Application Note: 31071

FG01
Combination Low Energy Electron/Ion Gun

Key Words
• Surface Analysis
• Charge compensation
• Electron/ion gun
• XPS spectra from insulators

Introduction

Until now, only simple electron flood guns have been available as components for charge compensation during XPS measurements. The more sophisticated and effective combination ion/electron guns have only been available as part of a complete XPS system. The FG01, Figure 1, from Thermo Electron Corporation is now available as a component. This combination source can deliver a beam of low energy electrons and a beam of low energy ions simultaneously. The FG01 is currently being used very successfully on Thermo's Sigma Probe and Theta Probe instruments.

Figure 1: The FG01 combination electron/ion gun.

Using the FG01 as an Electron Gun

It is important that the electron beam is of low energy to avoid unintended sample degradation caused by the electrons.

Equally important is that the electron energy spread is as small as possible. The surface of an insulating sample will charge to the potential of the most energetic electrons arriving at its surface, while all those at lower energies will be reflected away to the walls of the chamber. When X-rays impinge on part of the sample surface, there would be insufficient flux of these high-energy electrons to maintain the surface potential in this region. This would lead to differential charging and peak broadening.

In the FG01, the energy spread has been minimised by using a LaB_6 electron emitter in the electron gun. This source is beneficial in two ways:

- It is indirectly heated, eliminating the voltage drop which occurs along a conventional hot-filament source.
- It has a low work function which means that, for a given emission current, the temperature is lower than it would be for a filament source. Hence, thermal broadening is reduced.

Use of the LaB_6 emitter in the electron gun minimises the problems associated with a large energy spread in the electron beam.

Static Charge

A difficulty that can arise when analysing insulating samples is that a negative static charge can occur at the surface of the sample, illustrated in Figure 2.

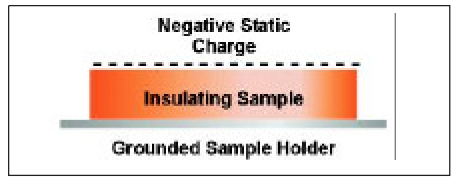

Figure 2: A negative static charge may occur at the surface of an insulating sample.

When the focused X-ray beam is directed to the sample, the negative charge is replaced by a positive charge in the area that is exposed to the X-rays (the analysis area) while the surrounding area remains negative, Figure 3.

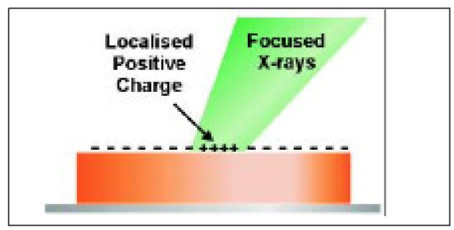

Figure 3: A localised positive charge is formed in the area exposed to the X-rays.

When the low-energy electrons are directed to the analysis position, they experience the field due to the large area of negative charge and are prevented from reaching the analysis position, Figure 4. Under these conditions, there is no effective charge compensation.

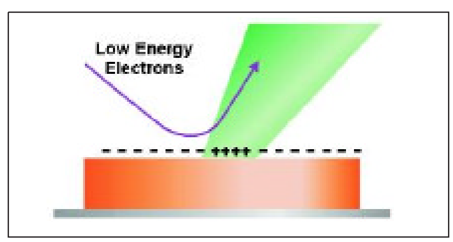

Figure 4: Low energy electrons are prevented from reaching the analysis position by the field due to the static charge on the sample.

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The problem can be overcome by removing the static charge using a low-energy ion beam. With the negative charge removed, the low energy electrons can now reach the analysis position, Figure 5.

By this means, good charge compensation can be achieved.

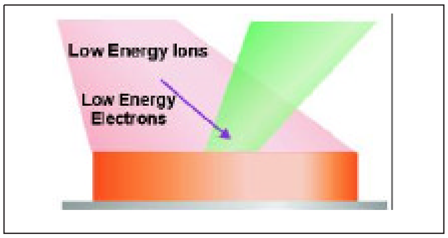

Figure 5: By flooding the surface with low energy ions, the negative charge is removed and electrons can now reach the analysis position.

