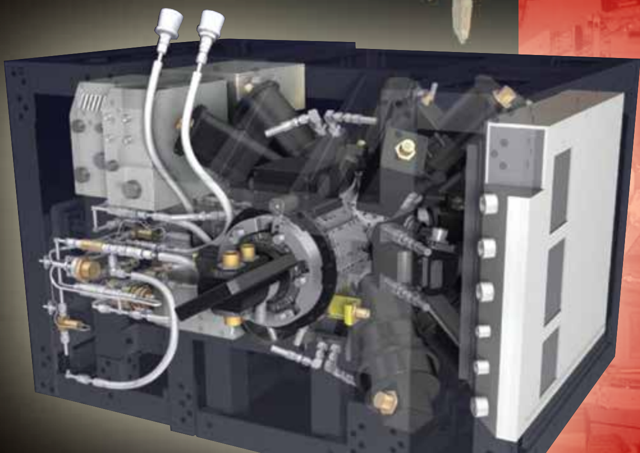
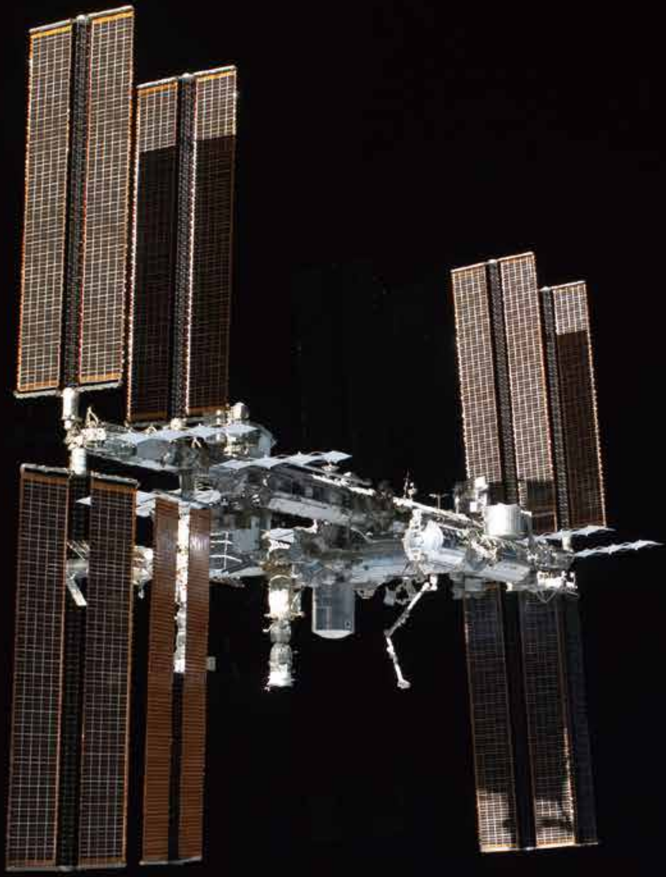


Beautifully made, levitating in space. That's the shape of the future.

