Reflectron Mass Spectrometer

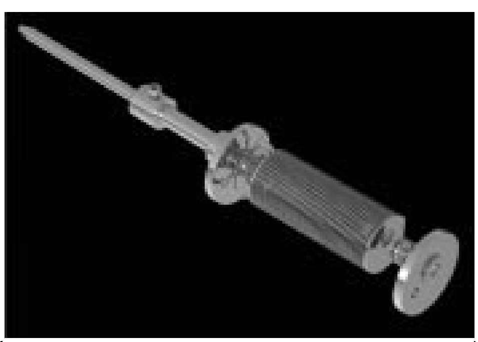
Real-Time Surface Analysis During Thin Film Growth at Pressures of 1mTorr

Ionwerks' Reflectron Mass Spectrometer is the only Time-of-Flight system that allows the simultaneous acquisition of surface information from three complementary surface analysis techniques - Mass Spectroscopy of Recoiled Ions (MSRI), Secondary Ion Mass Spectroscopy (SIMS), and Direct Recoil Spectroscopy (DRS). The Ionwerks MSRI spectrometer is uniquely capable of in-situ, real-time surface elemental analysis - even at pressures in excess of 1mTorr. This allows real-time thin film growth monitoring and control. The reflectron is also unique in its ability to perform both MSRI and SIMS under ultrahigh vacuum conditions. This combination of techniques provides complete quantitative and qualitative surface information for simplified data interpretation.

A comparison of MSRI, SIMS, and DRS spectra appears on the reverse side.

This system includes the following:

- Ion optics for secondary ion extraction, transport and reflectance for energy compensation and time refocusing suitable for high resolution time of flight mass spectroscopy
- Vacuum housing with provisions for differential pumping ports
- Detector hardware assembly, including channelplate (36mm non-imaging quality), proprietary fast anode, and mounting hardware



IONWERKS

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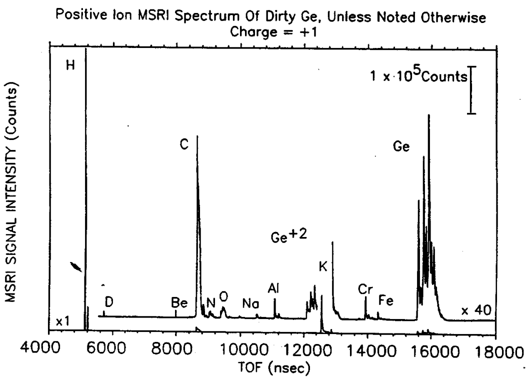
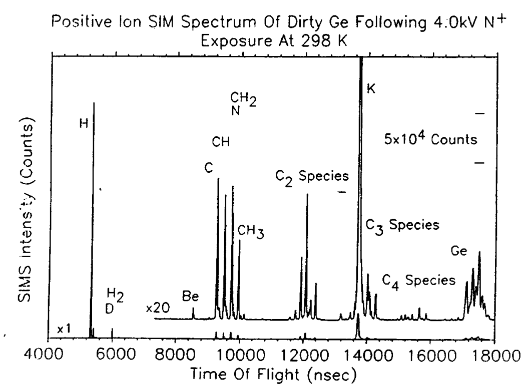
Sample Spectra

Mass Spectroscopy of Recoiled Ions (MSRI)



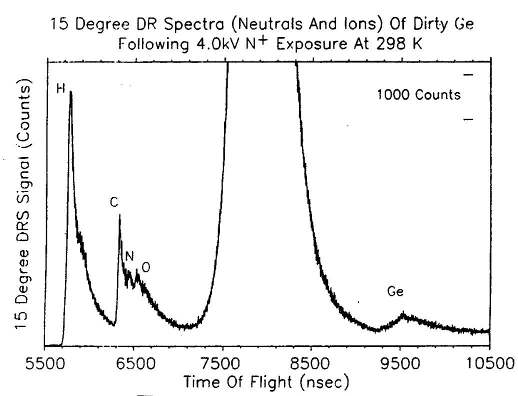
MSRI spectra are produced by tuning the reflector to reject low energy ions. MSRI is capable of high-resolution surface analysis *at mTorr ambient pressures*, making it well suited for real-time, in-situ analysis of film growth process The MSRI spectrometer detects elemental, not molecular ions, thus allowing quantitative measurement of surface composition using standards. Advantages of MSRI include the ability to detect all elements (including H, D, and He), distinguish different phases of films during growth, and measure the relative surface concentration of isotopes. MSRI is particularly good for identification of elements poorly detected by SIMS, such as N even during ECR or plasma processing.

Secondary Ion Mass Spectroscopy (SIMS)



SIMS spectra (only possible at lower pressures, e.g.10^{-6} Torr) are obtained by a slight retuning of the reflector . SIMS provides qualitative information regarding the molecular species present on a surface, and is able to provide clues as to the structure of extremely complex surface species. The SIMS resolution can be improved by translating the extraction optics from the “growth mode” position of 2” from the sample to a position of a few millimeters above the analate surface.

