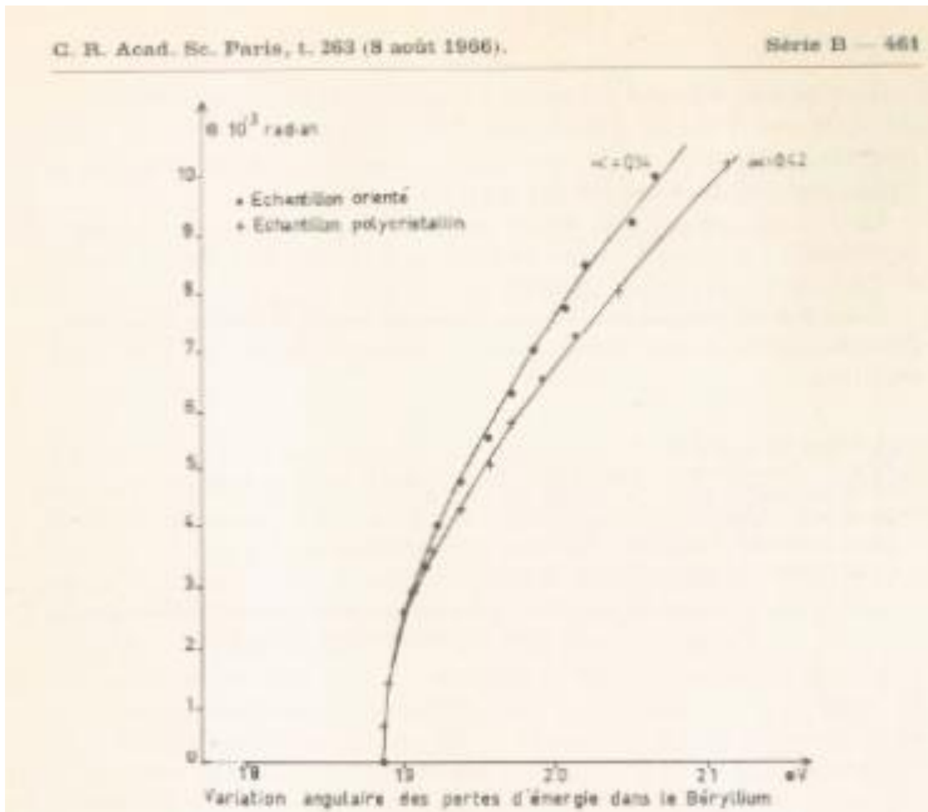
↓

Conception de nouveaux instruments

UNIVERSITÉ D'ARTOIS

Pendant son Doctorat

- **La spectroscopie de perte d’énergie des électrons** avec un instrument spécialement construit au collége de France.



avec Roger Vilanove

Influence de l’anisotropie du milieu cristallin sur les pertes d’énergie

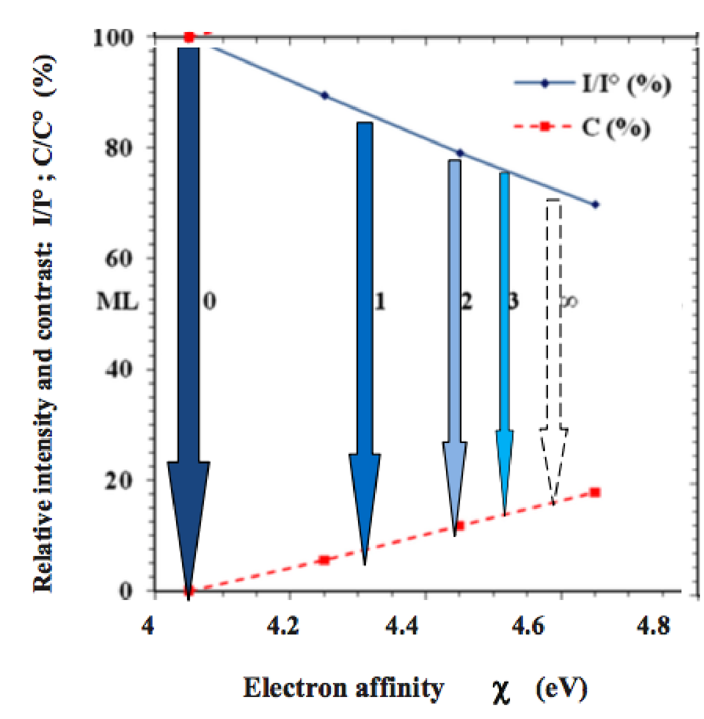
UNIVERSITÉ D’ARTOIS

Pendant son doctorat

En 1970, sa thèse

Contribution à l'étude de l'anisotropie des pertes d'energie caractéristiques et des constantes optiques entre 3 et 30 eV

→ Matériaux carbonés



En 2011, publication sur le graphene

APPLIED PHYSICS LETTERS 98, 013109 (2011)

Calculated dependence of few-layer graphene on secondary electron emissions from SiC

FIG. 3. (Color online) Influence of a χ-increase, horizontal scale, and the number of graphene monolayers, full vertical arrows, on the relative decrease of the SE intensities and the contrast change: n=1 ($\chi\sim$4.3 eV), n=2 ($\chi\sim$4.4 eV), n=3 ($\chi\sim$4.5 eV), and n=∞ ($\chi\sim$4.6 eV), vertical scale.

UNIVERSITÉ D'ARTOIS

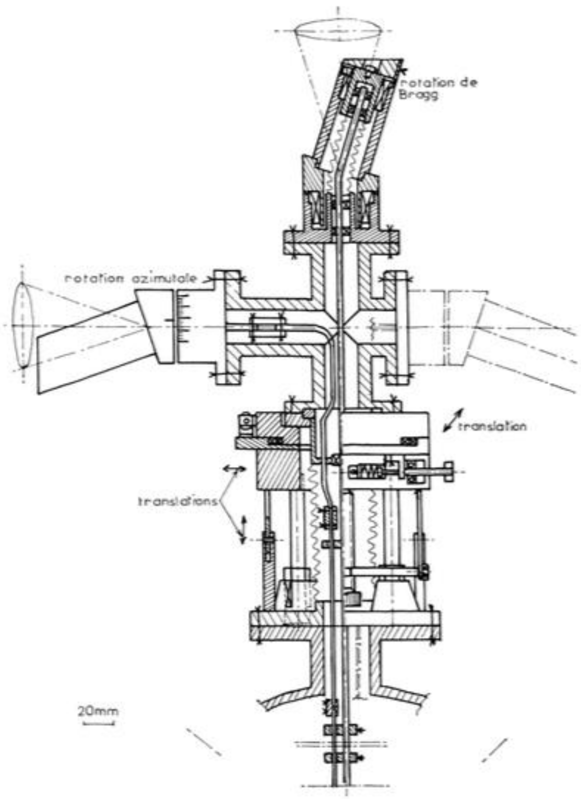
Durant son doctorat

Conception d'un porte échantillon Pour diffraction d'électrons

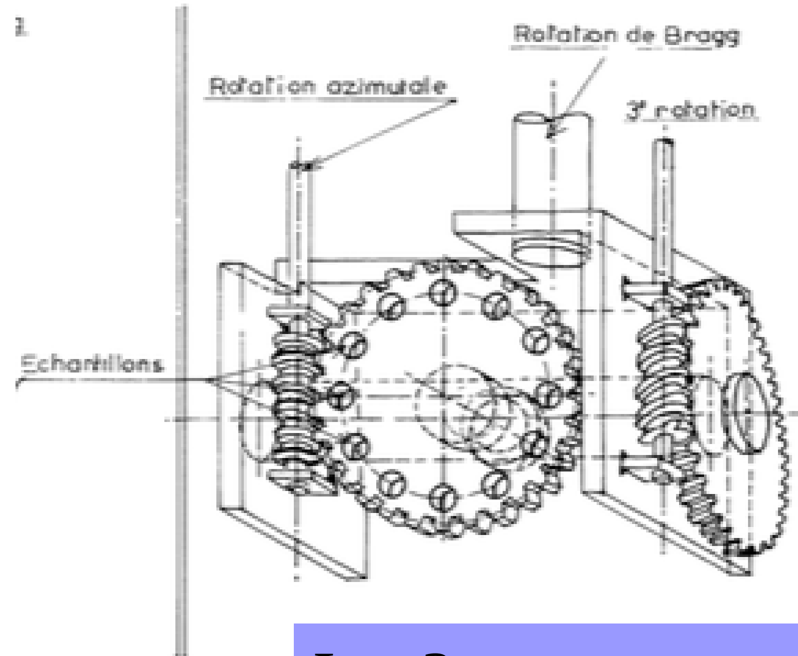
REVUE DE PHYSIQUE APPLIQUÉE TOME 2, MARS 1967, PAGE 62.