Electrostatic Levitation Furnace

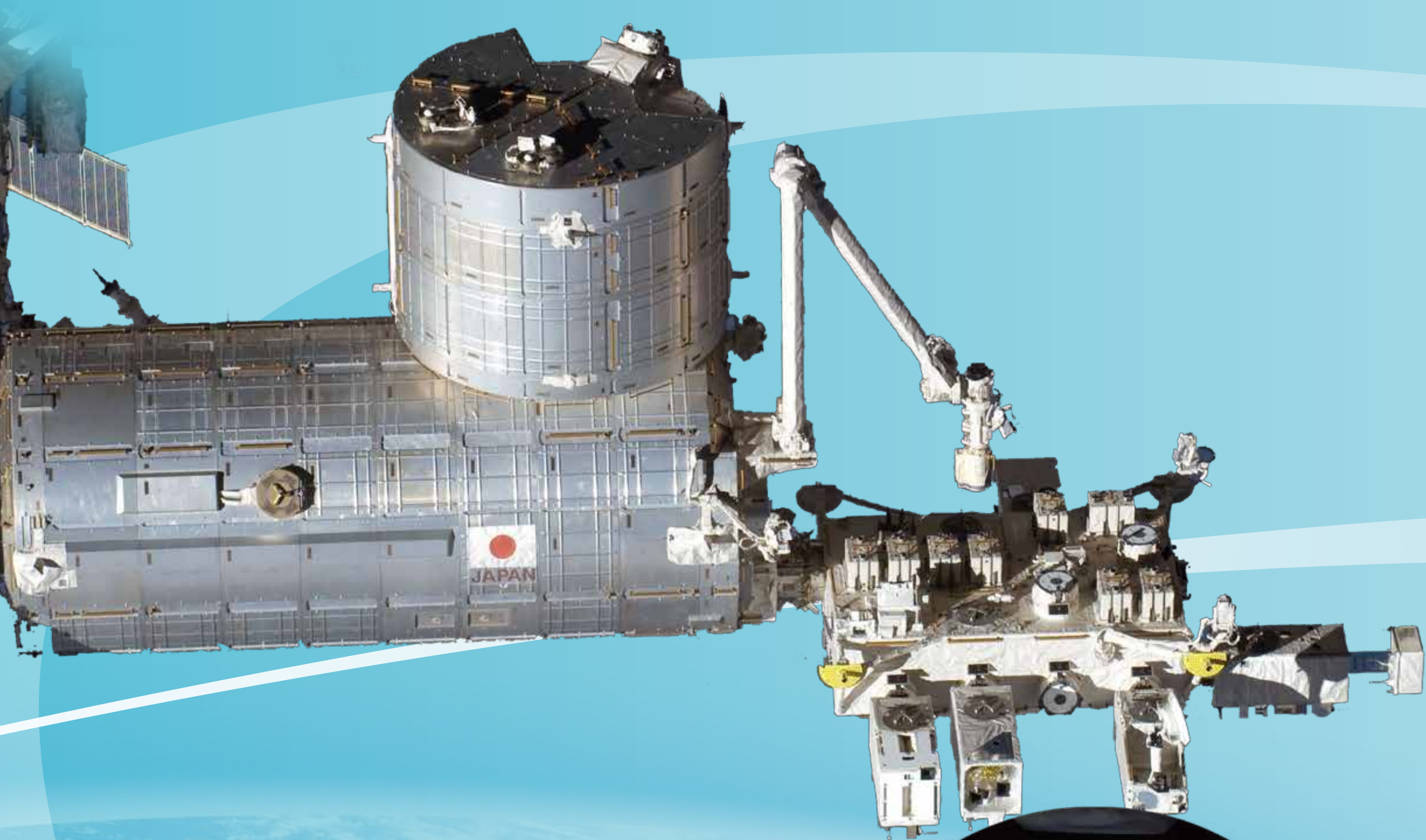
ELF



Small science
Big innovation

The Electrostatic Levitation Furnace (ELF) to be installed on the Japanese Experiment Module "Kibo" onboard the International Space Station (ISS) levitates materials by Coulomb force, and heats and melts materials to keep them in a stable (spherical) state. On Earth, a liquid needs a container to stay put. Because no containers are suitable for temperatures higher than 2,000°C, it is difficult to melt materials with a high melting point on Earth. Containers react to high temperature and contaminate the materials. In the microgravity environment on the ISS, liquid can be levitated easily and doesn’t need containers. This method of handling materials without containers is called "containerless processing." This processing allows us to closely investigate the behavior of materials in their molten state, which is difficult to do on Earth. We can also crystallize (rapidly solidify at a lower temperature than the melting point) the melted sample and bring it back to Earth for analysis. By using the ELF as a new achievement, we will hopefully lead the world by achieving something that is not possible on Earth.

