Raimond Castaing

1921-1998

Brief biography

Raimond Castaing was born on December 28, 1921 in Monaco. In 1940 he entered the Ecole Normale Superieure, (the highest academic institution for training in the physical sciences in Paris) and became the student of Frederic Joliot, at the College de France. He joined the French resistance during the war and graduated in 1946 with the highest grades for the teaching of physical sciences.



Castaing held the post of lecturer at the University of Toulouse from 1952 to 1956, then he became lecturer at the University of Paris from 1956 to 1959. He took part in the creation of the University of Paris, Orsay (with André Guinier), where he became a professor and Director of the Laboratory of Physics of Solids up to his retirement.

Electron probe microanalyzer (EMPA)

Castaing began his career as a research engineer at the Office National d'Etudes et de Recherches Aeronautiques (ONERA), where he did his thesis work under the direction of André Guinier. The work came from interest in aluminum-copper alloys, and the need to observe the zones of copper precipitation in the aluminum. The first EMPA was built by designing a new objective lens for the first French commercial TEM (made by CSF), which allowed x-rays to escape. It was fitted with a Johannson-crystal type of focusing wavelengthdispersive spectrometer, with a Geiger counter as the detector (Fig. 1). The first published report was in the proceedings of the 1949 Delft International EM meeting, then in the 1950 Paris International meeting, and finally in Castaing's 1951 thesis "Application des Sondes Electroniques a une Methode d'Analyse Ponctuelle Chimique et Crystallographique", for which he received his doctorate from the University of Paris. His thesis (Fig. 2) set out the principles for electron-probe microanalysis, which still apply today. Subsequently, he constructed a prototype EMPA, with magnetic lenses, at ONERA (Fig. 3), which, with minor modification, became the first commercial EMPA, the Cameca MS85 (1958).

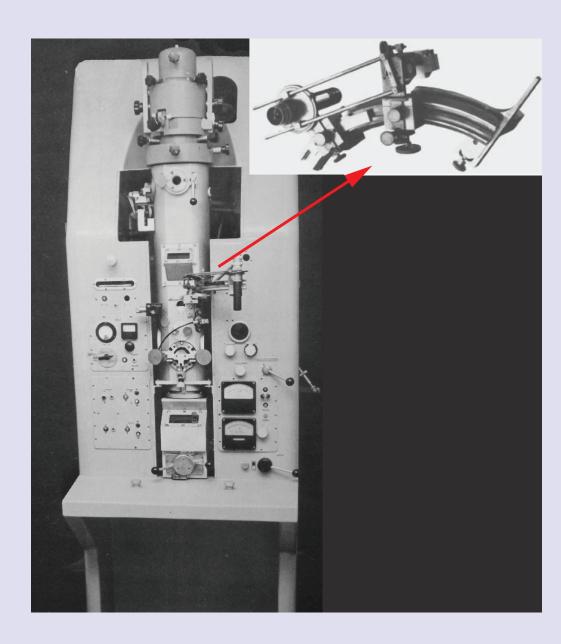


Fig. 1. The first electron microprobe, adapted from an CSF electrostatic TEM. Detail of the spectrometer is shown in the inset (image from Grivet, 1985).

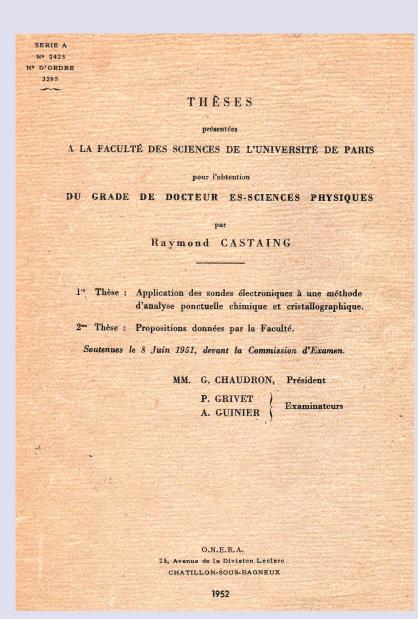


Fig. 2. Cover of Castiang's 1951 PhD thesis (scan courtesy of Peter Duncumb).

