Micrometeoroid Velocity-and-Trajectory Analyzer

The problem:
Mass spectrometry techniques have been used to ascertain the abundance of elements and isotopes in microscopic moving particles. Particles to be analyzed include micrometeoroids, droplets in atmospheric clouds, and ejecta from hypervelocity missile impacts or jet engine exhausts. In devices using these techniques, a microscopic particle impacting on the front face of an electrically-biased metallic surface such as tungsten produces positive ions which are directed to an ion detector by an electrostatic field. The kinetic energy of an impacting particle on the metal surface results in a portion of the particle being vaporized and ionized. Since only the kinetic energy of the particle causes vaporization and ionization, the devices have a relatively low efficiency, particularly for particles of low impact velocity (less than 5 km/s).

Another difficulty with such devices is that the elements in a particle which can be ionized most readily are disproportionately represented in the mass spectrum. Further, a phenomenon known as ghost spectra frequently occurs as a result of fragments of a particle impacting on metal parts, other than the impact surface, that are located in the impact surface housing. In response to such impacts, fragmentary particles may be produced which reach the impact surface slightly after the impact of the main part of the particle, producing ions from the impact surface at slightly-displaced time intervals. Because of the different travel times of ions of different elements from the impact surface to the ion detector, it is difficult to distinguish between ions derived from the main part of the particle and from fragments.

The solution:
By adding the potential energy of a charged capacitor to the kinetic energy of the impacting particle, a new technique causes a major fraction (10 to 100 percent) of the atoms in a microscopic particle impacting on a particle-receiving surface to be ionized.

How it's done:
The principal part of the new composition analyzer (see figure) is a capacitor consisting of a front electrode upon which the particle impacts, a rear electrode, and a solid dielectric sandwiched between the two. The front and back electrodes, as well as the dielectric and an accelerating grid, are accurately-shaped concentric segments of spherical shells having a common center and different radii. An ion detector is located approximately at the common center of the different spheres so that substantially all of the ions (continued overleaf)
ejected from the front electrode impinge on the
detector with a minimum amount of focusing
required. The front electrode and the dielectric
together have a thickness such that an impinging
microscopic particle can penetrate them both. This is
achieved by forming the front electrode from a thin
metal film, having a thickness typically on-the-order of
0.1 \( \mu \text{m} \). The metal film is deposited on an oxide
dielectric layer, having a thickness between 0.4 and
1 \( \mu \text{m} \), that in turn is formed on a doped semi-
conductor substrate which comprises the rear
electrode.

In response to a particle impacting on the front
electrode, the front and back electrodes become
electrically connected and are quickly discharged.
The resulting discharge spark causes positive ions to
be ejected from the front electrode. These positive
ions are formed from elements in the impinging
particle, as well as from elements contained in the
materials of the capacitor. Thus, it is preferable to
employ capacitor materials that do not include
elements that are normally expected to be in the
particles to be analyzed.

To enable positive ions to be ejected from the front
electrode of the capacitor, the front electrode is
negatively biased relative to the back electrode. The
positive ions ejected from the front electrode are then
accelerated by an electric field that is established in
front of the front electrode by a grid that is pervious to
the particles as well as to the ions. The grid is
positioned between the front electrode and an ion
detector that is biased so that substantially all ions
passing through the grid travel to the ion detector.
The positive ions produce an ion current pulse that
has been found to have a peak value on the order of 10
to 50 A and a duration on the order of 100 ns. The
10-A to 50-A ion current is to be contrasted with ion
currents of approximately 100 nA as generated by
previous devices.

The output of the ion detector is suitably connected
to the transient digitizer time analyzer. The time
arrival of the pulses at the ion detector, relative to the
impact time of the particle, provides an indication of
the mass of the ions received by the detector and
thereby of the constituent atoms of the particle.

The capacitor has a relatively-slow response time,
since it becomes so completely discharged in response
to an impacting particle that it cannot recover for
approximately 10 to 100 ms subsequent to the impact.
Therefore the ions derived from the front electrode, as
a result of fragments of the same particle which
caused an initial ionization, are not produced in
sufficient quantities relative to the number of ions
resulting from the initial impact to be detected. Ghost
spectra are thus substantially eliminated.

By converting a major fraction of the atoms in the
particle into ions, the signal-to-noise ratio of the
detected mass spectrum is improved by orders of
magnitude over that of previous analyzers. The need
for complex and costly electronic circuitry is thus
obviated. Because the capacitor supplies potential
energy to the impacting particle, which is added to the
relatively low kinetic energy of such particles, the new
technique can also be used to analyze particles having
relatively low impact velocities (as low as or lower than
1 km/s). Moreover, in contrast to previous tech-
iques, the chemical constituents of an impacting
particle are represented by the generated ion mass
spectrum in approximately the correct proportions.

Note:
Requests for further information may be directed
to:

Technology Utilization Officer
Goddard Space Flight Center
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Greenbelt, Maryland 20771
Reference: TSP74-10286

Patent status:
This invention is owned by NASA, and a patent
application has been filed. Inquiries concerning non-
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development should be addressed to:

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