PORTE-ÉCHANTILLON ULTRA-VIDE A TROIS TRANSLATIONS ET TROIS ROTATIONS POUR DIFFRACTION D'ÉLECTRONS

Par JACQUES CAZAUX, RAYMOND OBER et ROGER VILANOVE,



Le porte échantillon



Les 3 mouvements de rotation

UNIVERSITÉ D'ARTOIS

A l’ Université de Reims

1970

Jacques Cazaux, comme Professor de Physique, a initié un laboratoire dédié à l’analyse de surface et la caractérisation des matériaux.

Il continua à explorer les cristaux anisotropes avec la spectroscopie des pertes d’énergies des électrons

Il montra l’existence de plasmons de surface dans le carbone amorphe.

LE JOURNAL DE PHYSIQUE — LETTRES

TOME 38, 1er MARS 1977, PAGE L-133

Classification
Physics Abstracts
7.140 — 8.170 — 8.850 — 8.860

DISPERSION DES PLASMONS DE SURFACE DANS LES FILMS DE CARBONE AMORPHE

UNIVERSITÉ D’ARTOIS

A l’Université de Reims

La conception de nouveaux instruments

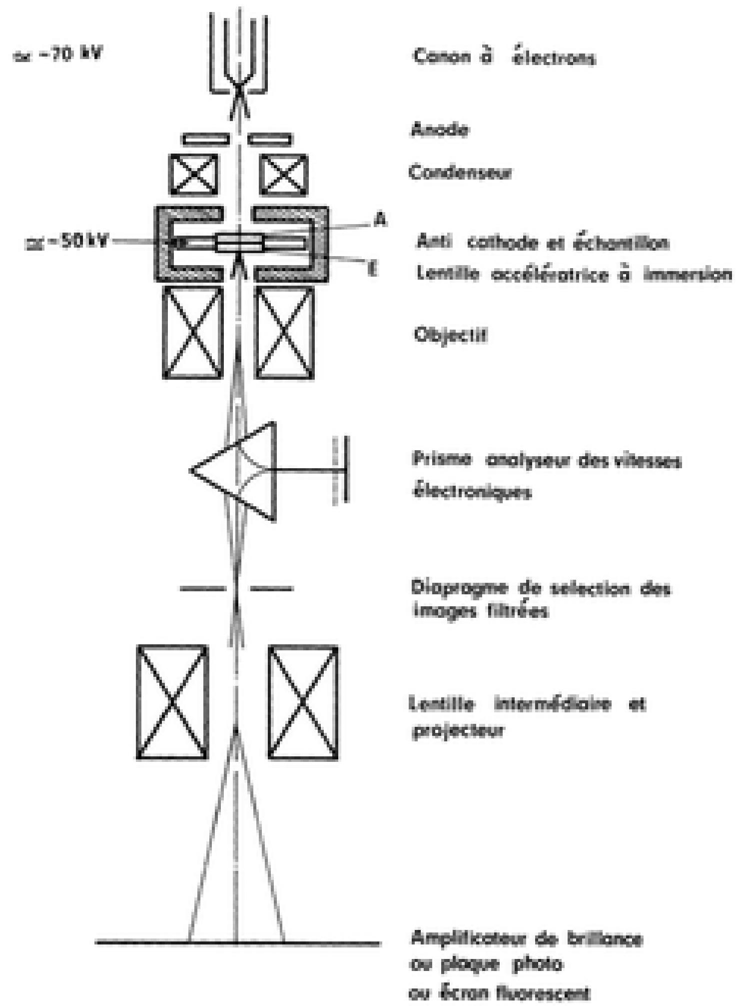
1973

Jacques Cazaux calcule les performances d’un microscope analytique basé sur le principe de L’ESCA

la position de l’échantillon en dessous de l’ anode

Calculs théoriques

Résolution meilleure qu’ 1 micron
Grandissement de 10^3 - 10^4 pour 64 elements

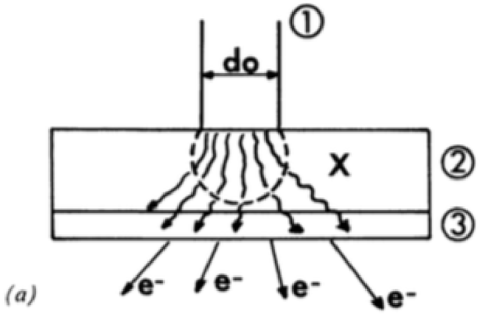


1975

La conception de nouveaux instruments

REVUE DE PHYSIQUE APPLIQUÉE TOME 10, SEPTEMBRE 1975, PAGE 263

MICROANALYSE ET MICROSCOPIE PHOTOÉLECTRONIQUES X : PRINCIPE ET PERFORMANCES PRÉVISIBLES (*)



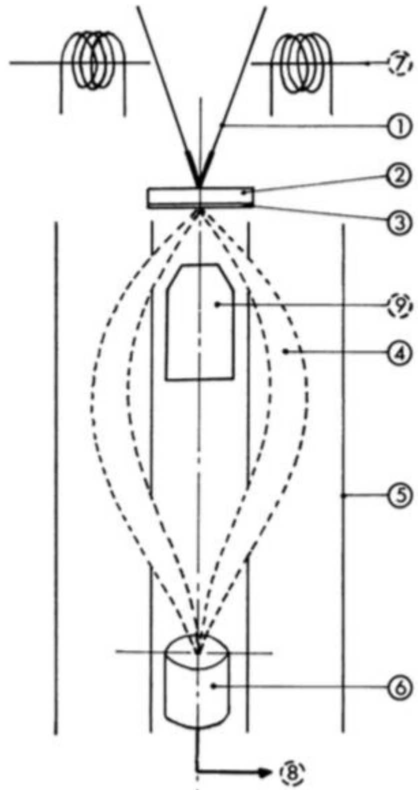


FIG. 1. — *a*) Système anticathode objet. *b*) Schéma de principe du microanalyseur et du microscope photoélectronique X. Microanalyseur : ① Sonde électronique. ② Anticathode. ③ Objet. ④ Faisceau électronique. ⑤ Analyseur miroir cylindrique (par exemple). ⑥ Détecteur. Microscope photoélectronique à balayage : en plus. ⑦ Bobines de balayage. ⑧ Vers le système de télévision. Accessoire supplémentaire pour l'analyse Auger : ⑨ Canon à électrons.

Calculs théoriques

la position de l'échantillon en dessous de l'anode (sous forme d'un film)

UNIVERSITÉ D'ARTOIS

1977

Scanning ESCA: A new dimension for electron spectroscopy

C. T. Hovland

Applied Physics Letters **30**, 274 (1977)

Basé sur l'idée de Cazaux

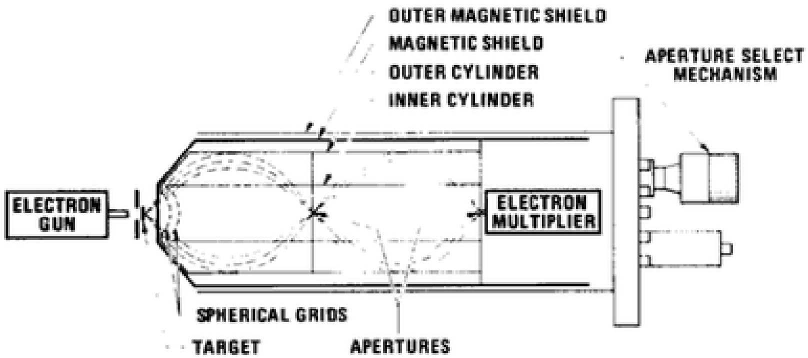


FIG. 1. Diagram of experimental apparatus.

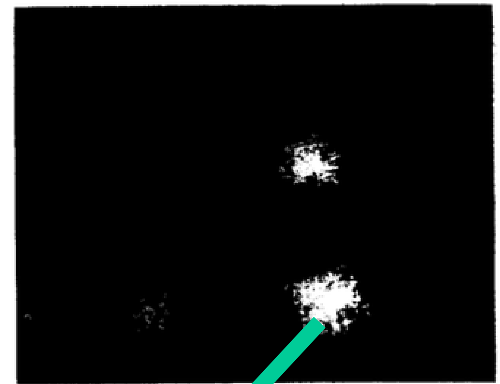


FIG. 2. Scanning ESCA image for oxygen photoelectron line (532 eV binding energy) showing oxygen distribution on aluminum foil covered by a 500-line/in. nickel mesh.