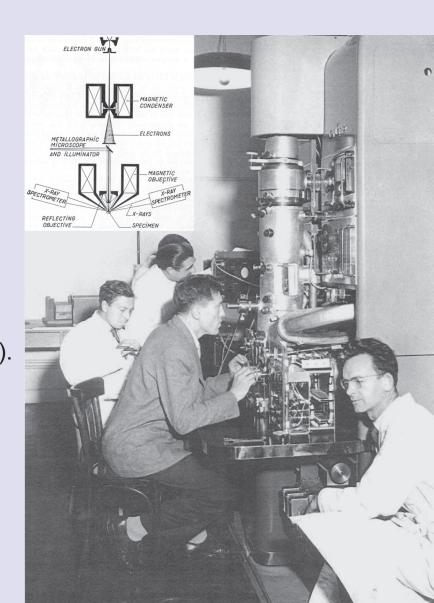
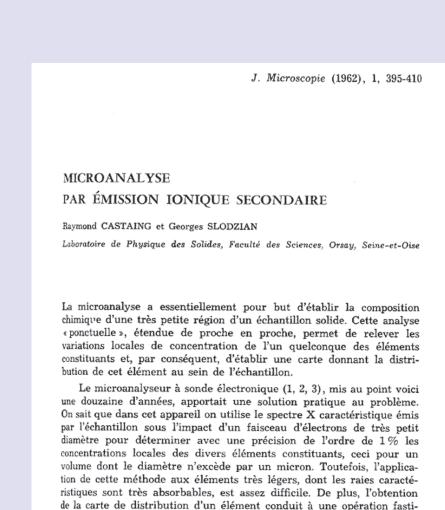


Fig. 3. Castiang operating his prototype ONERA EMPA (image from Castaing family; other individuals not identified).

Secondary ion microscopy and spectroscopy

Castaing was always interested in obtaining a compositional map of the specimen, although his original EMPA could only be used for point analysis. However he did not like the idea of scanning the specimen; he wanted direct images. The first realization of this was the secondary-ion microscope. This was initially developed as a student project under Castaing by Geroges Slodzian, who went on to pioneer SIMS (secondary-ion mass spectrometry). This was first reported in Castaing and Slodzian, 1962 (Fig. 4). A primary energetic ion beam sputters the sample surface. Secondary ions generated in this sputtering process are extracted from the sample and analysed by a mass spectrometer. The secondary-ion microscope required development of the first imaging mass spectrometer and a novel ion-to-electron converter in order to obtain adequate images (Fig. 5). The SIMS instrument (Castaing and Slodzian, 1981) provides: (1) Excellent depth resolution (a few nm), (2) High sensitivity (ppb), (3) Full periodic table coverage (including hydrogen), and (4) Rapid ion image acquisition capabilities. Slodzian's commercial realization was the Cameca SMI 300, and ultimately the Nanosims 50, which, in the interest of higher lateral resolution, was no longer a direct imaging device, but instead used a scanning ion probe (Hillion et al., 1993). It is interesting to note that the development work on the Nanosims project was done at ONERA, through the influence of Castaing.



dieuse, ou bien nécessite l'emploi d'un artifice de balayage électroni-

que (5, 6) ou mécanique (9). Nous nous proposons de décrire ici une

Il est bien connu que le bombardement de la surface d'un solide

par un faisceau d'ions provoque la pulvérisation de la cible; sous l'im pact des ions les atomes constituant l'objet sont arrachés. L'étude de

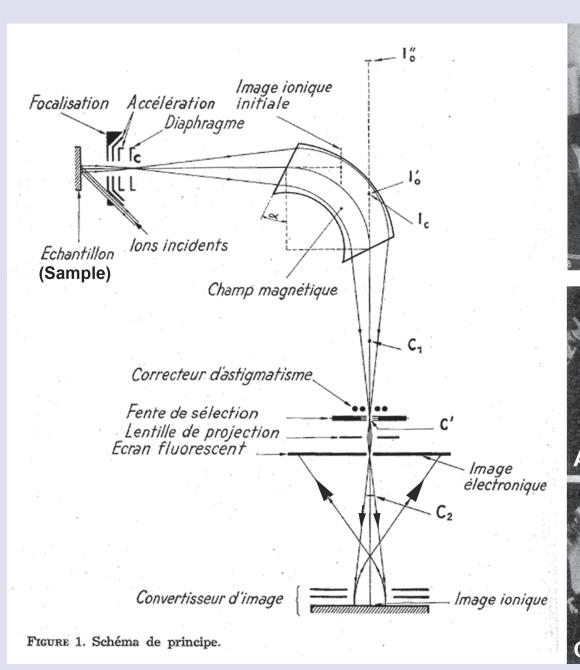
ce phénomène de « pulvérisation cathodique » montre qu'une proportion non-négligeable des particules ainsi extraites quitte la cible sous forme d'ions. Ces ions sont formés à partir des atomes qui constituent

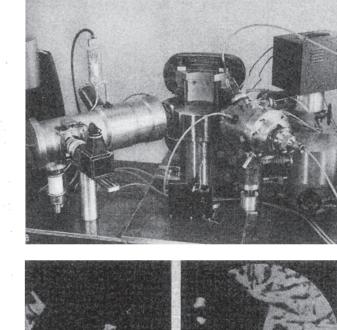
l'échantillon; ils sont donc caractéristiques des divers éléments présents

autre méthode de microanalyse, qui semble devoir pallier ces inconvénients. Elle relève d'un principe entièrement différent, le phénomène

de base étant l'émission ionique secondaire.

