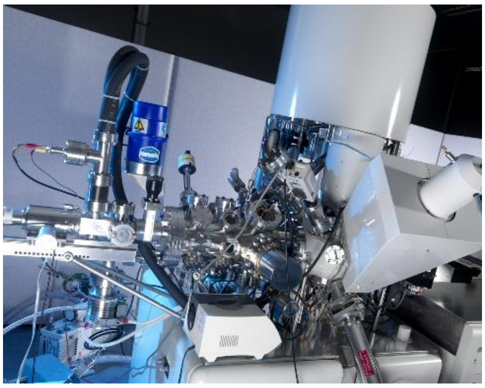
A quick NPL guide to…

X-Ray Photoelectron Spectroscopy

What does XPS do?

XPS is used for investigating the surface chemistry of electrically conducting and non-conducting samples. It provides the following information from the top 10nm of a sample with a spatial resolution between three to a few hundred µm.

- Elemental composition with up to 0.1% sensitivity
- Chemical state information
- Thickness measurement of overlayers of up to 8 nm on a substrate
- Surface chemical imaging with a resolution of 3 µm
- Angle resolved XPS for thickness and depth-distribution of chemical species
- Depth profiling using an ion gun to sputter away the surface during analysis
- Ultraviolet photoelectron spectroscopy (UPS) available in the same instrument provides information on the density of states in the valence band and electron work function



How does XPS work?

A surface is irradiated with X-rays (commonly Al Kα or Mg Kα) in vacuum. When an X-ray photon hits and transfers this energy to a core-level electron, it is emitted from its initial state with a kinetic energy dependent on the incident X-ray and binding energy of the atomic orbital from which it originated. The energy and intensity of the emitted photoelectrons are analysed to identify and determine the concentrations of the elements present. These photoelectrons originate from a depth of <10 nm therefore the information obtained is from within this depth. UPS uses a much lower energy source, He(I) and He(II), 21.2 eV and 40.8 eV respectively.

What is XPS used for?

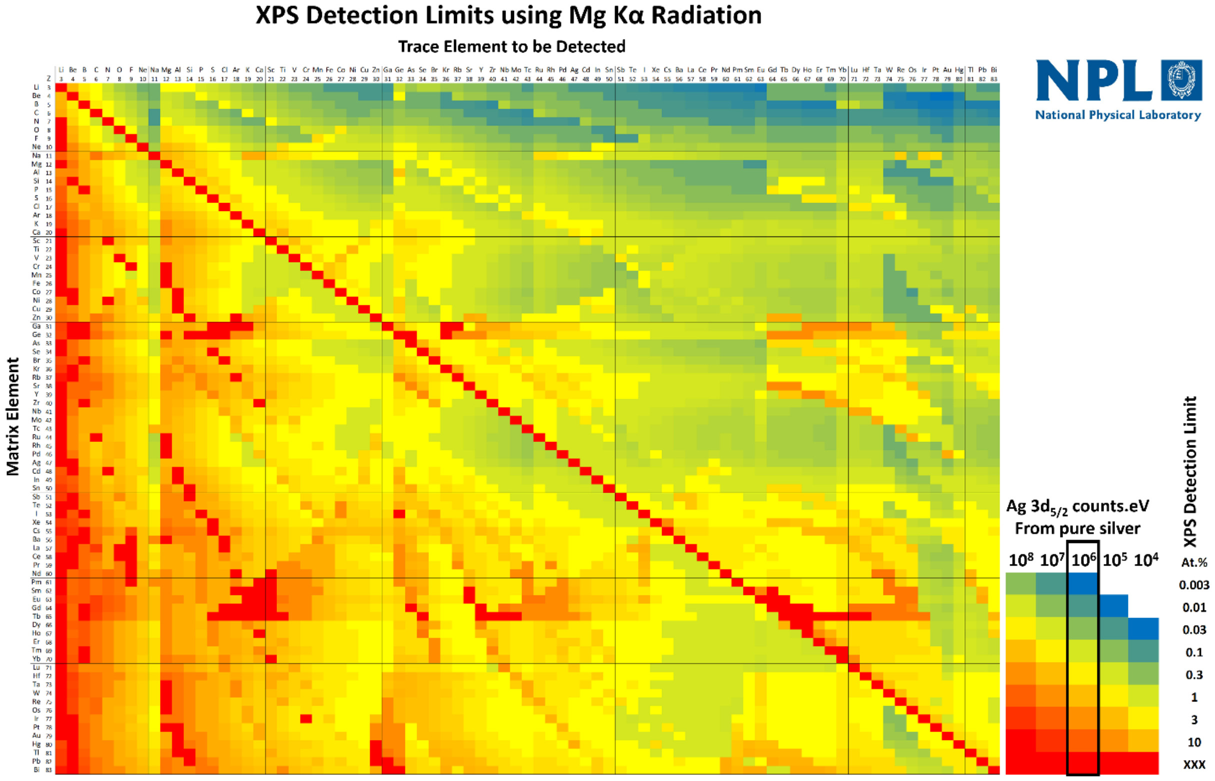
- Depth profiling on surfaces
- Identification and measurement of surface contamination and organic overlayers, e.g. to solve problems of adhesion of coatings on substrates
- Analysis of nanoparticles
- Silicon dioxide on silicon thickness measurement for the semiconductor industry
- Identification of counterfeit products
- Catalysis and corrosion studies
- Characterisation of a wide range of materials such as paints, polymers, ceramics and glasses
- UPS for characterisation of organic electronics