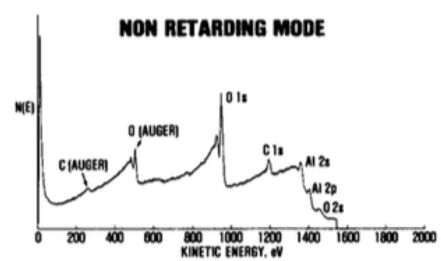


FIG. 5. Nonretarding mode spectrum taken from bright area of Fig. 2.

This technique will be useful when high spatial resolution chemical analysis is required with reduced radiation damage of the specimen

UNIVERSITÉ D'ARTOIS

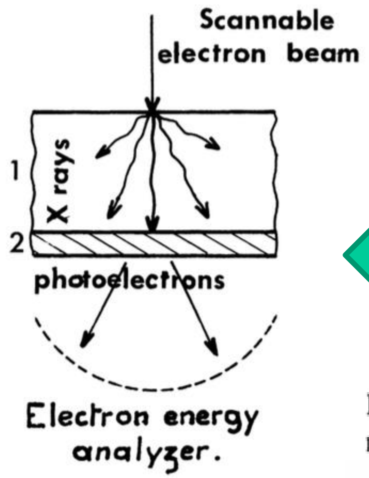
1977

La conception de nouveaux instruments

LE JOURNAL DE PHYSIQUE — LETTRES TOME 38, 1er DÉCEMBRE 1977, PAGE L-473

X-RAY ANALYSIS BY ELECTRON SPECTROSCOPY

J. CAZAUX



Arrangement Similaire

FIG. 2. — Proposed arrangement : *a*) for X-ray photoelectron microscopy and spectroscopy (I) : ① aluminium anode ② specimen ; *b*) for XAES : ① specimen ② converter.

Interêt

Analyse multiple dans un même appareil

Calculs théoriques

Une comparaison

	Energy resolution	Spatial resolution	Intensity cps/s	*S*/*N*	Quantitative analysis (precision)	Detection of light elements	Ease of operation
	—	—	—	—	—	—	—
XAES (proposed technique)	< 1 eV	1 µm	10^5-10^6	~ 10	10-20 %	yes easily	very
EDS (6)	150 eV	1 µm	10^5-10^6	20-50	1 %	no	very despite liquid N^2
WDS (6)	5 eV	1 µm	10^4-10^5	1 000	1 %	difficult	difficult

1981

Applied Physics Letters **38**, 1021 (1981)

Simultaneous bulk and surface microanalyis by electron spectroscopy

J. Cazaux, D. Mouze, J. Perrin, and X. Thomas
Laboratoire de Spectroscopie des Electrons Faculte des Sciences, 51062 Reims, Cedex, France

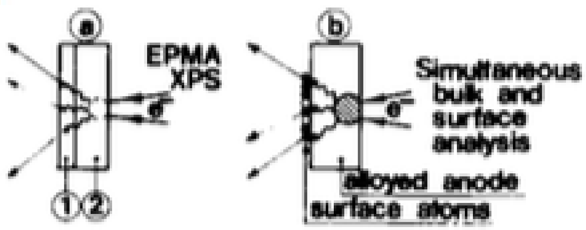
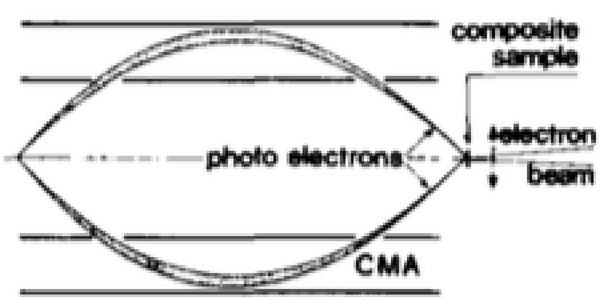


FIG. 1. Diagram of experiment arrangement and details of the composite sample used in (a) XPS; 1: sample, 2: anode and EPMA; 1: converter, 2: sample. (b) Experiment presented here.



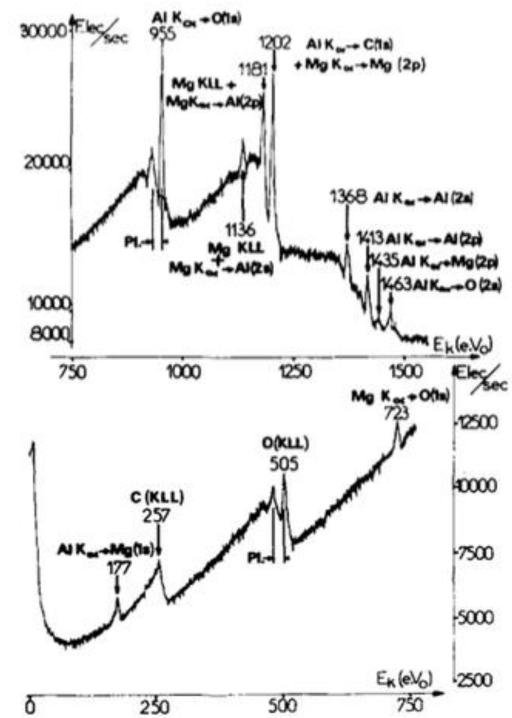


FIG. 2. Photoelectron spectrum that makes it possible to determine the surface and bulk compositions and concentrations of an Al/Mg sheet, 4 μm thick.

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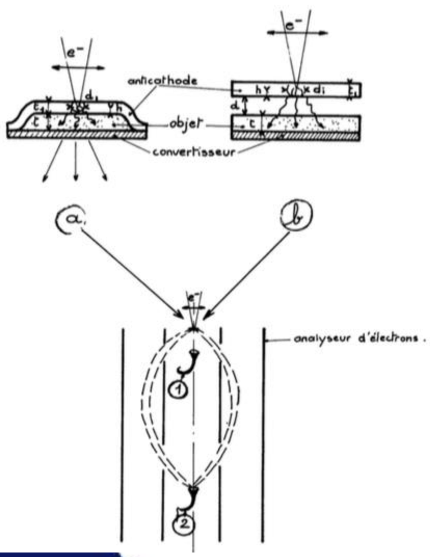
1979

La conception de nouveaux Instruments

LE JOURNAL DE PHYSIQUE — LETTRES TOME 40, 1er JUIN 1979, PAGE L-227

Microanalyse par radiographie X à balayage et fluorescence X : une conception nouvelle

Calculs théoriques



[Principle of scanning X-ray radiography : radiography without (*a*) or with (*b*) the ability to change the anode without ① or with ② energy selection of the photoelectrons.]

[Summary of the different possibilities studied here for X-ray radiography and X-ray fluorescence with estimates of the corresponding expected performances.]

Dispositif	Valeur de l'interstice d	Substitution d'anticathodes	Discrimination énergétique des photoélectrons	Résolution latérale δ (microns)	Epaisseur typique t (microns)	Evaluation du taux de comptage (cps/s)
Radiographie X (image globale)	~ 1 à 10 m	oui	non	20	$t = \frac{1}{\mu_{s0}}$ 0,3-10	
Radiographie X à balayage	qq microns	oui	non	10-30	0,3-10	10^7-10^9
	0	Non (utilisation de composés $Z+1$, $Z-1$)	oui	1-10	0,3-10	10^3-10^5
Fluorescence X	qq microns	oui	oui	10-100	10-100	10^3-10^5

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1982

Journal of Applied Physics **53**, 3299 (1982)

Scanning x-ray radiography: First tests in an electron spectrometer

J. Cazaux, D. Mouze,[a] and J. Perrin

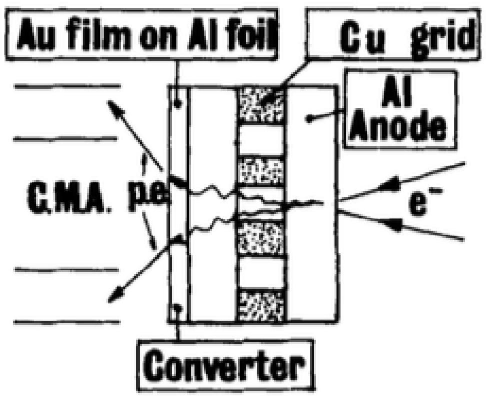


FIG. 1. Experimental arrangement. CMA = cylindrical mirror analyzer; p.e. = photoelectrons.