Fig. 4. First report of the development of secondaryion microscopy.





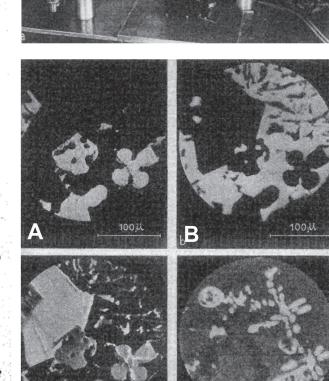


Fig. 5. Diagram and picture of the first secondary-ion microscope. Note that the ion-to-electron converter projects the image back to the fluorescent screen. Images: (A) Mg+ image of an Al-Mg-Si alloy, (B) Al+ image of the same specimen, (C) Si+ image of the same specimen, (D) Cu+ image of solid Cu with Cu2O inclusions.

(from Castaing and Slodxian, 1962).

Electron energy-loss imaging and spectroscopy

Consistent with his desire to from direct (and quantitative) compositional images, and at about the same time as he was working on secondary ion microscopy with Georges Slodzian, Castaing set another student, Lucien Henry, to the task (as his thesis work) of designing an imaging electron energy filter for the TEM. The Castaing-Henry filter (Castaing and Henry, 1962; Castaing, 1975, Fig. 6) consisted of a triangular magnetic sector and an electrostatic mirror. This filter eventually appeared in a commercial TEM, the Zeiss EM902 (Fig. 7), and it encouraged development, by others, of other types of in-column energy filter, now used to great advantage in Zeiss and JEOL TEMs.

ACADÉMIE DES SCIENCES OPTIQUE ÉLECTRONIQUE. — Filtrage magnétique des vitesses en Microscopie électronique. Note de MM. RAYMOND CASTAING et LUCIEN HENRY, transmise par M. Gaston Dupouy.

Le problème du filtrage des vitesses en microscopie électronique a été

abordé notamment par Boersch, puis repris par Beaufils (1); ces auteurs utilisaient une méthode de contre-champ et aboutissaient à un filtrage « passe-haut » où les électrons diffusés inélastiquement sont éliminés de l'image définitive. Hennequin (2) a montré pour sa part l'intérêt d'un filtre « passe-bande » qui permette de prélever pour la formation de l'image les électrons ayant subi une perte d'énergie déterminée, et étudié dans ce but les propriétés optiques d'un prisme magnétique à induction uniforme. Watanabe et Uyeda (3) ont récemment abordé ce dernier problème et proposé un montage où le système dispersif est constitué par une lentille de Möllenstedt. Cette lentille électrostatique présente toutefois des caractéristiques qui rendent assez malaisée son utilisation pour la formation d'images filtrées : l'obtention d'une bonne résolution en énergie conduit, en effet, à réduire le champ objet à une bande très étroite, et une image ne peut être obtenue qu'au prix d'un artifice de balayage consistant à déplacer de façon synchrone les images intermédiaire et finale; des difficultés analogues interviennent lorsqu'il s'agit d'enregistrer un spectre s'étendant sur une bande d'énergies importante. La lentille de Möllenstedt introduit d'autre part sur l'image un astigmatisme et une aberration chromatique importants; l'obtention d'un bon pouvoir séparateur exige donc l'emploi d'un stigmateur auxiliaire, et la bande d'énergies utilisée doit rester très étroite. L'appareil que nous avons réalisé, et qui est issu des travaux préliminaires conduits par Hennequin (3) et Mile Paras (4) dans notre Laboratoire, permet, dans les conditions normales de fonctionnement d'un microscope, d'observer successivement le spectre des pertes d'énergie produites par une région donnée de l'échantillon, puis l'image de cette région, formée par des électrons dont l'énergie occupe une bande de largeur et de limites réglables à volonté. Le système dispersif n'introduit sur l'image ni astigmatisme ni aberration chromatique. Le faisceau image, issu du « cross-over » C1, de très petites dimensions, produit par un objectif double, subit dans un prisme magnétique une

première déflexion à 90° qui vient le faire converger en un point S où se trouve disposé le « sommet » d'un miroir électronique; la réflexion

