HIDEN ANALYTICAL

Time-resolved measurements of mass and energy spectra for plasmas

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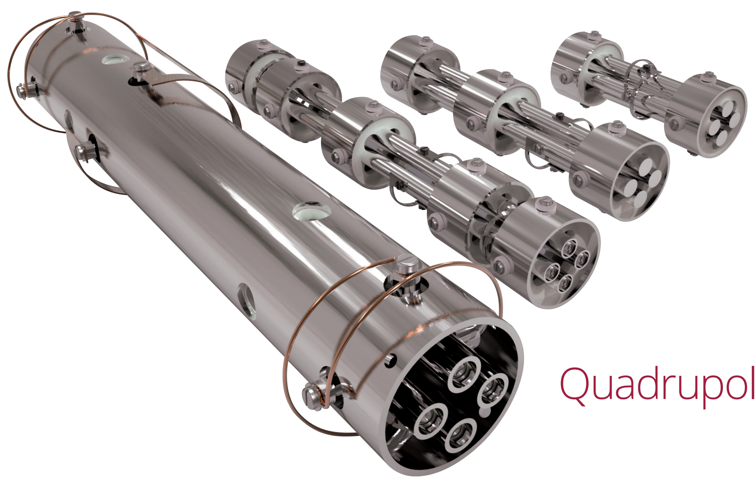
Argon Plasmas:

The direct measurement of mass spectra and energy distributions for mass-identified positive and negative ions arriving at target surfaces in plasma reactors has produced much useful information.

The measurements have been, in the great majority of cases, of the time-averaged distributions even when the applied power to the plasma has been pulsed. Time-resolved data particularly during initiation and decay of pulsed plasmas would be advantageous. To facilitate such studies we have incorporated a Multi-Channel Scaler device into the ion detector system of a Hiden EQP instrument.



Quadrupole Mass Filters

As examples of the new capabilities of the EQP instrument we show below data obtained for plasmas in a parallel-plate reactor operated using either argon or nitrous oxide as the test gas and with power supplied from an RF supply at 13.6MHz repetitively gated using a square-wave envelope from a signal generator at frequencies of around 500Hz.

For the gated RF plasmas, using argon as the test gas, the ion energy distributions had considerable structure. A typical family of IED scans for Ar^+ ions is shown in figure 2 for a 25 Watt plasma at 35mTorr. The data show in particular how the number of ions with high energy arriving at the sampling orifice of the EQP decays rapidly as the plasma becomes established.