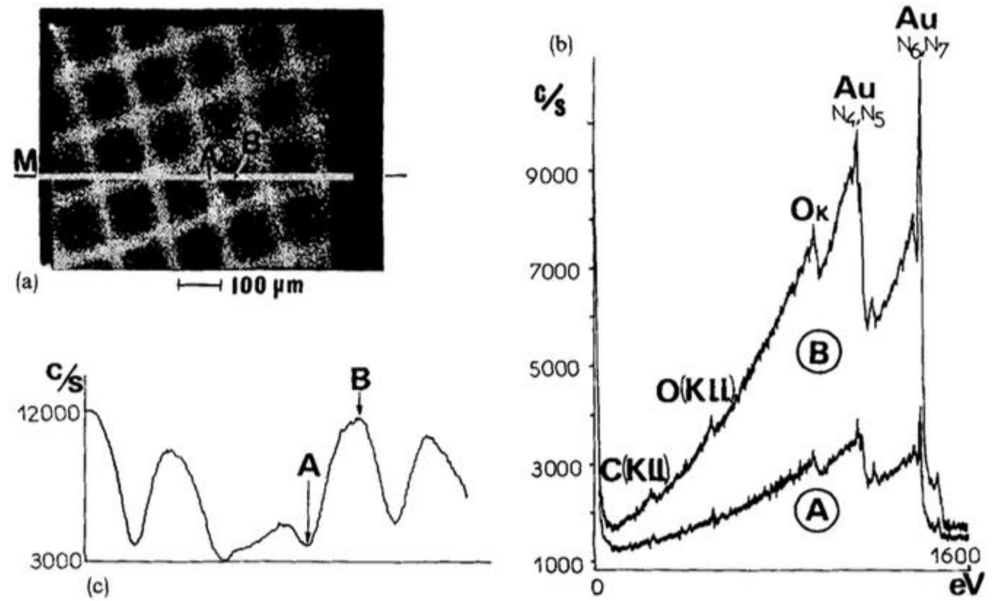


FIG. 2. (a) Two x-ray radiograms of a copper grid obtained in the counting mode (negative). (b) Point analysis in A and B. (c) Line profile MN (using Au $N_{6,7}$ emission line).

Cet appareil fut construit par Riber S.A

1982

Journal of Applied Physics **53**, 3299 (1982)

Scanning x-ray radiography: First tests in an electron spectrometer

J. Cazaux, D. Mouze,[a] and J. Perrin

un radiographe X à balayage est proposé à partir d'un MEB

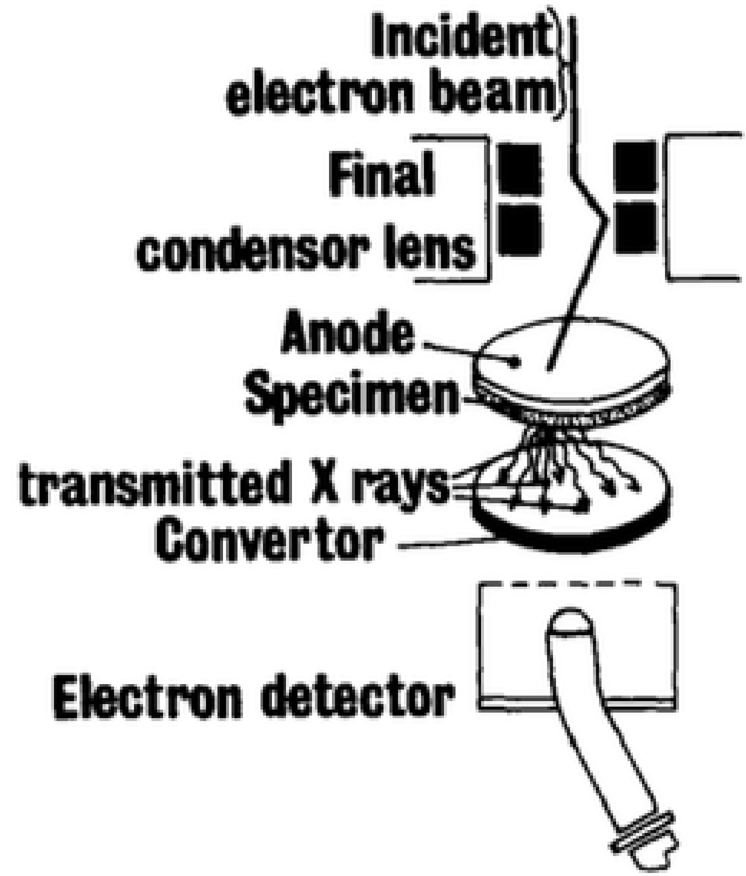
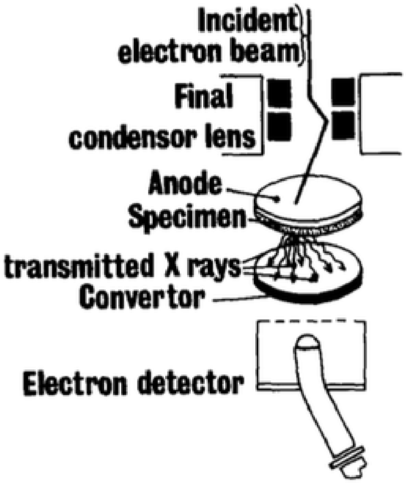
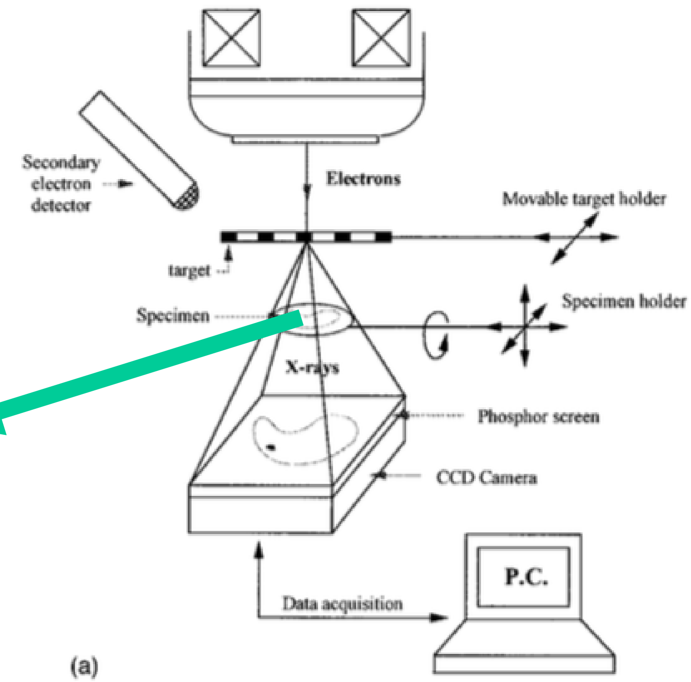


FIG. 4. Schematic drawing of a scanning electron microscope modified for scanning x-ray radiography.

Le radiographe X à balayage

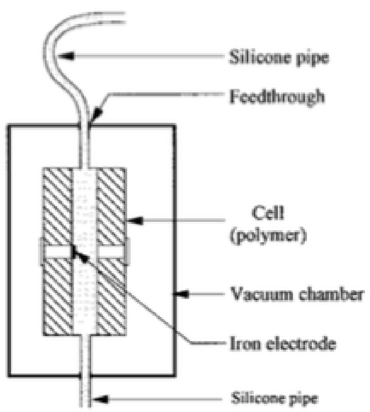


La Conception de nouveaux instruments



Échantillon épais

Environment varié (gaz , liquide)