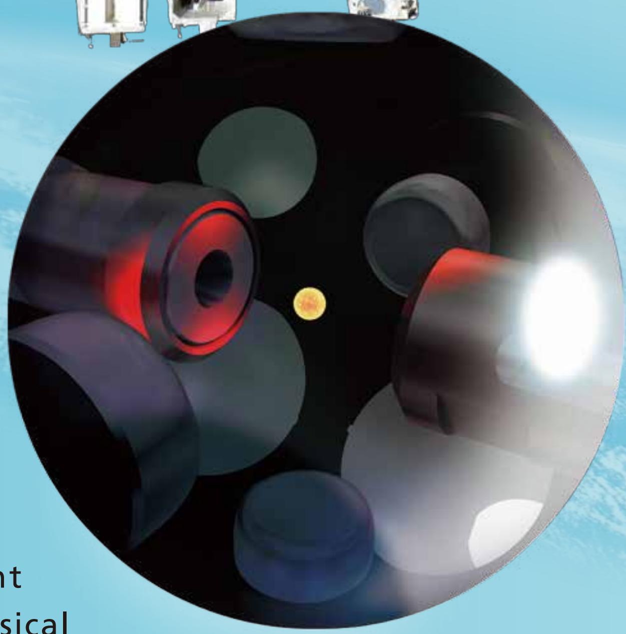
Reveals the unknown properties of refractory materials



The Electrostatic Levitation Furnace (ELF) is a facility for material science that melts levitating materials having a very high melting point, measures their properties, and then solidifies them from supercooled phase by taking advantage of the microgravity environment.

Many scientific results have already been obtained ahead of the world from ground-based research conducted prior to the space experiment on the International Space Station (ISS).

With the ELF in the ISS/Japanese Experiment Module "Kibo", we can reveal the thermophysical properties of high temperature melts that are very difficult to measure on Earth, and obtain entirely new and innovative materials.



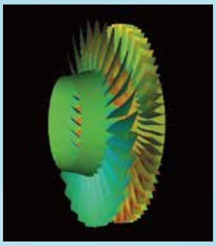
Towards the next generation of jet engines

Streamlining the molding process through acquisition of accurate thermophysical properties

During the preparatory research for the ELF on the "Kibo", the techniques of measuring the thermophysical properties of high temperature melts have been improved with a ground-based facility. Many thermophysical properties of refractory metals have been revealed for the first time in the world.
With the ELF, the thermophysical properties (density, surface tension, and viscosity) of oxidized materials, which are difficult to levitate on the ground, will be measured.
The thermophysical data acquired in "Kibo" will dramatically improve the fundamental data of material science. And these thermophysical properties will be utilized as the basic data for computer-based casting simulation programs, in order to develop high-performance heat resistant coating technology to be applied to efficient turbines for electric generation systems, aircraft, and the next generation of jet engines.

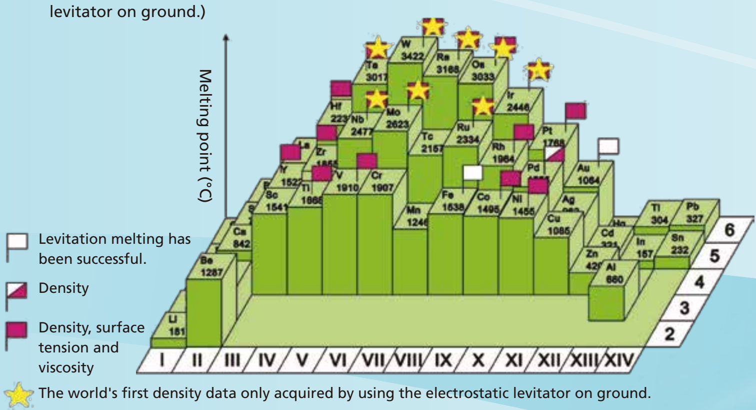
■Application for precise castingsimulation of jet engine turbine blades

To find the optimum condition for precision molding of refractory alloys, numerical simulations are used to reduce experimental trial and error. The highly accurate thermophysical properties data acquired with the ELF will improve the accuracy of computer simulation and accelerate the development of next-generation jet engines.



■Thermophysical properties of refractive metallic elements acquired with the ground-based electrostatic levitator

With the ground-based electrostatic levitator we have already acquired such thermophysical properties as the density, surface tension, and viscosity 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. (Stars in the figure denote the world's first viscosity data only acquired by using the electrostatic levitator on ground.)

