Experiments underway on board the Japanese Experiment Module “Kibo” on the ISS!

“Kibo” Utilization Services

Material Science

Material Science on board the International Space Station (ISS)

Thermophysical Property Measurements of High Temperature Melt & Exploration of New Materials

Beautifully Made, Levitating in Space
Unveil the Unknown Properties of Refractory Materials

Have you ever seen an image in which an astronaut is letting spherical water in the air? In the Japanese Experiment Module “Kibo” on the International Space Station (ISS) equips a material experiment facility capable of melting materials with high melting points, such as glass, while levitating by taking advantage of the microgravity environment.

1. Levitating materials in space, “container-free”

On Earth, a liquid needs a container to stay put. In the microgravity in space however, liquids can float in the air without containers. This makes it possible to determine the liquid’s characteristics, to understand chemical reactions, to develop new materials with new functionality in a containerless environment, and develop new materials free from any contamination from containers. The method to handle materials without containers is called “containerless processing”.

2. Original properties hidden on Earth

On Earth, a material is produced by putting its material substance into a crucible, melting by heating the crucible. When the material has high melting temperature the material easily reacts with the crucible during melting, and then are contaminated. This contamination hinders studying the properties of the melted subject materials accurately, or even handling the experiment itself on Earth.

3. Innovative invention! “Containerless processing” that melts materials while levitating

Containerless processing enables precise measurements of physical properties of molten materials by levitating and fixing the positions. The method allows for the supercooled condition as well as prevents contamination and nucleation due to no container even when a material is heated up to a high temperature. JAXA successfully developed an electrostatic levitation furnace after long years of study of the electrostatic levitation method, a containerless processing technique that enables position control by the Coulomb force in the electrostatic field.

4. Demand of high-accuracy data

Heavy industries – Improvement in the accuracy of manufacturing process model

In terms of refractory materials for aircraft and power generation system, such as turbine blades, and structural materials for ships and bridges, their optimum conditions for processes including casting and welding are determined based on the past achievements. However, the recent sophistication of materials demands aide using more highly accurate numerical analysis.

Material manufacturers – quantitative evaluation of new materials

The metal material manufacturing industry has seen sophisticated and diversified needs of users along with increasing growth of overseas competitors. Currently demanded are proper evaluation of materials with high potential demands in the growing market and the development of the material-related technology thoroughly focused on performance and price. To achieve this requires quantitative exploration of new materials with an exclusive commitment to the necessity-oriented elucidation of their creation process is anticipated.
The Electrostatic Levitation Furnace (ELF)

**Overview**
Experiments using the ELF are conducted by remote control from Earth to precisely measure the materials, and with the acquired data being downlinked automatically to Earth.

**Major specifications**

<table>
<thead>
<tr>
<th>Type</th>
<th>Sample type</th>
<th>Sample size</th>
<th>Ambient</th>
<th>Heater</th>
<th>Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>On Earth</td>
<td>Elemental metals and alloys</td>
<td>40 mm (general laser mg)</td>
<td>Vacuum (Ultimate vacuum approx. 10⁻⁴ Pa)</td>
<td>Carbon dioxide laser 200 W</td>
<td>299 – 3500</td>
</tr>
<tr>
<td>In space</td>
<td>Magnetically suspended, Semiconductors, Insulators, Alloys, and Oxides are also available</td>
<td>Standard: 40 mm (Available up to 50 mm)</td>
<td>Ar, Ne, the air, etc. (Up to 2 atm)</td>
<td>980 nm semiconductor laser Up to 40W x 4 directions</td>
<td>299 – 3000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type</th>
<th>Obtaining properties during the process</th>
<th>Change of materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>On Earth</td>
<td>Metals available</td>
<td>Melting, Supercooling</td>
</tr>
<tr>
<td>In space</td>
<td>Available*</td>
<td>Available</td>
</tr>
</tbody>
</table>

*Under adjustment. Contact when necessary.

**Tip of ELF – Melting while levitating!**

Thermophysical properties measurable in a wide temperature range within 30 minutes covering from melting to solidification

Levitating sample is spherically shaped
Obtain images of a sample during supercooled

- Calculate density by obtaining the volume from image analysis
- Mass is obtained by weighing after returning to Earth

**From basic research to applied utilization**

Thermophysical property measurements of materials with a high melting point and solidification from supercooled phase are expected to contribute to the optimization of the material production process and the creation of new-functional materials.

- **People working in following research who handle materials with high melting point, thermophysical properties, structural analysis, interface phenomena, crystal growth, containerless processing technique, etc.**

- **Numerical calculation researchers of companies that deal with crystals, containerless processing technique, etc.**

- **Researchers working at manufacturers of materials, including metals and ceramics, and semiconductors.**

- **Researchers working at universities related to materials science, including casting, welding, and spraying.**

- **Researchers working at research institutes, and companies.**

**Basic research**

**Applied utilization**

**Project Flow**

- **Recruiting samples**
  JAXA accepts application of space experiment samples from universities, research institutes, companies.

- **Selecting experiments**
  JAXA selects experiments based on the content and anticipated result of the experiments.

- **Examine experiment conditions**
  In cooperation with researchers, JAXA determines the best conditions of the space experiments by examining the properties of the materials with ground-based equipment.

- **Screening flight sample**
  Confirm basic laser compatibility, Dnatocois, and vibration tolerance.

- **Transport to International Space Station**
  Prepare sample in the sample holder and deliver to ISS.

- **Conduct experiments on board “Kibo”**
  Conduct experiments on board “Kibo” and its data acquired by remote control from ground operator.