La microscopie X

1994

Following Ion Diffusion in Solution

SCIENCE • VOL. 263 • 25 MARCH 1994 1739

S. Rondot, J. Cazaux, O. Aaboubi, J. P. Chopart, A. Olivier

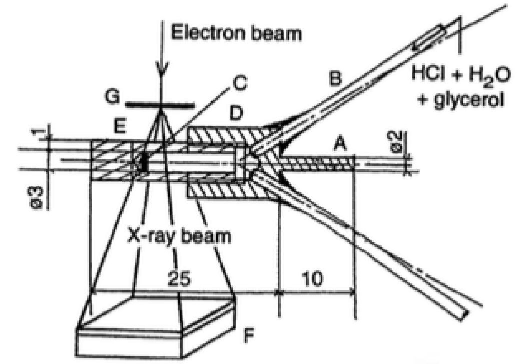
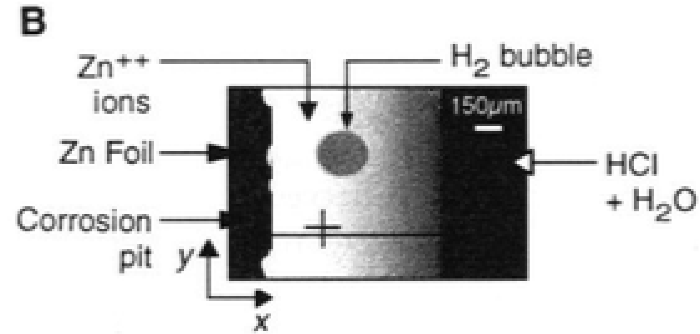
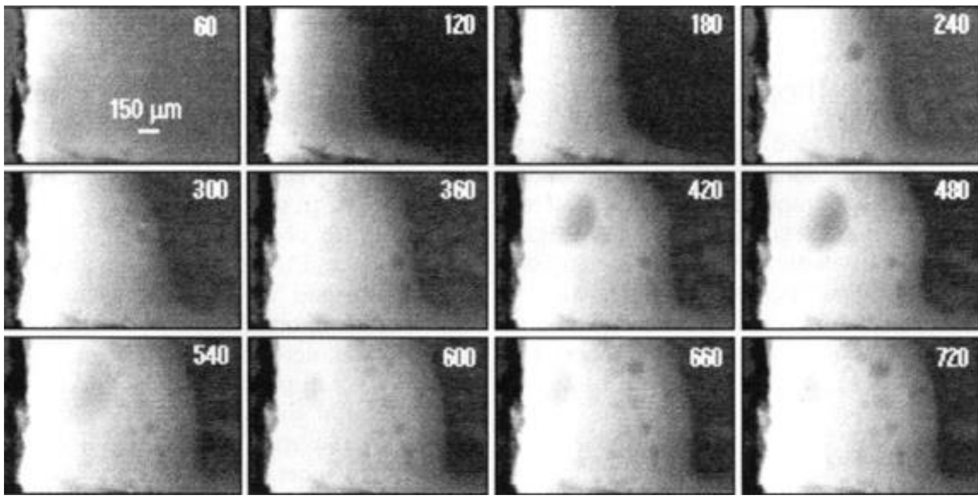


Fig. 1. Schematic diagram of the solution cell. (A) Support allowing the fixing of the cell in the moving specimen holder, (B) PTFE pipe, (C) Zn foil, and (D and E) PTFE walls. Experimental arrangement: (F) detector and (G) target holder. The indicated dimensions (ϕ indicates diameter) are in millimeters.





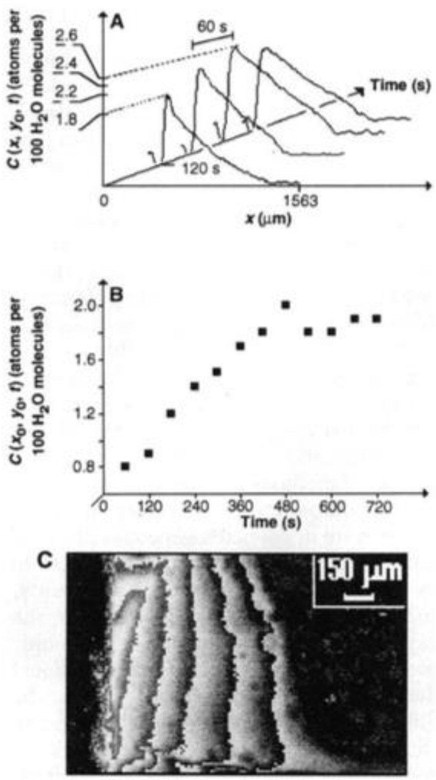


Fig. 4. (**A**) Evolution of a given concentration profile (y_0 = 300 µm, black line in Fig. 2B) as a function of time for four successive images taken before t = 300 s. (**B**) Variation of the local concentration of Zn^{2+} ions for a given pixel (x_0 = 545 µm and y_0 = 313 µm, black cross in Fig. 2B). The change of slope at t = 480 s suggests the influence of other additional phenomena (such as convection) on the diffusion process, but the uncertainty of the measurements (±5%) does not permit claims about oscillation effects. (**C**) Isoconcentration lines of the Zn^{2+} ions in solution, deduced from the image in Fig. 2A taken at t = 300 s.

Un ion Zn^{2+}

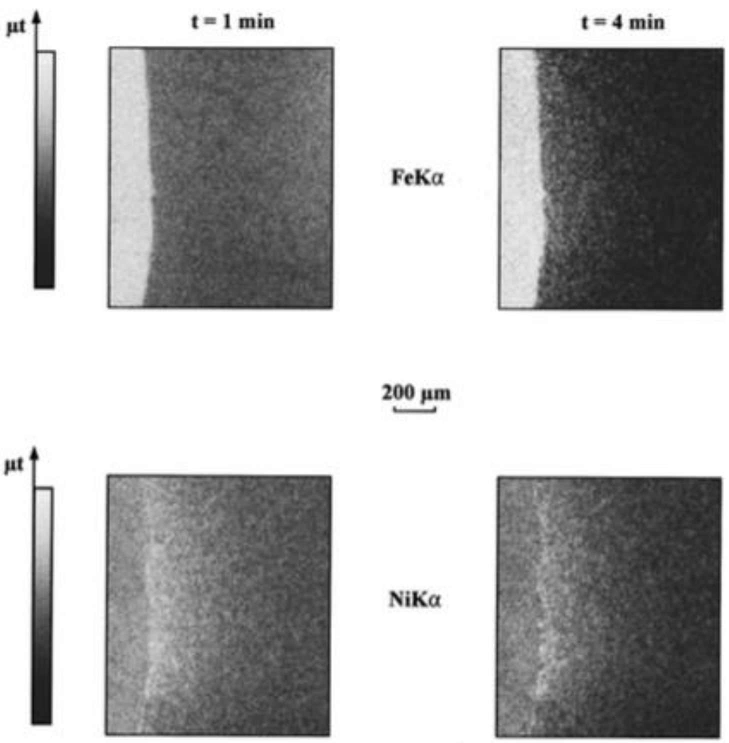
UNIVERSITÉ D'ARTOIS

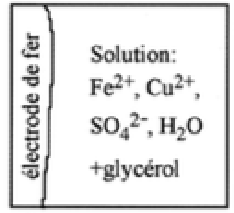
1997

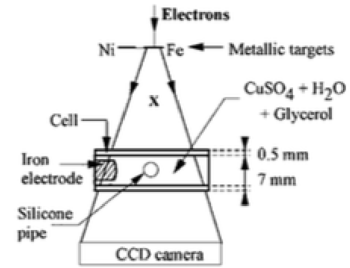
Review of Scientific Instruments **68**, 1787 (1997)

Quantitative mapping of species moving in solution by x-ray projection microscopy

S. Rondot and J. Cazaux







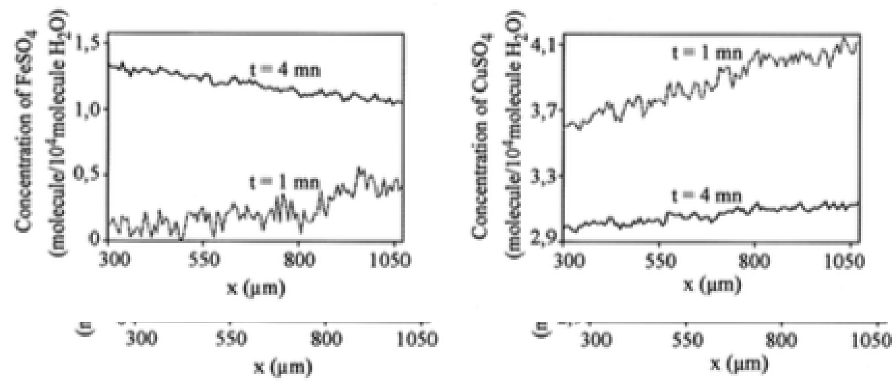


FIG. 2. **Top insert**: sketch of the specimen. **Main part**: example of pairs of μt maps of the chemical process acquired at two different times: $t = 1$ min (left side) and $t = 4$ min (right side), using two different characteristic radiations (top Fe$K\alpha$, bottom Ni$K\alpha$). On the left-hand side of each image is the iron electrode. The right-hand side of each image shows the absorption of the solution containing the two compounds $FeSO_4$ and $CuSO_4$ in a water and glycerol solution. White areas correspond to strong absorption that means strong concentrations of the species. The lighter zones in the solution near the electrode show that Fe and Cu ions pile up.