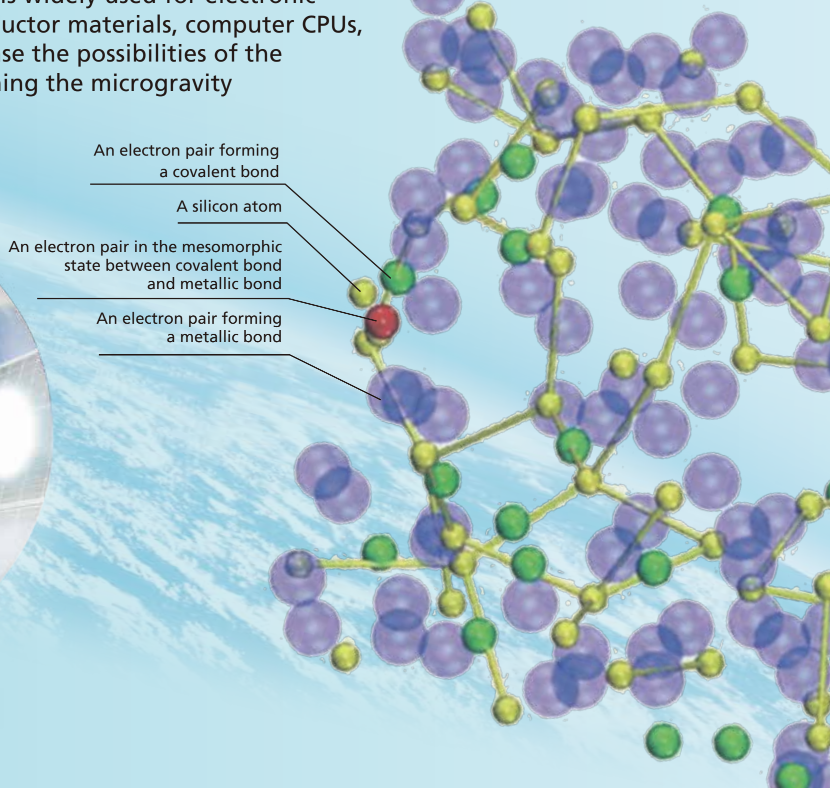


Exploring new possibilities of silicon, which changes to metallic after melting

Opening a new science with the electrostatic levitation method

By downsizing the electrostatic levitation equipment thorough technological innovation during the flight hardware development for the ELF, a new type of structural analysis of high temperature liquid with an electrostatic levitator combined with high power X-rays becomes possible. As a result, the ground-based experiment has achieved the world's first success in revealing the unique electronic structure of liquid silicon, which is widely used for electronic devices supporting our daily lives such as semiconductor materials, computer CPUs, and solar batteries. This scientific result will increase the possibilities of the material for future usage. In the future, by combining the microgravity experiments in "Kibo" and structural analysis with X-rays on the ground, we expect to investigate the unknown liquid states of oxidized materials and achieve breakthroughs in science as well as in materials development.

▼ The atomic position and electron distribution in liquid silicon, revealed by JAXA for the first time

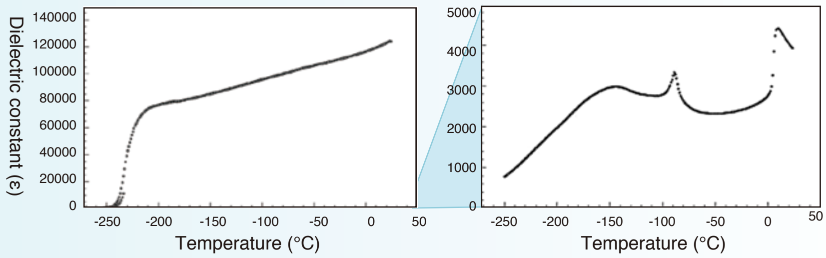


Innovative achievements: High performance capacitor and glass

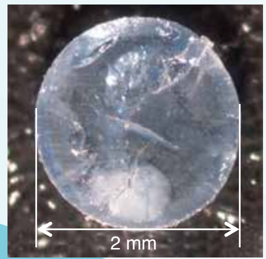
Creating materials with new properties using containerless processing