Direct Recoil Spectroscopy (DRS)



The 20MHz forward scatter detector produces DRS spectra containing ions and neutrals. DRS resolves ions at a higher count rate than MSRI, but with less mass resolution. However, DRS can be calibrated to surface coverage because both neutrals and ions are detected [1]. The sensitivity of DRS to surface H is orders of magnitude higher than that of any other technique.

These spectra illustrate the results of 3 time-of-flight spectra taken with the Ionwerks reflectron. All spectra are of the same dirty GE sample. The DRS and MSRI spectra were collected simultaneously, while the SIMS spectra was obtained immediately following the DRS and MSRI spectra. Data collection time for all three techniques was two minutes.

MSRI Tutorial

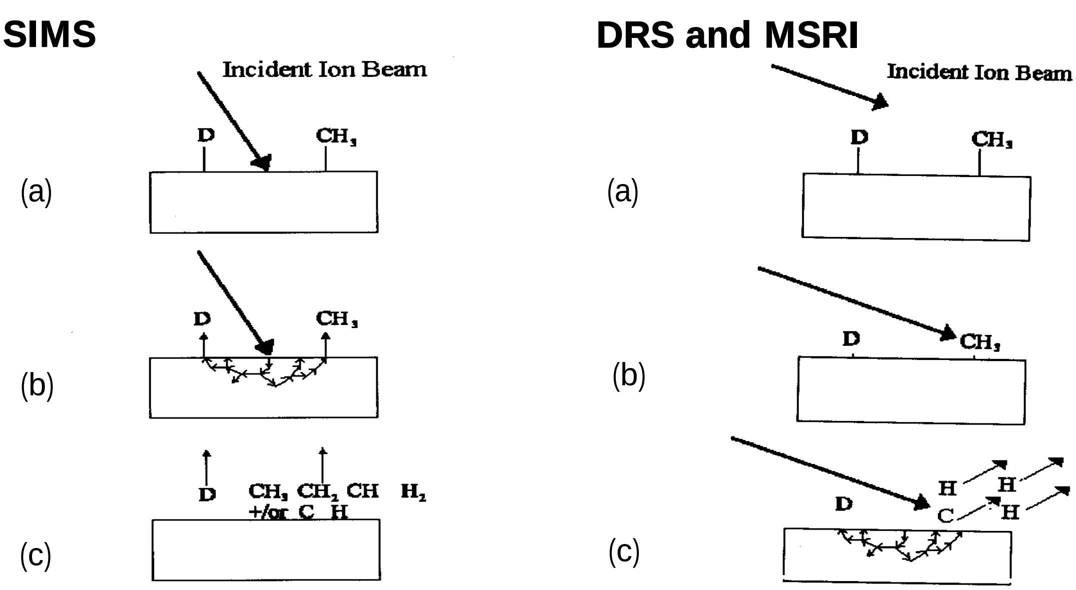
What is MSRI?

The Mass Spectroscopy of Recoiled Ions (MSRI) technique [1,2], developed at Ionwerks, enables the detection of surface atoms which are ionized during a binary forward recoil sequence when a primary ion of few tens of keV energy impinges the surface at grazing incidence. The violence of the binary collision destroys any molecular ions, and the resulting mass spectrum (see other side) consists of only elemental ions and their isotopes. The simplicity of the MSRI spectra makes elemental and isotopic identification easy. Furthermore, the high energy of the recoils tends to “freeze” the recoiled ions in their charged state as they rapidly exit the surface. Thus the “matrix” effects which complicate SIMS analysis are less of a problem with MSRI[1].

Applications of MSRI

MSRI is a particularly good technique for identification of elements which are poorly detected by SIMS. For example, sensitivities to nitrogen and boron differ by less than a factor of 20[2]. Trace element detection is possible [3], as is isotopic identification (including H and D[4]). MSRI is particularly useful for elemental analysis during thin film growth at pressures up to several tens of mTorr. As a consequence, the reflector is designed to allow differential pumping so that the instrument can be used in real time thin film growth monitoring.

Comparison of Ion Spectroscopic Techniques



SIMS	DRS and MSRI
(a) Incident ion beam induces a collision cascade in the surface region	(a) Incident beam induces a binary collision with the surface atoms
(b) Some of the cascades return to the surface and result in the ejection of molecular fragments and elemental species, some of which are ionized	(b) The energy of the collision results in complete molecular decomposition. Only elemental species are ejected and detected
(c) Energy of the ejected species is <20eV	(c) Energy of the DR atoms and ions is high (few hundred ev to KeV)

For Reference:

[1] M.S. Hammond, J. A. Schultz, A.R. Krauss. “Surface Analysis at Low to Ultra-High Vacuum by Ion Scattering and Direct Recoil Spectroscopy”, JVST A, 13(1995) 1136.

[2] K. Eipers-Smith, K. Waters and J. A. Schultz, J. Ceramic Soc. 76 (1993) 972-973.

[3] K. Waters, A. Bensaoula, A. Schultz, K. Eipers-Smith, A. Freundlich, J. Crystal Growth 127 (1993) 972-973.

[4] D. D. Koleski, S. M. Gates, J. A. Schultz, “Facile Abstraction of Chemisorbed D on Si(100) by Atomic H”, J. Chem. Phys. 99 (1993) 5619.