Using the FG01 as a Low-energy Electron/Ion Gun

The use of a single gun to produce both the focused low-energy electron beam and the large area ion flux has a number of distinct advantages over the use of independent sources. A new, combined ion/electron gun has been designed which incorporates all the above advantages.

This novel design uses a LaB_6 emitter to produce a bright source of low energy electrons, with an energy spread of only about 0.3 eV. These are focused to a small spot on the sample. Precise alignment to the X-ray beam is provided using integral X-Y deflectors.

Figure 6 shows a schematic diagram of the combined gun.

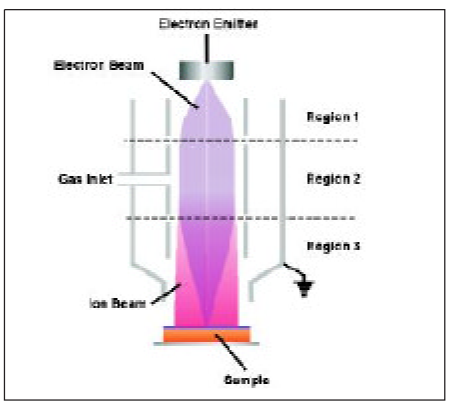

Figure 6: Schematic representation of the combined electron/ion gun used in Sigma Probe and Theta Probe. (For improved clarity, the steering electrodes have been omitted from the diagram).

Within the electron gun, the electrons are accelerated by a small amount to ensure efficient ionisation of the noble gas (usually argon). This gas is injected directly into the gun and a sufficiently high flux density of ions is generated at a low chamber pressure. The ion beam is well collimated but still covers an area several times larger than the electron beam. The electron beam is retarded to its original energy of a few eV before leaving the gun.

In this way, charge neutralisation is rapid and easy, on even the largest samples.

Table 1 Processes occurring in each region of the combined ion/electron gun.

REGION	ELECTRONS	IONS
1	Accelerated	N/A
2	Cause ionisation	Formed
3	Retarded	Accelerated

Digital Power Supply

The combination ion/electron gun is controlled using a digital power supply, operated from the *Avantage* data system. All of the operating parameters are controlled this way and their values can be stored for future use on all similar samples.

Conclusion

This newly designed FG01 is now available as a component and provides a major improvement in small spot XPS performance.

The combination ion/electron gun is suitable for a wide range of samples and can be used without the need for masks or grids. An example of an XPS spectrum of PET is shown in Figure 7, this was collected using a Theta Probe fitted with the FG01 flood gun. For more examples of data collected using FG01, refer to Application Note AN30067.

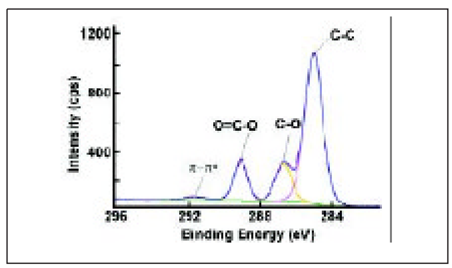

Figure 7: PET spectrum from Theta Probe using the FG01 flood gun.

This type of charge compensation system does not put any restriction upon the size of the sample.

We recommend the use of the FG01 with the XR5 X-ray monochromator.

Dimensional Information

The dimensions of the FG01 are shown in Figure 8.

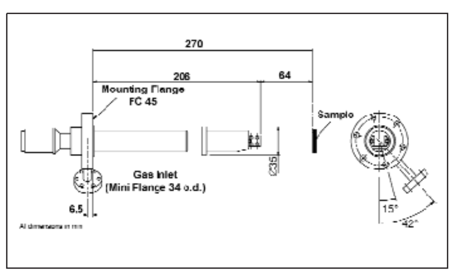

Figure 8: Dimensions of the FG01 flood gun.

In addition to these offices, Thermo Electron Corporation maintains a network of representative organizations throughout the world. For detailed technical information please contact +44 1342 327 211

Australia
+61 2 8844 9500
Austria
+43 1 333 50340
Belgium
+32 2 482 30 30
Canada
[redacted]
China
+86 10 5850 3588
France
+33 1 60 92 48 00
Germany
+49 6103 4080
India
+91 22 2778 1101
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+39 02 950 591
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+81 45 453 9100
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South Africa
+27 11 570 1840
Spain
+34 91 657 4930
Switzerland
+41 61 48784 00
UK
+44 1442 233555
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