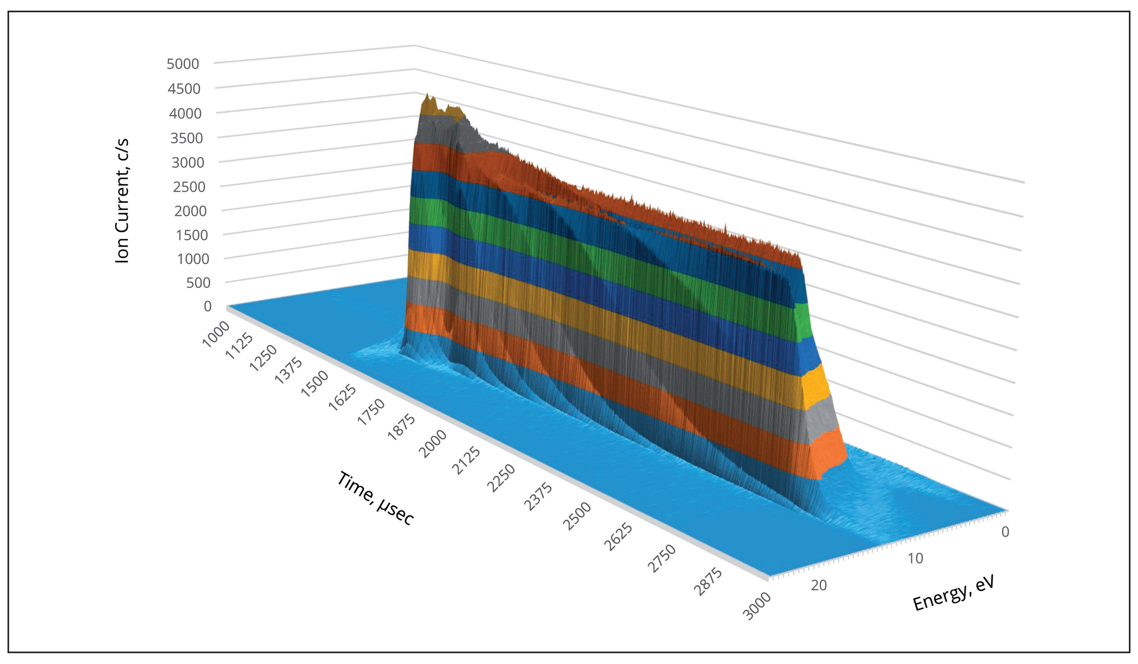


Figure 2. RF Plasma in argon at 35mTorr.

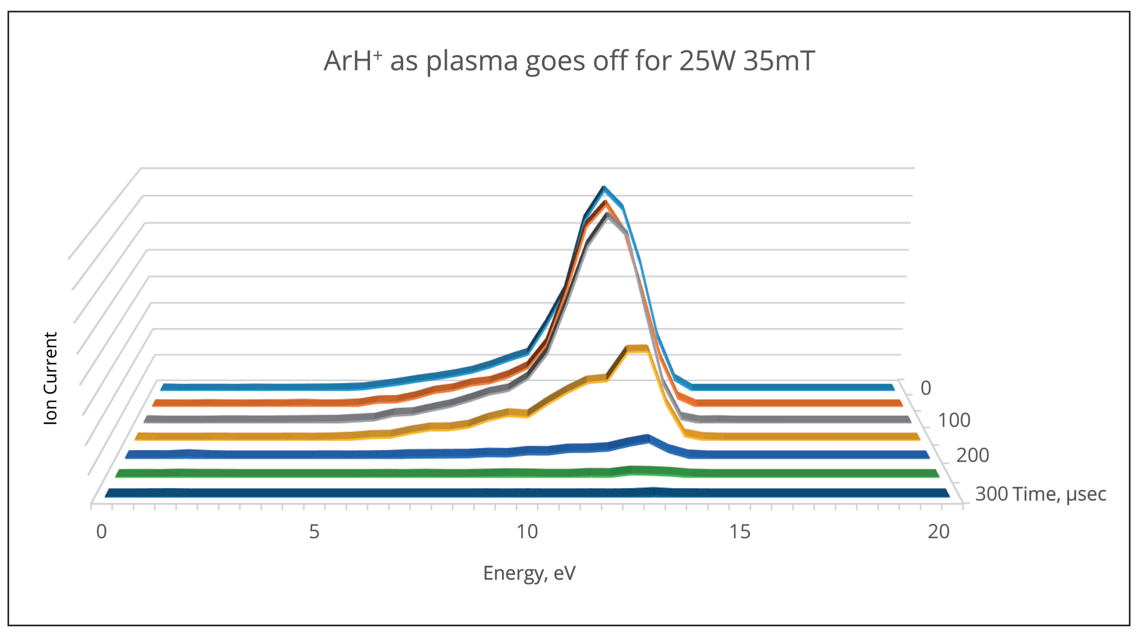


Figure 3.

It is, of course, possible to look at selected IEDs for any time during the period covered. Figure 3 shows a set of IEDs for ArH^+ ions in a 25W RF plasma at 35mT taken at 50µsec intervals as the plasma decays when the gating envelope reduces the applied RF power to zero.