Containerless processing can provide a large supercooled state and form different crystalline structures and phases, from which new materials can be created.
We levitated and melted barium titanate ($BaTiO_3$) without a crucible during a ground-based experiment and crystallized it through supercooling. As a result, we succeeded in developing a high performance material that has a huge dielectric constant and is unaffected by temperature changes. We can apply this high quality barium titanate to a capacitor, in order to enable the downsizing of mobile communication equipment and high-capacity information transfer.
Levitated and melted without a crucible and rapidly cooled to a supercooled state, the barium titanate ($BaTi_2O_5$) also vitrified to a new glass material with a large refractive index comparable to that of diamond. This glass is now being researched for possible application in a variety of fields. New materials and the processes to create them will be discovered on "Kibo" and open the way for future practical application and production on Earth.

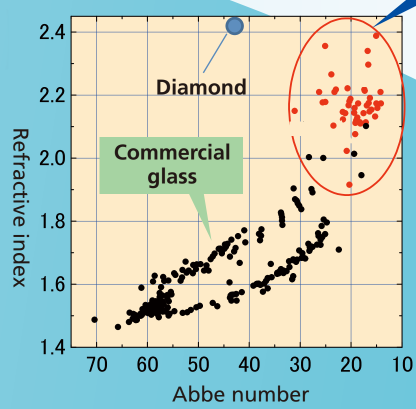
■The dielectric constants of barium titanate processed with the electrostatic levitator on Earth (left) and normal container processing (right)



■Barium titanate created with the electrostatic levitator on Earth

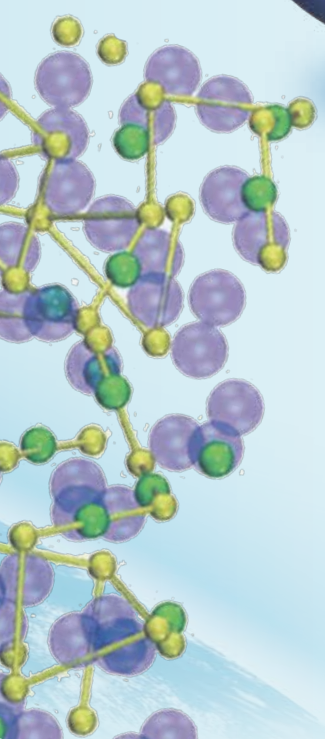


This barium titanate has a large dielectric constant of more than 100,000 at room temperature, which is 30 times greater than that of ordinary barium titanate, and its application in industrial capacitors with a high dielectric constant can be expected. We also discovered that the material has incredible temperature stability, keeping a high dielectric constant in the range from room temperature to 70K (-203.15°C).



■Refractive index of glass
(new glass in red, commercial glass in black)

The refractive indexes of new glass, made by using containerless processing in an ground-based aerodynamic levitator, concentrated above 2.0. The material was changed to a special glass with a high refractive index comparable to that of diamond (with a refractive index of 2.42).



Leading science and technology, through extreme temperature higher than 3,000°C

By using the electrostatic levitation technology developed by ground-based research, we will measure the thermophysical properties of diverse high temperature melts, including oxidized materials that are difficult to charge and levitate on Earth. Such measurement is only possible in "Kibo" in space.
We also expect to find new characteristics of materials through crystallization using containerless processing.

Overview of Electrostatic Levitation Furnace (ELF)

STEP 1 Load a cartridge containing a holder with 15 samples.

STEP 2 Charge a sample approximately 2 mm in diameter, and position it with 3-axis control using Coulomb force.