Fig. 6. First report of electron-energy-loss

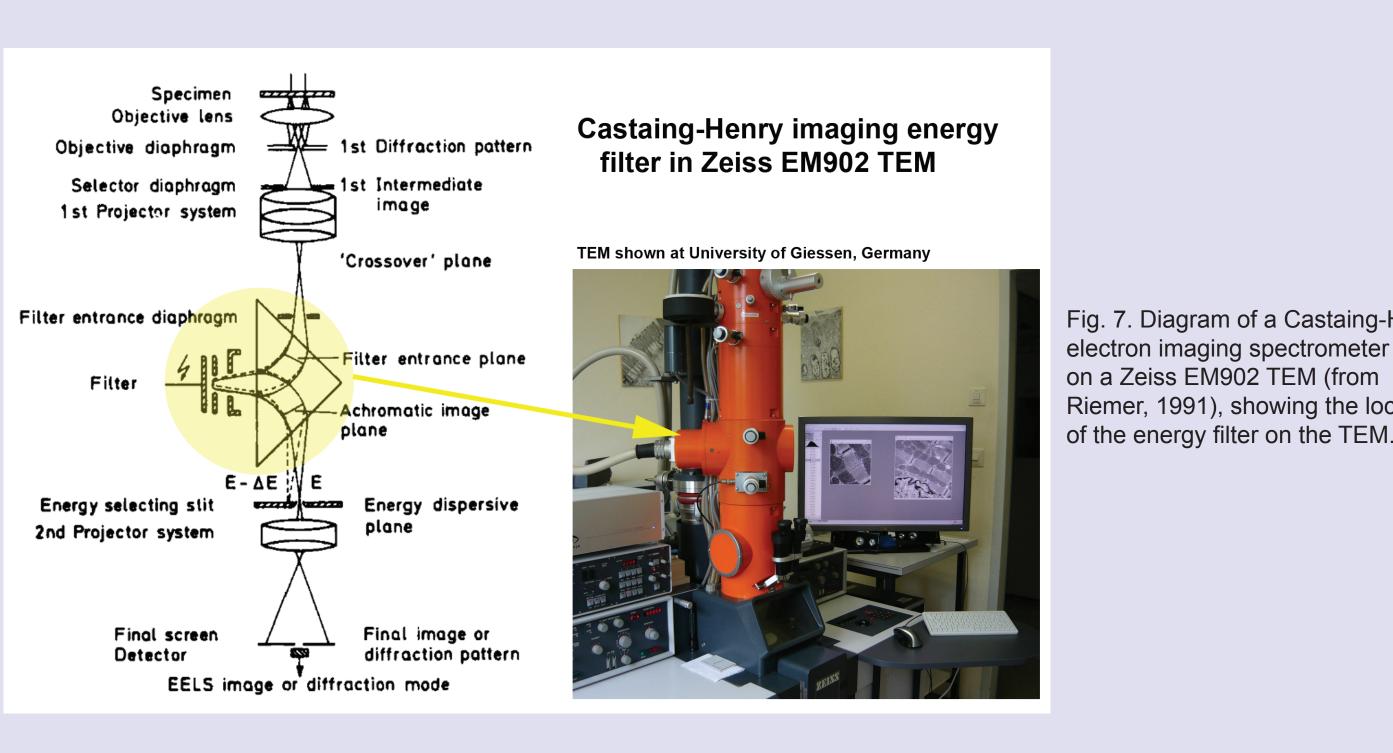


Fig. 7. Diagram of a Castaing-Henry electron imaging spectrometer on a Zeiss EM902 TEM (from Riemer, 1991), showing the location

Later responsibities

Concurrently with being Director of the Laboratory of Physics of Solids of the University of Paris, Orsay, Castaing was scientific director and then General Director of ONERA from 1968 to 1973. He was elected to the Council of Nuclear Security in 1982 and was a member of the Atomic Energy Committee from 1982 to 1987. He was Administrator of the French civil research organization, CNRS, from 1983 to 1989, a member of the Administration Committee of Usinor (the French steel company) from 1984 to 1987, and in 1996 he became President of the Commission on the fast breeder reactor Superphenix.

Honors

Castaing was elected to the French Academy of Sciences in 1977, the same year he received the Roebling Medal of the Mineralogical Society of America. He was made an honorary member of MAS in 1974, the first year such titles were granted. In 1982 MAS established the Castaing Award for the outstanding student paper, with support (very appropriately) from Cameca. In 1993 he received the IMS Sorby award, that Society's highest. At M&M 1999 in Portland OR, MAS held a special symposium celebrating 50 years since Prof. Castaing reported his development of the electron microprobe (Fig. 8). At this time, MAS distributed copies of the Duwez and Wittry translation of Castaing's 1952 thesis.