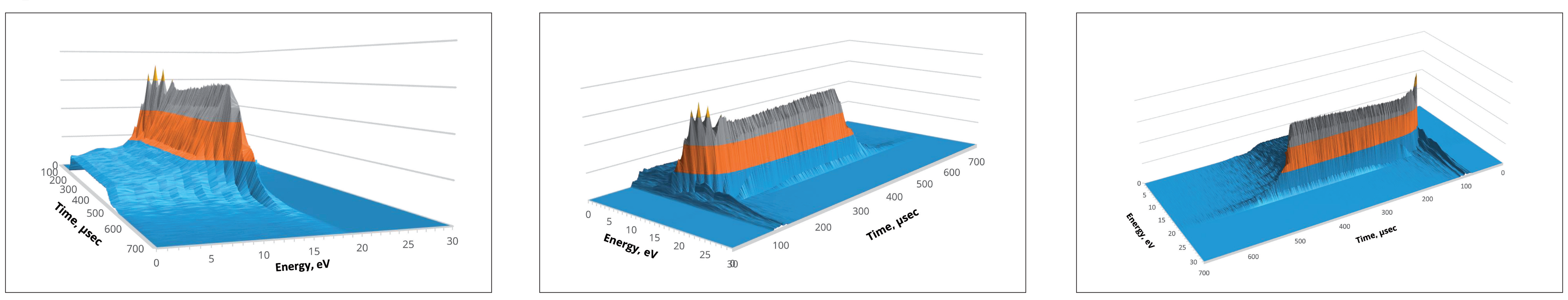
Nitrous oxide plasmas.

a) Positive ion energy distributions.

Time-resolved measurements for both positive and negative ions in nitrous oxide were made using a different parallel plate reactor. The plasma was again operated using a gated 13.6MHz power supply. For the positive ion measurements the plasmas were 5Watt peak power at 28 and 42mTorr. The RF power was gated at 1kHz using a square-wave generator.

For the N_2O^+ and NO^+ ions at 4W, 28mT the time-resolved energy distributions were as shown in figure 4. The general features of the IEDs for NO^+ ions were broadly similar, as shown in figure 5, to those for NO_2^+ ions which were presumably formed in secondary collisions between the NO^+ ions and atomic oxygen, or between O^+ ions and either neutral N_2O or NO.

N_20^+ ions at 4Watts 28m Torr



$N0^+$ ions at 4Watts 28m Torr

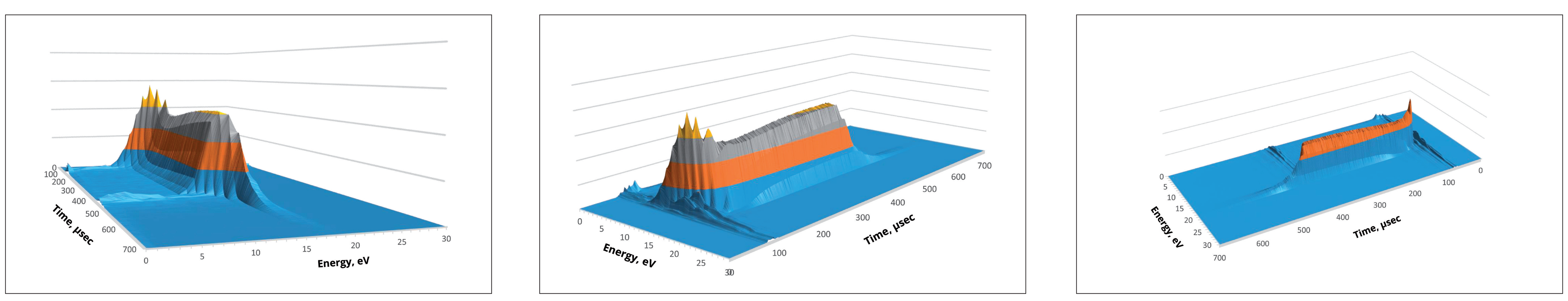


Figure 4.