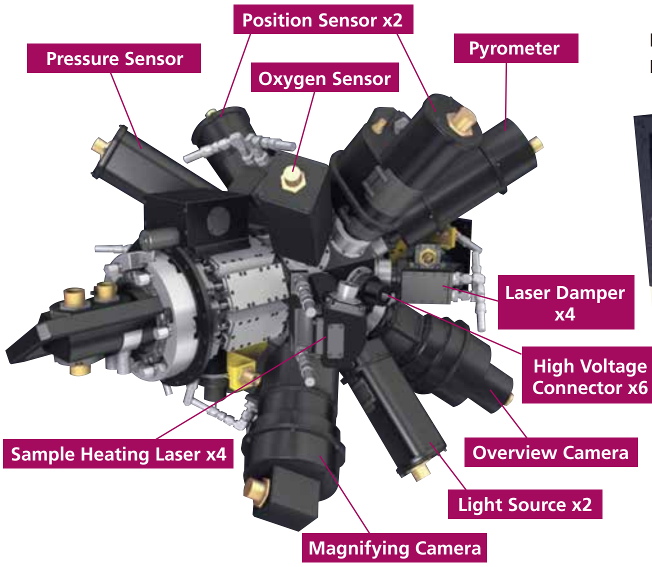
STEP 3 Heat the sample with heating lasers and melt the material without a crucible

STEP 4 Measure the density, surface tension, and viscosity of the sample in its molten state.

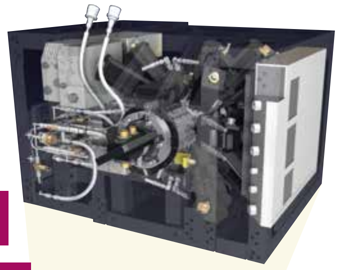
STEP 5 After stopping lasers, observe the cooling and recrystallization phases of the material.

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.
After the experiment, the sample holder is collected for its return to Earth aboard spacecraft such as Dragon and Soyuz for more detailed analysis.

Structure of Electrostatic Levitation Furnace



Main body of Electrostatic Levitation Furnace



Sample Holder

Sample Cartridge

Electrostatic Levitation Furnace ELF installation image in the MSPR Work Volume

Specification

Item	Specification
Size	590 × 887 × 787 mm (Main body) + 226 × 259 × 347 mm (UV lamp)
Mass in orbit	Approx. 220kg
Maximum power consumption	Approx. 550W
Heater	Heating laser (Semiconductor laser, wavelength: 980 mm, maximum optical output: 40 W x 4)
Sample	Mainly oxides; metal, alloy, and semiconductor are also available. Sample in spheroidal form with φ1.5-2.1 mm (Up to φ5 mm is possible by replacing the cartridge.)
Temperature measurements	Measuring range: 300-3,000°C Sampling rate: 100 Hz
Magnified measurements	Using ultraviolet background light for observation at 140 pixels/radius or higher with a diameter of 2 mm, measures the sample's contours of light emitted at high temperatures.
Surface tension, viscosity	Measures surface tension by the resonant frequency of melts, and density by the attenuation rate of vibration. Vibrational excitation (1-600 Hz)
Solidification observation	Resolution: 640 x 480, frame rate: 30 fps, dynamic range: 120 dB or more
Ambient	Air pressure: 2 atm (oxygen concentration: 10%), N2: 2 atm, Ar pressure: 2 atm, vacuum (through JEM evacuation line)
Accuracy of positioning	3-axis control, control period: Max. 1 kHz, absolute positioning accuracy: ± 100μm

JAXA Japan Aerospace Exploration Agency

Human Spaceflight Technology Directorate, JEM Utilization Center
KIBO Promotion Office
Tsukuba Space Center
2-1-1, Sengen, Tsukuba-shi, Ibaraki Pref. 305-8505
TEL : +81-50-3362-3202 FAX : +81-29-868-3950 mail : Z-KIBO-PROMOTION@jaxa.jp

Institute of Space and Astronautical Science (ISAS)
3-1-1, Yoshino-dai, Chuo-ku, Sagamihara-shi, Kanagawa Pref. 252-5210
TEL : +81-42-751-3911 (Rep.)

Information on the ELF (Specification)
http://iss.jaxa.jp/en/kiboexp/pm/elf/

ISAS, Ishikawa Lab. (Written in Japanese)
http://ishikawa.isas.jaxa.jp/