les profils à t = 4 min montrent les gradients des 2 ions

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La microscopie X

La conception de nouveauxinstruments

microtomographie X

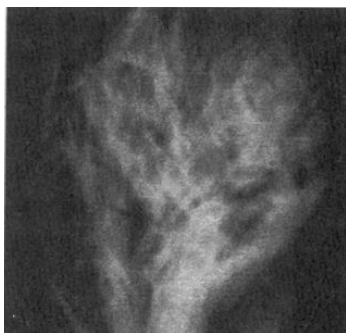
1996

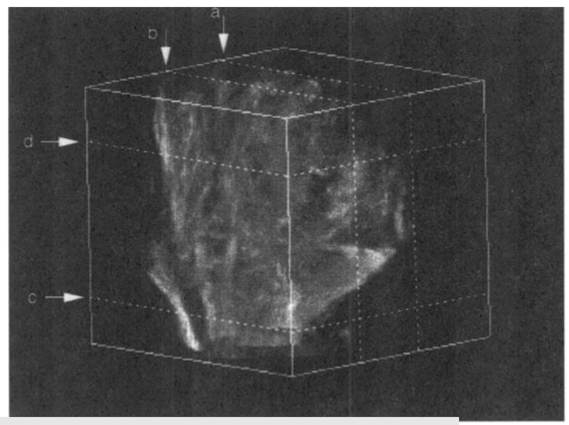
Pour explorer à l'intérieur du materiaux

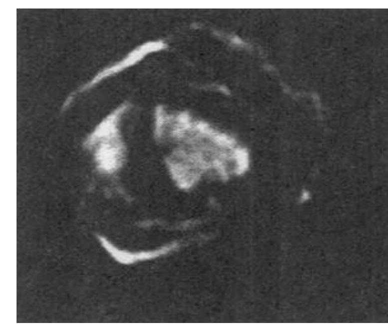
Microscopie et microtomographie X : application en biologie

H. Elhila, A. Zolfaghari, J. Cazaux, J.C. Audran* et D. Mouze

Bourgeon de vigne à differents stades







Total X-ray reflection microscopy

1996

JOURNAL DE PHYSIQUE IV
Colloque C4, supplément au Journal de Physique III, Volume 6, juillet 1996

Microscopie X par réflexion totale et diffraction de Kossel à incidence rasante : premiers résultats

D. Erre, H. Jibaoui et J. Cazaux

L'émission AUGER

De nombreuses publications sont reliées à la microscopie et spectroscopies AUGER.

Le choix des conditions opératoires (énergie, intensité, taille du spot du faisceau d'électrons incidents, durée de l'analyse, résolution spatiale, limite de détection) sont examinées.

UNIVERSITÉ D'ARTOIS

The AUGER Emission

62 SURFACE AND INTERFACE ANALYSIS, VOL. 6, NO. 2, 1984 **J. Cazaux and S. Moutou**

1984

The Influence of X-Ray-Induced Auger Electrons in Quantitative Electron-Induced Auger Spectroscopy

Il développe des expressions analytiques donnant les intensités des pics Auger en fonction de leur mécanisme d'émission (photons X, électrons)

2013

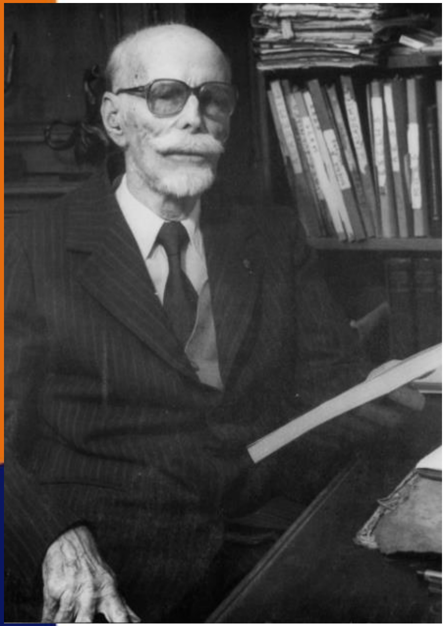
Journal of Electron Spectroscopy and Related Phenomena 187 (2013) 23–31

Influence of electron refraction effects at surfaces and interfaces in quantitative surface analysis with XPS and AES

The influence of the refraction effects in quantitative surface analysis is evaluated when Auger electrons or X-ray photoelectrons cross the sample/vacuum surface and other interfaces. Based on elementary quantum mechanical arguments, this evaluation concerns the determination of surface concentrations of homogeneous samples, as well as the determination of thicknesses of over layers or subsurface layers of stratified samples. From various numerical applications, such as the thickness determination of a graphene monolayer in X-ray Photoelectrons Spectroscopy (XPS), it is established that the refraction effects may lead deviations – with respect to the so-called straight-line approximation –, which may reach tenths of a percent for photoelectrons induced by soft X-rays when they are issued from metals and detected at decreasing take-off angles. The consequence in XPS – including Angle-Resolved XPS – and in Auger Electron Spectroscopy (AES) is discussed and some aspects of the discussion may also concern LEED (Low Energy Electron Diffraction) via the fact that the refraction effects results from the difference between the inner and the outer energy of the electrons of interest, a difference equals to the sum of the Fermi energy and the work function and often referred in the LEED literature as inner potential *U*.

Jacques Cazaux était aussi un grand admirateur de Pierre Auger

J Cazaux,J.P. Langeron



Pierre AUGER

Fascinating Auger effect but also fascinating **Pierre Auger**. For most of the people involved in Practical Surface Analysis by Auger spectroscopy, the man was quite unknown and the technical details of his decisive discovery were not very clear, even for French scientists. The opportunity to discover the man was given to a few of us in Paris, March 1989, upon the occasion of his 90th birthday. We find a man who, when he was 24 years old, established the key aspects of the "effet photoélectrique composé" using very rustic but very clever equipment (see the illustration).

After such a discovery most people would spend their scientific life exploiting the scientific and personal benefit of such a finding. Most people that is except P. Auger who was, in 1928, on board a liner going from Le Havre to Rio de Janeiro to study Cosmic rays at the Equator. Following the exile of Ch. de Gaulle to London, he emigrated to the United States in 1940 and then went on to create an Anglo Canadian laboratory in Montreal (Canada).

After World War II, he participated successively and successfully in the creation of the CEA (French Atomic Energy Commissariat), the Science Department of UNESCO (United Nations of Education, Science and Culture Organization) and CERN (European Organization for Nuclear Research).

In the sixties he also founded the CNES (National Center for Space Studies) and the ESRO (European Space Research Organization). In parallel he found time to write poetry (in English !) and to sculpt small objects at lost wax.

On the 24th December 1993, Pierre Auger passed away after a fantastic life. This issue of Microscopy, Microanalysis, Microstructure is not dedicated to all the aspects of his scientific activity. It concentrates on the recent applications of Auger spectroscopy to the chemical charaterization of surfaces. This is an exploding and living field which, at the end of this century, is full of promising consequences and which has its origins in the pioneering work of Pierre Auger, carried out alone and during such a short period of his life.

Preface du numéro spécial deMicroscopy Microanalysis, Microstructure (1995)

Les effets de charges

1986

Journal of Applied Physics **59**, 1418 (1986)

Some considerations on the electric field induced in insulators by electron bombardment

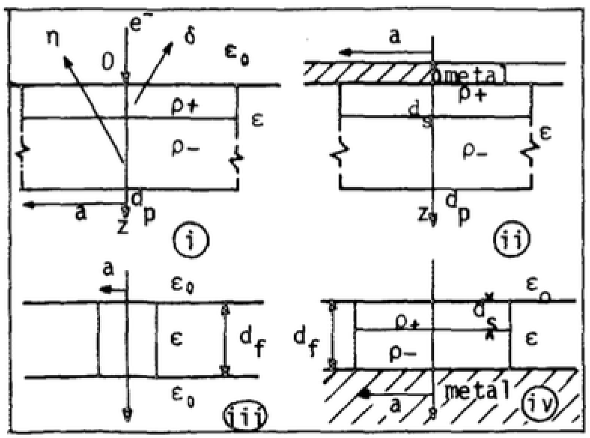


FIG. 1. Model for the charge distributions in four situations: (i) semi-infinite bulk sample bounded by a vacuum, (ii) semi-infinite bulk sample covered by a conducting layer, (iii) thin-film sample bounded by a vacuum, and (iv) thin-film sample covering a conducting substrate and bounded by a vacuum.

