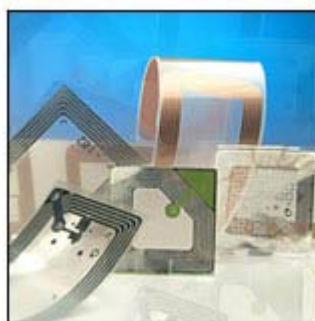


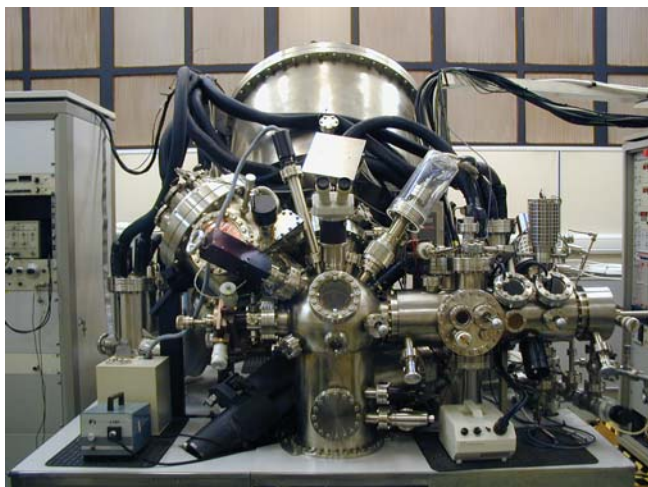
XPS Characterization of Technological Polymer Surfaces.

The surface and interface regions of organic polymers play a vital role in many aspects of modern everyday life. In areas such as biotechnology, electronic devices, composite materials, corrosion protection, packaging and decorative coatings, the properties of polymer surfaces and interfaces have an important influence on the performance of technology. Polymers are amenable to controlled surface modification processes such as flame or plasma treatment or the use of a surface segregating chemical component, thus allowing surface properties to be optimised while retaining desirable bulk properties.



Everyday polymer products

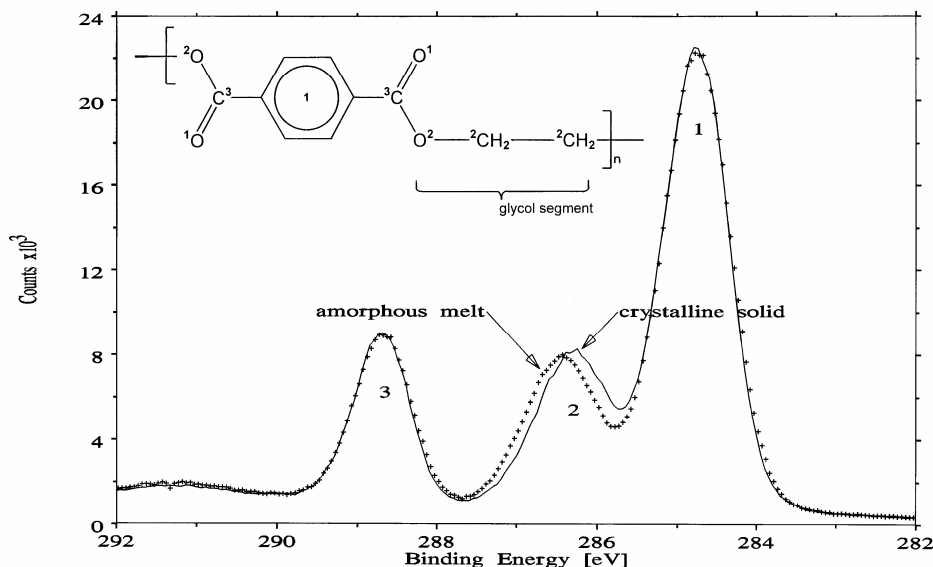
Scientists from the National Centre for Electron Spectroscopy and Surface Analysis (NCESS) at Daresbury Laboratory have used x-ray photoelectron spectroscopy (XPS) to characterise the uppermost surface regions (1 – 5 nm) of a wide range of technologically important polymers.



The NCESS ESCA300 XPS spectrometer.