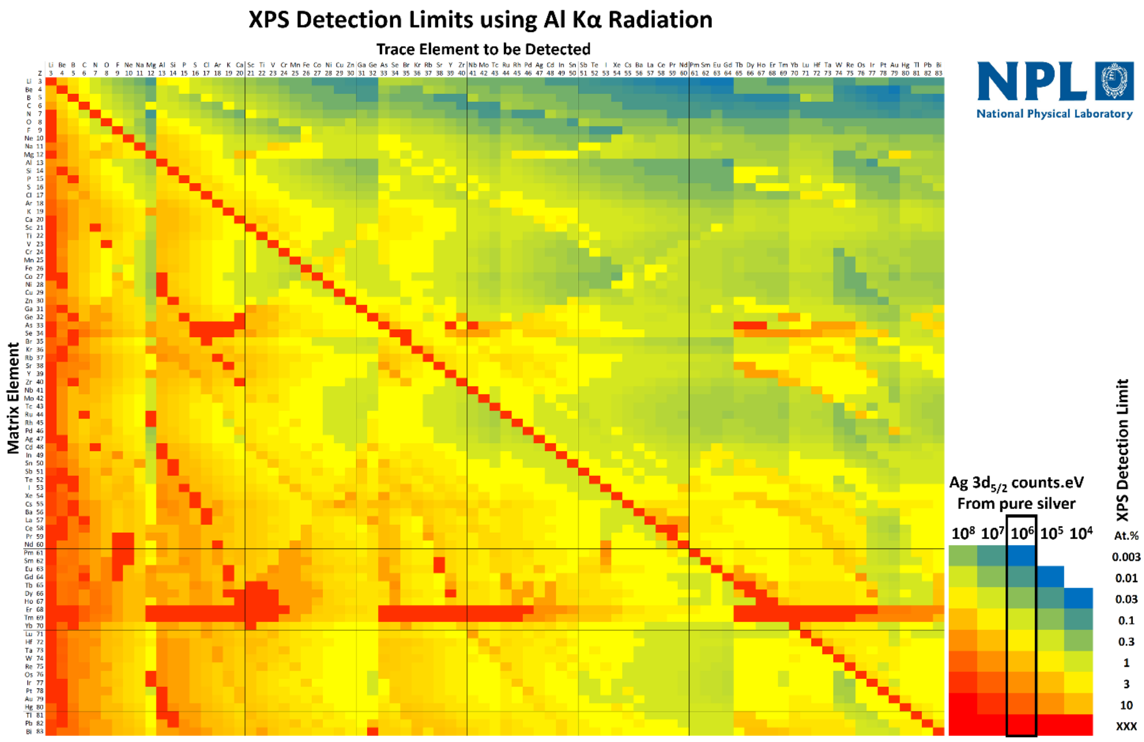
See our **XPS measurement services** page to find out how XPS may help with your specific application.

What are the measurement challenges?

Curved surfaces or those with topography and samples that have dimensions of the order of nanometres cause handling and quantification problems. NPL has determined correction factors that can be applied to XPS for overlayers on curved or samples of known topography and are investigating the sample preparation and characterisation of micro and nanoparticles. Quantitative organic depth profiling using XPS is also being studied. NPL is improving the depth range and accuracy of XPS by calibrating high energy XPS instruments and analysing the shape of backgrounds in an XPS spectrum.

XPS detection limits





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See our **Services** page for more on quantitative XPS analysis.