MAS Celebrates Fifty Years of Electron Probe Microanalysis A Symposium Dedicated to Prof. Raimond Castaing Keynote Address: *The Time of the Pioneers* Jean Philibert Microprobe Design in the 1950's - Some Examples in Europe Peter Duncumb Kurt Heinrich The Golden Age of Microanalysis Development of Electron Probe Instrumentation During those Early Days when Ryuichi Shimizu Professor Castaing Visited Japan Crystal Spectrometers and Monochromators in Microanalysis David Wittry Advances in WDS Crystal Performance Charles Nielsen EDS and WDS Automation: Past Development and Future Technology Jon McCarthy Today's and Tomorrow's Instruments Claude Conty Quantitative Electron Probe Microanlysis: Fifty Years of Developments in the Application of Castaing's "Z" and "A" Corrections John Armstrong Characterization and Continuum Fluorescence in Electron Beam X-ray Clive Nockolds Fundamental Constants for Quantitative X-ray Microanalysis Minimizing Errors in Electron Microprobe Analysis Eric Lifshin Selecting Standards to Optimize Electron Microprobe Analysis Eric Essene Application of the Electron Probe Microanalyzer to the Analysis of Planetary and Geological Materials: A Historical Perspective A Few Examples of Electron Micronanalysis of Art Objects at the Boston Museum Minimally Invasive (Energy) Dispersive Analytical Spectroscopy (MIDAS). The Golden Touch for In-Situ X-ray Microanalysis of Bulk Bio-Organic Samples Patrick Echlin

Castaing's Electron Microprobe and its Impact on Materials Science

Source material

the MSA newsletter, MicroNews.

Fig. 8. Program of the Castaing symposium organized by MAS at M&M 1999.

References

Castaing R and Guinier A (1949) Application of electron probes to metallographic analysis. In: Proceedings of the 1st International Congress on Electron Microscopy, Delft, pp 60–63.

Castaing R and Guinier A (1950) Sur l'exploration et l'analyse élémentaire d'un échantillion par une sonde éléctronique. C.R. Premier Congrés International Microscopie Éléctronique 391-397.

Castaing R (1951) Application of electron probes to local chemical and crystallographic analysis. PhD Thesis, University of Paris [English translation by P Duwez and DB Wittry, California Institute of Technology, 1955].

Castaing R and Henry L (1962) Filtrage magnetique des vitesses en microscopie electronique. C. R. Acad. Sci. Paris B255:76-86.

Castaing R and Slodzian G (1962) Microanalyse par émission ionique secondaire. Journal De Microscopie 1:395-410.

Castaing R (1975) Energy filtering in electron microscopy and electron diffraction. In: Physical Aspects of Electron Microscopy and Microbeam Analysis (Ed. B. Siegel B). Wiley, NY, pp 287–301.

E: Scientific Instruments 14(10):1119-1127.

Hillion F, Daigne B, Girard F and Slodzian G (1993) A new high performance instrument: the Cameca "Nanosims 50." SIMS 9:254-257.

Castaing R and G Slodzian G (1981) Analytical microscopy by secondary ion imaging techniques. Journal of Physics

Academic Press, NY 13:317-386.

Conty C (2001) Today's and tomorrow's Instruments. Microsc. Microanal. 7:142–149.

Grillon F and Philibert J (2002) The legacy of Raimond Castaing. Microchimica Acta 138(3-4): 99-104.

Grivet P (1985) The French electrostatic electron microscope (1941-1952). In: Advancs in Electronics and electron physics, suppl. 16 (Ed. PW Hawkes) Academic Press, NY, pp 225-274.

Portions of the biography were taken from the obituary written by Ryna Marinenko in the Spring-Summer 1998 issue of

Figure 3 was taken from John Fournelle's article in the Spring-Summer 2011 issue of the MSA newsletter, MicroNews.

Castaing R. (1960) Electron probe microanalysis. In: Advances in Electronics and Electron Physics (Ed. L. Marton)

Dale Newbury

Newbury DE (2001) Castaing's electron microprobe and its impact on materials science. Microsc. Microanal. 7:178-

Riemer L (1991) Energy-filtered electron microscopy. In: Advances in Electronics and Electron Physics (Ed PW Hawkes) 81: 43-118.

Slodzian G (2008) Secondary Ion Microscopy and Spectrometry. Explorer's notes over a half-century journey. 21st SIMS Workshop San Antonio 2008, pp 1-15.