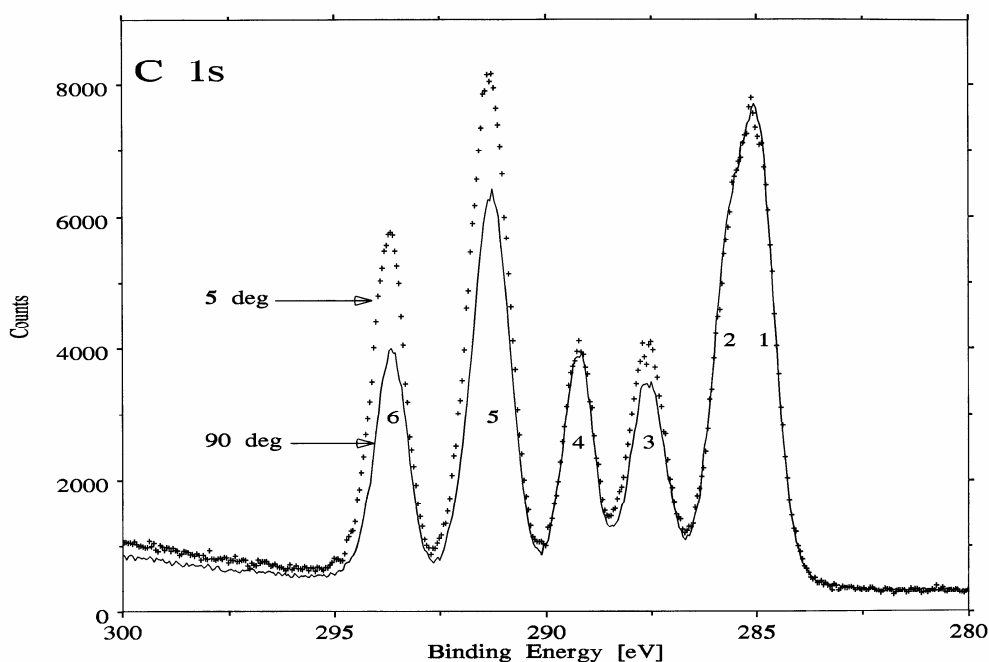
For poly(ethylene terephthalate) (PET), widely used in bottles, packaging and film, the high energy resolution of the ESCA300 spectrometer was used to discover that the shape of the polymer chains influences the C 1s spectrum, thus providing a diagnostic for the

crystalline/amorphous nature of the polymer surface [1]. By comparing XPS and FTIR spectra it was also shown that thermal treatment causes the surface chains to rearrange more quickly than those in the bulk. [2]. For poly(ethylene glycol) (PEG) the high intensity of the ESCA300 was used to show that the chain shape influences the XPS valence band, again providing a diagnostic for the crystalline/amorphous nature of the surface [3]. Chain shape effects have also been detected in a number of other polymers including nylon 12 [4] and the biodegradable polymer poly(ϵ -caprolactone) [5].

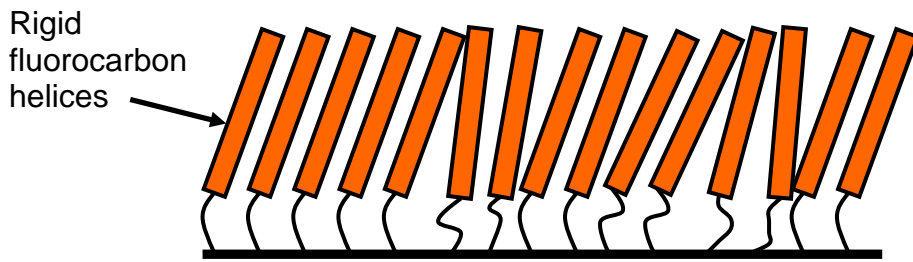


C 1s spectra of crystalline and amorphous PET.

Polymers with fluorinated side chains are widely used in “anti” applications including anti-wetting, anti-adhesion and anti-fouling. The side chains form an array at the uppermost surface with the efficacy as an “anti” material dependent on the linearity, order and packing of the side chains. A series of 10 fluorinated side chain polymers were synthesised at NCESS and investigated by XPS and water contact angle measurements. Detailed analysis of the data allowed deductions to be made concerning the relative order and linearity of the side chains [6].

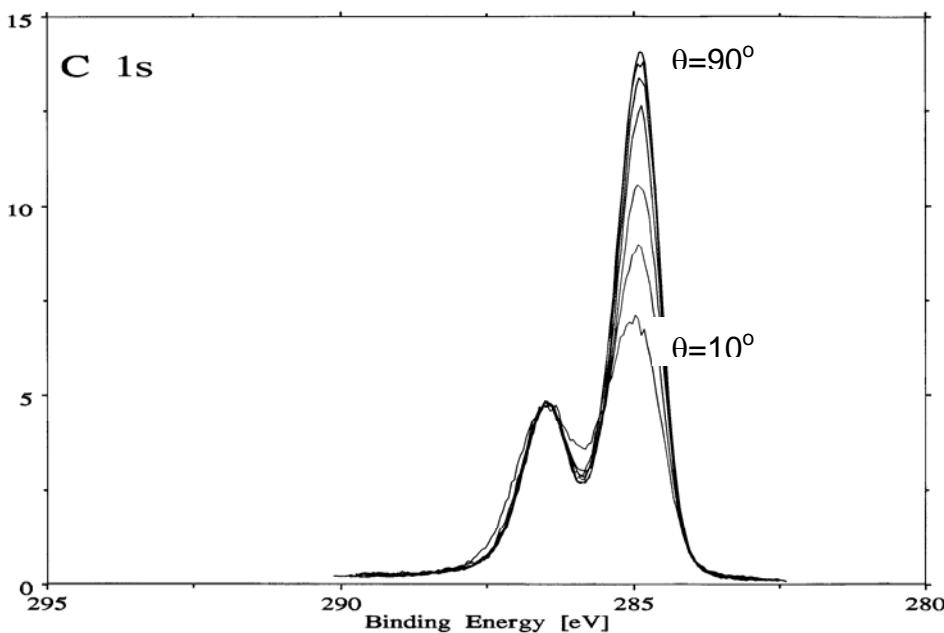


Angle resolved C 1s spectra of a fluorinated side chain polymer.