Starting from a simple model of the distributions of charge created in an insulator by bombardment with electrons, the components of the electric field are evaluated by using Maxwell's equations and image effects. The results are applied to the most common experimental situations: a semi-infinite sample (i) bounded by a vacuum or (ii) covered by a conducting film, and a sample in the form of a film (iii) unsupported or (iv) covering a conducting substrate. The results are compared to some experimental data concerning, for instance, electromigration and electron-stimulated desorption. In surface analysis the decay of the Auger signal from ions of opposite charges and the opposite behavior of ions of the same charge are explained. Similar effects observed in electron-probe microanalysis of glasses are also elucidated. The results concern scanning electron microscopy, transmission electron microscopy, and electron-beam lithography applied to biological objects, polymers, ceramics, minerals, glasses, and electronic devices. With slight modifications, the same model can be applied to cases of irradiation with ions or x rays. The evolution of the trapped charges with time is suggested, and the need to indicate the electric parameters (ϵ and γ) of the investigated samples is outlined.

200 citations in Scopus

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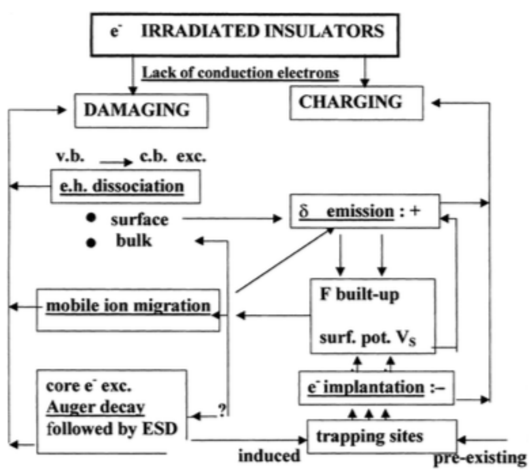
Les effets de charges

Journal of Electron Spectroscopy and Related Phenomena 105 (1999) 155–185

1999

Mechanisms of charging in electron spectroscopy

From the use of physical arguments based on classical electrostatics and elementary solid state physics, the role of the various parameters involved in the charging mechanisms of insulating materials is analysed in detail when these insulating specimens are investigated by surface analytical techniques (mainly XPS and e⁻ AES). The role of the sub-surface composition and structure is outlined and the strong correlations between charging effects and some radiation damage effects are pointed out. Some strategies are also deduced to minimise these effects.



Scheme 1. Correlations between charging and damaging mechanisms in insulating materials in eAES. For XPS the electron implantation contributing to a negative charging has to be suppressed.

141 citations in Scopus

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Les effets de charges

63 citations in Scopus

Journal of Electron Spectroscopy and Related Phenomena 113 (2000) 15–33

2000

About the charge compensation of insulating samples in XPS

In electron spectroscopy, charging of insulating specimens is characterised by a normally steady surface potential, V_S, which results from the equilibrium between the electron emission into the vacuum, I (out), and various compensation mechanisms contributing to I (in). Continuing from a recent paper (J. Cazaux, J. Electr. Spectrosc. Rel. Phen. 105, 1999, 155), this emission and these compensation mechanisms (including the role of flood guns) are analysed here in more detail for a situation mainly restricted to conventional XPS. In particular, a new graphical representation can be used to explain why the irradiation conditions and the environment of the specimen play a role on the charging shift, V_S, and on differential charging, ΔV_S, that is more important than its exact chemical composition. A critical analysis of the negative (and positive) biasing of the specimen is also performed. Various practical consequences are deduced from an approach based on I(in)=I(out) at the steady state. Additional electrostatic considerations are given, extending the investigation to small spot XPS and some consequences may also be easily transposed to SEM (scanning electron microscopy) and to AES (Auger electron spectroscopy).

Journal of Electron Spectroscopy and Related Phenomena 176 (2010) 58–79

2010

Secondary electron emission and charging mechanisms in Auger Electron Spectroscopy and related e-beam techniques

Mechanisms of charging in AES are reconsidered to the light of recent developments concerning the leading role of secondary electron emission (SEE) in the self-regulation processes taking place in insulating materials irradiated with keV-electrons. A specific attention is paid to SE angular distribution and to distortion of SE trajectories by the electric field build-up into the vacuum when the surface potential is negative. These external mechanisms are associated to internal mechanisms resulting from the effect of low potential barrier or of low hollow in the SE generation region. From these investigations the main parameters governing the time dependence of charging have been identified and the fact that the critical energy (between positive and negative charging region at steady state), E_2^C, is less than the convention critical energy $E°_2$ (where the total SEE yield is unity) has been re-confirmed for AES. Common points and differences between AES and other electron beam techniques (such as those based on external collector positively biased in SEE yield measurements) are also discussed in detail and possible experimental artefacts are also pointed out (such as those resulting from the incorrect use of the shift of Duane-Hunt limit with a X-ray detector in a SEM). Some practical consequences to minimize charging effects (specimen preparation, operating conditions and use of additional irradiations) have been deduced.

Les effets de charges

2014

La dernière publication

Journal of Electron Spectroscopy and Related Phenomena 192 (2014) 40–51

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journal homepage: www.elsevier.com/locate/elspec

Work function effects on the positive charging of supported insulating samples exposed to X-rays (as in XPS) and other irradiations

J. Cazaux *

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Avec le MEB

A partir de physique de l'émission des électrons secondaires

2004

Jacques Cazaux explore le rôle des SE_1, SE_2 and SE_3 et le rôle de la geometry de leur detection dans le MEB à basse tension

Journal of Microscopy, Vol. 214, Pt 3 June 2004, pp. 341–347

About the role of the various types of secondary electrons (SE_1; SE_2; SE_3) on the performance of LVSEM