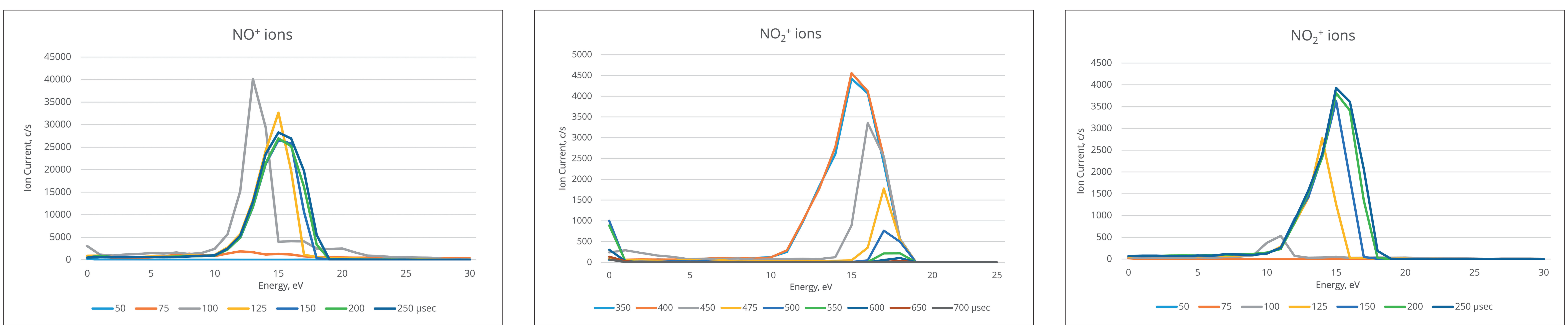


Figure 5. IEDs of NO^+ and NO_2^+ ions during initiation and decay of the plasma

b) Negative ion energy distributions.

For similar plasma conditions in nitrous oxide (4Watts RF, 42mTorr), the dominant negative ions were O^- ions, the ions arriving at the sampling orifice having energies of up to and beyond 20eV. Since the gas pressure was high, the number of really high energy ions formed in the sheath at the driven electrode surviving to reach the orifice were low. For selected ion energies, the variation in intensity with time during a single period of the gated RF power was as shown in figure 8. The most obvious features of the distributions are the two peaks at the earliest and latest times. At all ion energies there is a peak in intensity as the plasma turns on and a secondary peak as the plasma turns off but the latter feature is only for ions with energies between 2 and 8eV.

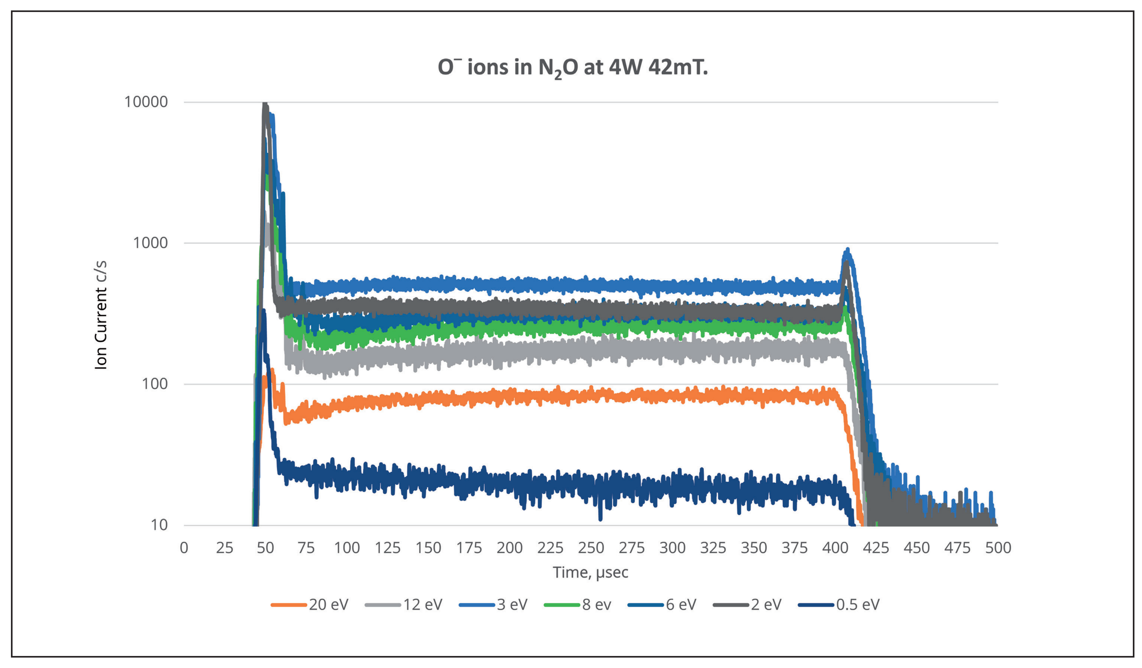


Figure 6. Time dependence of O^- ions of selected energies.

c) Positive ion mass spectra.

