STARDUST : NASA’s Comet Sample Return mission

Cometary dusts collected : Jan. 2, 2004

Artist concept depicting STARDUST spacecraft flyby comet Wild-2 to collect dust particles.

Comet Wild2’s nucleus and the outflowing jets. Image taken by STARDUST onboard camera

http://stardust.jpl.nasa.gov
Cometary dusts analyzed by onboard TOF MS

Mass spectrum of a detected stardust by CIDA TOF MS during the flyby of comet Wild2

DUST-BUSTER --- An Isotope TOF-MS for stardust

Chun-Yen Chen¹
Wally F. Calaway²
Typhoon Lee¹
Jerry E. Moore²
Mike J. Pellin²
Igor V. Veryovkin²

¹: Institute of Earth Sciences, Academia Sinica, Taipei, Taiwan
²: Material Science Division, Argonne National Laboratory, USA

Supernova Theory and Nucleosynthesis workshop, July 17, 2004
Goal: look for large isotope effect in small grains

Dust size $\sim 1 \, \mu m$, $\sim 10^{-12}$ gram, $\sim 10^{10}$ atoms

$3\sigma \sim 10\%$ effect

Cover as many as isotope ratios over large mass range in order to examine the structure of individual source star of solar system nuclides.

Picture of the SPIRIT instrument at APS–developed by the ANL group.

Instrument efficiency measured $> 12\%$

We are using SPIRIT to develop SI-TOF MS for isotope analysis; DUST-BUSTER at IES is ongoing.
Ionization potentials of atomic elements vs. laser wavelength

<table>
<thead>
<tr>
<th>Atomic number Z</th>
<th>Ionization potential (eV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Li</td>
<td>2.1</td>
</tr>
<tr>
<td>B</td>
<td>2.9</td>
</tr>
<tr>
<td>N</td>
<td>7.6</td>
</tr>
<tr>
<td>O</td>
<td>11.7</td>
</tr>
<tr>
<td>C</td>
<td>8.5</td>
</tr>
<tr>
<td>Mg</td>
<td>13.3</td>
</tr>
<tr>
<td>Si</td>
<td>18.8</td>
</tr>
<tr>
<td>S</td>
<td>20.4</td>
</tr>
<tr>
<td>K</td>
<td>10.6</td>
</tr>
<tr>
<td>Ca</td>
<td>8.1</td>
</tr>
<tr>
<td>Ti</td>
<td>8.2</td>
</tr>
<tr>
<td>Fe</td>
<td>8.2</td>
</tr>
<tr>
<td>Ni</td>
<td>7.8</td>
</tr>
<tr>
<td>Cu</td>
<td>8.5</td>
</tr>
<tr>
<td>Zn</td>
<td>10.1</td>
</tr>
<tr>
<td>Se</td>
<td>11.8</td>
</tr>
<tr>
<td>Sr</td>
<td>12.2</td>
</tr>
<tr>
<td>Zr</td>
<td>12.5</td>
</tr>
<tr>
<td>Au</td>
<td>15.7</td>
</tr>
</tbody>
</table>

Laser wavelengths:
- 213 nm (Nd-YAG x5)
- 193 nm (ArF excimer)
- 157 nm (F₂ excimer)
Ion optics simulation of the new instrument design

3D SIMION software was used to simulate, predict transmission and useful yield for the new reflectron time-of-flight (TOF) mass spectrometer.
Assembled DUST-BUSTER parts

Photo-ion extraction system

Ion beam bending & detection housing

Reflectron side view

Reflectron front view
Ni-58/60: -0.1 +/- 0.6
Ni-61/60: -11.7 +/- 1.9
Ni-62/60: -7.1 +/- 1.1
Ni-64/60: -14.0 +/- 1.9
Ni
Fe

mass (amu)

detector analog signal (10^5 mV)

52 54 56 58 60 62 64 66

Fe-54/56

-0.9 +/- 0.5

Ca-42/40

deviation to normal (%)

23.0 +/- 8.8

Cape York iron meteorite

Titanite: CaTiSiO_5
earth lower crust

deviation to normal (%)

mass (amu)

detector analog signal (10^5 mV)

40,42,44,46,48

28 SiO

38 39 40 41 42 43 44 45 46 47 48 49 50 51 52
Titanite: CaTiSiO$_5$; earth lower crust

- CaO
- Si$_2$
- TiO

Detector analog signal ($10^5$ mV)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>46,47,48,49,50</td>
<td>14.0 +/- 0.4</td>
<td>6.7 +/- 0.5</td>
<td>31.5 +/- 1.2</td>
<td>1.1 +/- 1.7</td>
</tr>
<tr>
<td>28,29,30</td>
<td>-3.2 +/- 0.6</td>
<td>2.2 +/- 0.3</td>
<td>29.7 +/- 2.0</td>
<td>13.2 +/- 0.8</td>
</tr>
</tbody>
</table>

Titanite: CaTiSiO$_5$; earth lower crust

CaTiSiO$_5$; earth lower crust
CPX: MgCaSi$_2$O$_6$, earth mantle

![Graph showing detector analog signal (10$^5$ mV) vs. mass (amu).]

- Masses: 24, 25, 30, 35, 40, 45, 50, 55, 60
- Signals: 28, 29, 30 Si
- 24, 25, 26 Mg
- 23 Na
- 27 Al

Deviation to normal value (%):

- Mg-25/24: 23.6 +/- 0.9
- Mg-26/24: -7.0 +/- 1.3
- Si-29/28: 241.6 +/- 5.3
- Si-30/28: 19.2 +/- 2.7

Masses and Elemental Symbols:

- 44 Ca
- 28 SiO
- 27 AlO
- 40 CaO
- 28 Si$_2$
Conclusions

Mass spectrometer is promising.

Efficiency > 10%; Isotope ratio measurements are reproducible to within 3% level on most cases.

Next:

DUST-BUSTER : speed up assembling and test runs

Comet samples : prey for safe return with pristine stardusts

Experiments : investigate to minimize the molecular interference effects, such as reducing the forming of hydrides, oxides, hydroxides etc.

Instrument improvements needed:

Higher mass resolving power \((m/\Delta m >3500)\) to resolve MgH, SiH molecular interferences.

Large detector dynamic range to cover good precision measurements on both high and low abundance elements in one single experiment.