2005

Journal of Microscopy, Vol. 217, Pt 1 January 2005, pp. 16–35

REVIEW ARTICLE

Recent developments and new strategies in scanning electron microscopy*

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A propos du MEB

2005

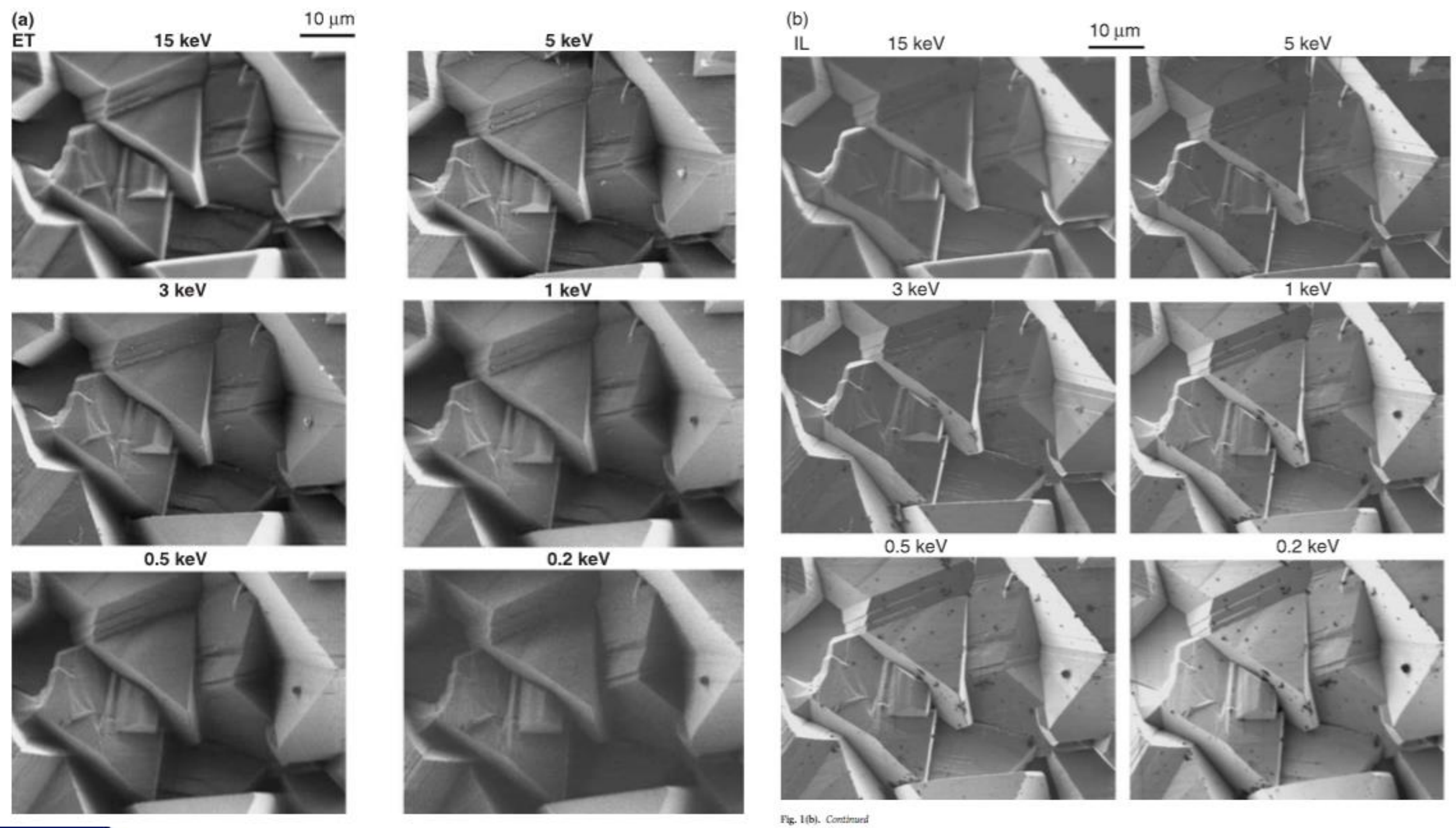

Fig. 1(a). Series of images of a micro-structured diamond specimen with graphitized residues obtained using a SEM (LEO, Gemini DSM 982) at a working distance of 2 mm when the beam energy is changed from 15 keV (i) to 0.2 keV (vi). A lateral detector (ET) is operated for (a); an in-lens detector is operated for (b) (see next page). The upper left image (a) is similar to that obtained with a 'old' SEM and the other images illustrate some advantages of LVSEM.

Grand Interêt

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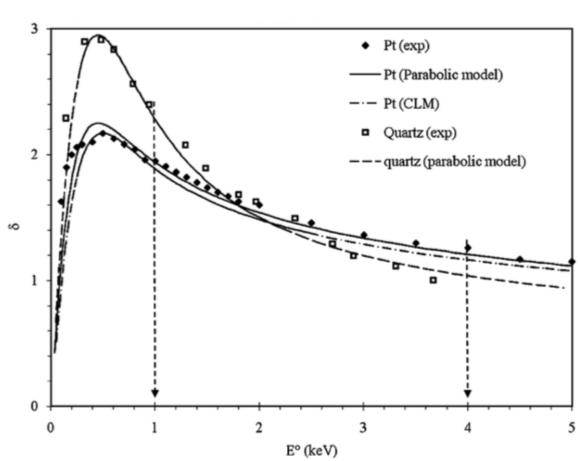
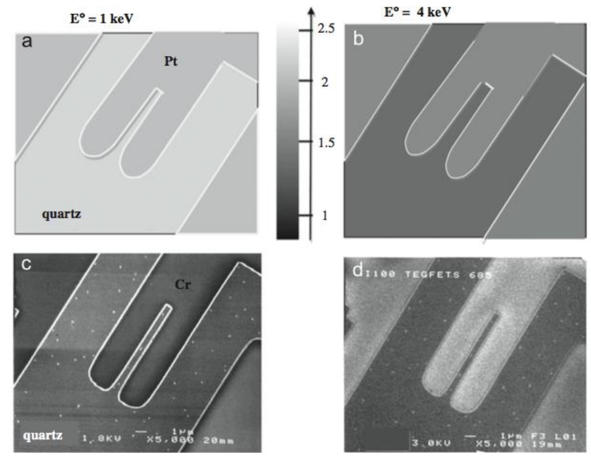
A propos du MEB

2008

Ultramicroscopy 108 (2008) 1645–1652

On some contrast reversals in SEM: Application to metal/insulator systems





2010

Ultramicroscopy 110 (2010) 242–253

Material contrast in SEM: Fermi energy and work function effects

Is it possible to assign various grey levels of a scanning electron microscope (SEM) image to different omponents of a given sample? Among other instrumental effects, the answer is not only a function of he respective secondary electron emission (SEE) yields of the components, δ, but also of the angular raction of the secondary electrons (SE)s being collected, k_α and of a possible voltage contact effect etween sample and detector, k_ϕ. Expressed as a function of E_F, Fermi energy, and ϕ, work function of

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2011

A propos du MEB

2012

Un excellent review

From the physics of secondary electron emission to image contrast in scanning electron microscopy

Journal of electron microscopy 61(5) 261-284 (2012)

Corrélation entre la physique de l'émission des SE avec les différents contrastes obtenus pour des matériaux non magnétiques

A propos du MEB

2013

Ultramicroscopy 135 (2013) 43–49

Backscattered electron imaging at low emerging angles: A physical approach to contrast in LVSEM

J. Cazaux [a,*], N. Kuwano [b], K. Sato [c]

Due to the influence of refraction effects on the escape probability of the Back-Scattered Electrons (BSE), an expression of the fraction of these BSE is given as a function of the beam energy, E°, and emission angle (with respect to the normal) α. It has been shown that these effects are very sensitive to a local change of the work function in particular for low emerging angles. This sensitivity suggests a new type of contrast in Low Voltage Scanning Electron Microscopy (LVSEM for $E^{\circ} < 2$ keV): the work function contrast. Involving the change of ϕ with crystalline orientation, this possibility is supported by a new interpretation of a few published images. Some other correlated contrasts are also suggested. These are topographical contrasts or contrasts due to subsurface particles and cracks. Practical considerations of the detection system and its optimization are indicated.

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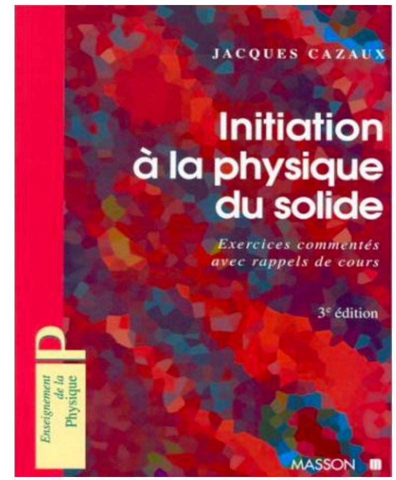
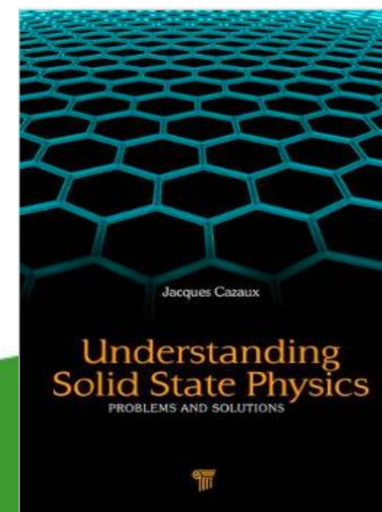
Jacques Cazaux, l'enseignant

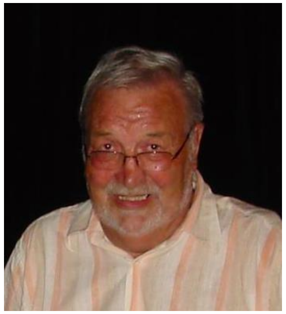
Un professeur passionné à l'Université de Reims

Auteur d'ouvrages publiés par Masson en France.
(troisième édition)
Disponible aussi en anglais





Conclusion



- Jacques Cazaux a exploré la spectroscopie de perte d’énergie des électrons, la physique de l’émission des électrons secondaires, l’emission Auger, les effets de charges dans les isolants et le contraste dans les images dans le MEB (150 publications).

-Son livre dédié à la physique de l’état solide est un ouvrage de référence pour les étudiants en physique, en chimie et en science des matériaux.

-Au dela de ses contributions , Jacques Cazaux était une personnalité inimitable avec son accent du sud surtout lorsqu’il s’exprimait pour nous expliquer les nombreux sujets qui le fascinaient.

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•*REMERCIEMENT*

Cette présentation est inspirée en partie des hommages posthumes de Christian Colliex et Jacky Ruste.

Merci pour votre attention

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