- **Return to Earth, handover to researchers**
  Solidified samples after the experiments are retrieved, transported to Earth, and handed over to researchers.

**The Japanese Experiment Module “Kibo” on the ISS is a space laboratory where unique research is possible. JAXA provides comprehensive support and facilitate utilization so that the many people engaged in research.”

**Overview Camera**

- **Pressure Sensor**
- **Pyrometer**
- **Laser Damper**
- **High Voltage Connector x6**
- **Sample Heating Laser x4**
- **Oxygen Sensor**
- **Position Sensor x2**
- **Light Source**
- **Magnifying Camera**
- **Light Sensor x2**

**Major specifications**

- **Sample type**
  - Elemental metals and alloys
  - Magnetically suspended, Semiconductors, Insulators, Alloys, and Oxides are also available

- **Sample size**
  - 40 mm (general laser mg)
  - Standard: 40 mm (Available up to 50 mm)

- **Ambient**
  - Vacuum (Ultimate vacuum approx. 10⁻⁴ Pa)
  - Ar, Ne, the air, etc. (Up to 2 atm)

- **Heater**
  - Carbon dioxide laser 200 W
  - 980 nm semiconductor laser Up to 40W x 4 directions

- **Temperature**
  - 299 – 3500 °C

**Type**

- **On Earth**
  - Metals available
- **In space**
  - Available*

**Change of materials**

- **Melting, Supercooling**

*Under adjustment. Contact when necessary.

**Basic research**

- **Applied utilization**

**Tip of ELF – melting while levitating!**

- **Thermophysical properties measurable in a wide temperature range within 30 minutes covering from melting to solidification**

- **Levitating sample is spherically shaped**

Obtain images of a sample during supercooled

- Calculate density by obtaining the volume from image analysis
- Mass is obtained by weighing after returning to Earth

Obtain surface tension of the melted liquid based on the attenuation of oscillating droplet

Obtain surface tension of the melted liquid based on the attenuation frequency of oscillating droplet

**From basic research to applied utilization**

Thermophysical property measurements of materials with a high melting point and solidification from supercooled phase are expected to contribute to the optimization of the material production process and the creation of new-functional materials.
What is the difference between JAXA’s ELF and levitation furnace (electromagnetic levitator) of other agency on board the ISS?

JAXA’s electrostatic levitation furnace (ELF) is the world’s only equipment capable of measuring the properties of insulators with a high melting point by melting at an extremely high temperature (3000 °C) while levitating, which is impossible by electromagnetic levitators.

Could you introduce the size and the number of samples to be launched?

Each sample is 1.5 – 2.1 mm in diameter and up to 15 samples can be installed in the sample holder and launched on board the ISS.

What results is the ELF expected to produce?

Our ELF is expected to contribute to the improvement in accuracy and reliability of numerical simulation which models the manufacturing process using materials in a liquid state for casting, welding, spraying and crystallizing. The contribution of the ELF will lead to the decrease in the number of experiments required for narrowing parameters and verification, improvement in the reliability, sophistication, and precision of simulation data, speeding of new material development, hold-down of the development costs.

If you are interested in using ELF, please contact JAXA. z-kibo-promotion@ml.jaxa.jp

Thermophysical properties of metallic element melts acquired by measuring with the Ground-based electrostatic levitator

The ground-based electrostatic levitator experiments have made many achievements, as exemplified by improvement in the thermophysical properties measurement for its application in experiments on board the Japanese Experiment Module “Kibo” and acquisition of high-temperature thermophysical properties data of elemental metal melts.

With the ground-based levitator we have already acquired viscosity coefficient data of refractory metals having a melting point higher than 3,000°C, including tungsten (chemical symbol: W) that has the highest melting point among metals. (Shown with stars in the figure).

In addition, a wide-ranging temperature coverage data has been acquired for the first time in the world.

Material Informatics Cooperation

ISS-JEM “Kibo” Experiments

Thermophysical Properties Data
Liquid State simulation
Structure Analysis Data
High Temperature liquid Observation

Global access to world’s first thermophysical properties data
Breakthroughs of innovation & discovery leading to increased economic growth
Acceleration from ideas to develop efficient turbines, aircraft, and jet engines
Enhancement & verification of numerical & analytical liquid state models
Advancement of fundamental research of material science

Example of Heavy industry: casting of turbine blades and reproduction of welding defects

Thermophysical properties data by the ground-based electrostatic levitator can reproduce the flow condition at melting with the thermophysical properties of a high melt was applied to simulation of high-temperature melt phenomena which include melting defects caused at casting and welding. The application ground-based electrostatic levitator contributed to the consideration of measures for improving the yield ratio and review of the optimum conditions.

●Example of Manufacturer: New material development

With the ground-based electrostatic levitator, the measurement of thermophysical properties in the development materials for semiconductors and circuit boards used for solar power generation and rechargeable batteries was conducted and brought performance evaluation and manufacturing process evaluation of new materials and the data serving the manufacturing process assessment.
For inquiries on the leaflet and “Kibo”,
contact Kibo Utilization Promotion Office at Z-KIBO-PROMOTION@ml.jaxa.jp

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Detailed information about ELF (specifications)
To whom are interested in using ELF, see:
http://iss.jaxa.jp/en/kiboexp/pm/elf/

Ishikawa Lab. (Electrostatic Levitation Targeted
Research Laboratory), Institute of Space and
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http://ishikawa.isas.jaxa.jp/index_en.html

Human Spaceflight Technology Directorate
Japan Aerospace Exploration Agency

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