National Physical Laboratory

Key Publications

Comparisons of Analytical Approaches for Determining Shell Thicknesses of Core–Shell Nanoparticles by X-ray Photoelectron Spectroscopy, CJ Powell, WSM Werner, H Kalbe, AG Shard, DG Castner, *The Journal of Physical Chemistry C*, 122 (7), 4073-4082 (2018)

Summary of ISO/TC 201 standard: ISO 19668—Surface chemical analysis—X-ray photoelectron spectroscopy— Estimating and reporting detection limits for elements in homogeneous materials, A. G Shard and C. A. Clifford, *Surface and Interface Analysis*, 50(1), 88–89 (2018)

A simple approach to measuring thick organic films using the XPS inelastic background, A. G. Shard and S. J. Spencer, *Surface and Interface Analysis*, 49(12), 1256-1270 (2017)

'Versailles project on advanced materials and standards interlaboratory study on measuring the thickness and chemistry of nanoparticle coatings using XPS and LEIS', Natalie A Belsey, David JH Cant, Caterina Minelli, Joyce R Araujo, Bernd Bock, Philipp Brüner, David G Castner, Giacomo Ceccone, Jonathan DP Counsell, Paul M Dietrich, Mark H Engelhard, Sarah Fearn, Carlos E Galhardo, Henryk Kalbe, Jeong Won Kim, Luis Lartundo-Rojas, Henry S Luftman, Tim S Nunney, Johannes Pseiner, Emily F Smith, Valentina Spampinato, Jacobus M Sturm, Andrew G Thomas, Jon PW Treacy, Lothar Veith, Michael Wagstaffe, Hai Wang, Meiling Wang, Yung-Chen Wang, Wolfgang Werner, Li Yang, Alexander G Shard, *The Journal of Physical Chemistry C*, 120(42), pp 24070-24079 (2016)

'Evaluation of Two Methods for Determining Shell Thicknesses of Core–Shell Nanoparticles by X-ray Photoelectron Spectroscopy', CJ Powell, WSM Werner, AG Shard, DG Castner, 120(39), pp. 22730-22738 (2016)

'A technique for calculation of shell thicknesses for core-shell-shell nanoparticles from XPS data', D J H Cant, Y C Wang, D G Castner, A G Shard, *Surface and Interface Analysis*, 48, 274–282 (2016)

'Analysis of protein coatings on gold nanoparticles by XPS and liquid-based particle sizing techniques', N A Belsey, A G Shard, C Minelli, *Biointerphases*, 10(1), 019012 (2015)

'Evaluating the Internal Structure of Core-Shell Nanoparticles Using X-ray Photoelectron Intensities and Simulated Spectra', M Chudzicki, W S M Werner, A G Shard, Y-C Wang, D G Castner, C J Powell, *Journal of Physical Chemistry C*, 119, 17687-17696 (2015)

'Detection limits in XPS for more than 6000 binary systems using Al and Mg K X-rays', A G Shard, *Surface and Interface Analysis*, 46 (3), 175-185 (2014)

"Universal Equation for Argon Gas Cluster Sputtering Yields", M P Seah. *Journal of Physical Chemistry C*, 117 (24), 12622-12632 (2013)

"An accurate and simple universal curve for the energy-dependent electron inelastic mean free path", M P Seah. *Surface and Interface Analysis*, 44, 497-503 (2012)

"Summary of ISO/TC 201 Standard: ISO 14701:2011 – Surface chemical analysis - X-ray photoelectron spectroscopy - measurement of silicon oxide thickness", M P Seah. *Surface and Interface Analysis*, 44, 876-878 (2012)

"Summary of ISO/TC 201 Standard: ISO 18115-2:2010 - Surface chemical analysis – Vocabulary - Terms used in scanning probe microscopy", M P Seah. *Surface and Interface Analysis*, 44, 879-880 (2012)

"A Straightforward Method For Interpreting XPS Data From Core-Shell Nanoparticles", A G Shard. *Journal of Physical Chemistry C*, 116 (31), 16806-16813 (2012)

"Simple universal curve for the energy-dependent electron attenuation length for all materials", M P Seah. *Surface and Interface Analysis*, 44, 1353-1359 (2012)

"Attenuation lengths in organic materials", M P Seah, S J Spencer. *Surface and Interface Analysis*, 43, 744 (2011)

"Energy dependence of the electron attenuation length in silicon dioxide", M P Seah and S J Spencer. *Measurement Science and Technology*, 22, 115602 (2011)

"Quantitative Analysis of Adsorbed Proteins by X-ray Photoelectron Spectroscopy", S Ray, A G Shard. *Analytical Chemistry*, 83, 8659 (2011)

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