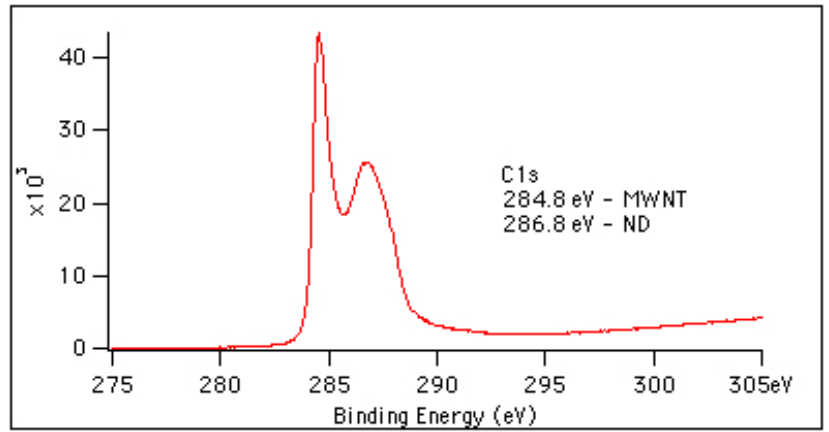
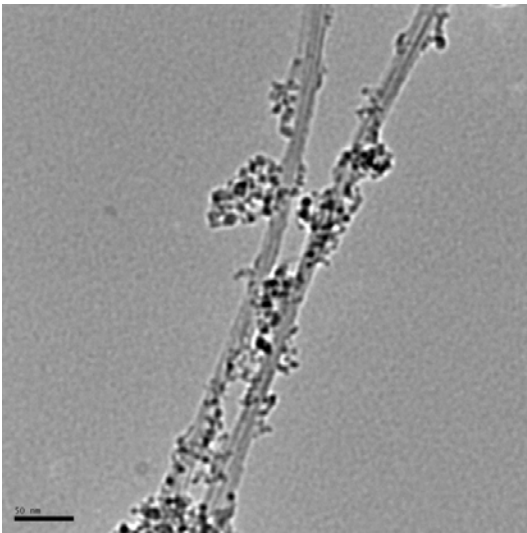
Model for the surface of a fluorinated side chain polymer.

The blending of polymers is an important way of modifying both bulk and surface properties. However polymer blends are complex and require a multi-technique characterisation approach. Current work at NCESS is directed towards using XPS and AFM (Atomic Force Microscopy) to understand blends of polystyrene and poly(vinyl ethyl ether) as a function of polymer molecular weight and film thickness. Modelling of the XPS data allows extraction of the composition depth profile and AFM provides information on phase separation.



Angle resolved C1s spectra of a polystyrene + poly(vinyl ethyl ether) blend.

Polymers are often reinforced with fibres (e.g. carbon fibre, glass fibre) or powders to generate stronger and tougher composite materials and there is currently much interest in using nanoscale reinforcement to produce nanocomposites with improved properties. The surface chemistry of the nanomaterial is crucial as this provides interfacial bonding between the polymer and the nanoparticles. Scientists from NCESS and the Universities of Liverpool and Florida State have characterised the surfaces of carbon nanotubes (CNT), nanodiamonds (ND) and silica nanoparticles for use in polymer composites. It has been found, for example, that CNTs coated with ND considerably improve the ballistic resistance of composites for body armour applications.



SEM image of CNTs coated with ND and the corresponding C1s XPS spectrum.

The NCESS research programme into polymer surfaces is set to continue into the future and interested parties are encouraged to contact the Unit either directly or via Daresbury SIC.

References.

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- [2] N.W.Hayes et al, *Surf. Interface Anal.*, **24**, 723 (1996).
- [3] G.Beamson et al, *J. Phys. Chem. B*, **104**, 2656 (2000).
- [4] G.Beamson, *J. Elec. Spectrosc. Relat. Phenom.*, **121**, 163 (2001).
- [5] G.Beamson, *J. Elec. Spectrosc. Relat. Phenom.*, **154**, 83 (2007).
- [6] G.Beamson et al, *Surf. Interface Anal.*, **36**, 323 (2004).