For the gated RF plasmas in nitrous oxide, the ion species observed included, in addition to the parent N_2O^+ ions, NO^+, N_2^+, N_2H^+, O_2^+, O^+ and N^+ ions and impurity H_2O^+ and $H_2.H_2O^+$ ions.

Their relative abundances at the sampling orifice of the mass spectrometer as a function of time during one "on" period of the gated RF were as shown in figure 7 for an energy of 16eV, which was the plasma potential for a 4Watt plasma at 40mTorr.

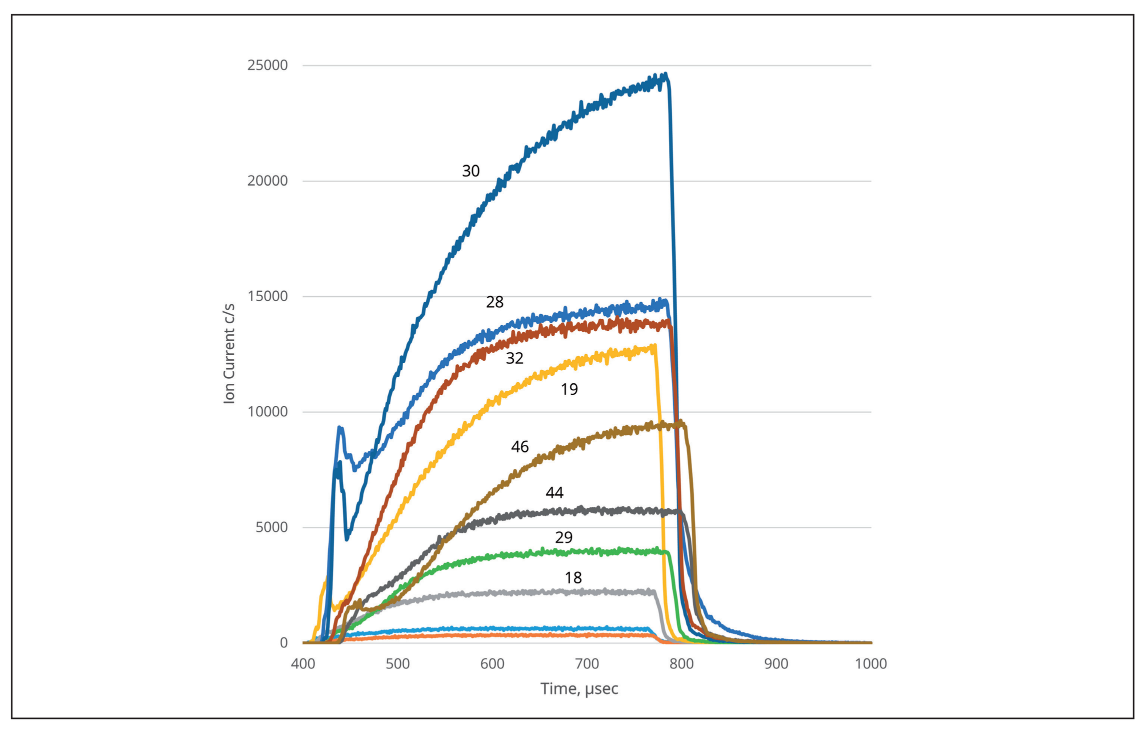


Figure 7. Time dependencies of selected positive ion species at an energy of 16eV

Conclusions.

The data presented here give an indication of the capabilities of the new detector system fitted to the mass/energy spectrometer. The ability of the system to allow time-resolved measurements of the mass and energy spectra of species from a plasma with a resolution of down to 50nsec will clearly be of considerable value in tracking high speed changes in a wide variety of plasma reactor systems.

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