Equipment for Collaborative Research in 2020

1. Materials Synthesis Station

1-1 Electron Beam Lithography & Ion Milling System

Building No. 2, Room 211

Microfabrication at a sub-micron scale can be performed by a 50 kV thermionic electron gun to obtain micro-sized structures of approximately 100 nm. Photolithography in combination with electron beam lithography equipment using a photomask aligner with large-area processing can be used to fabricate devices. An attached secondary ion mass spectrometer enables depth profile measurement using ion milling.

ELIONIX: ELS-7500 (2003)

1-2 Multi-Target Reactive Sputtering (Ion Beam Sputtering)

Building No. 2, Room 111

This multi-target reactive sputtering (ion beam sputtering) system enables the preparation of thin films/multi-layer samples without Ar plasma damage. This sputtering system consists of three ion source guns for sputtering and one ion milling gun for cleaning. There are six sputtering targets that can be installed in the deposition chamber.

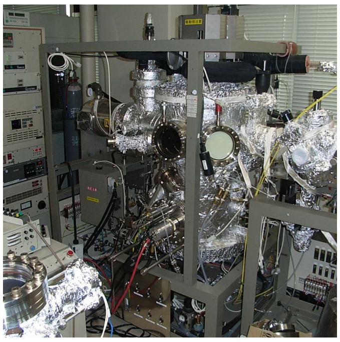
Toei Scientific Industrial Co., Ltd: 3000HC (1989)

1-3 Reflection High-Energy Electron Diffraction System

Building No. 2, Room 111

This system consists of a main deposition chamber and a load lock chamber. In the main deposition chamber, epitaxial thin films/metallic superlattice samples can be developed while monitoring the film growth by reflection high-energy electron diffraction (RHEED). This RHEED system has a 30 kV-accelerated electron gun and a 150 mm-diameter screen. Moreover, a PC software for monitoring and analyzing RHEED patterns is available.

(1997)

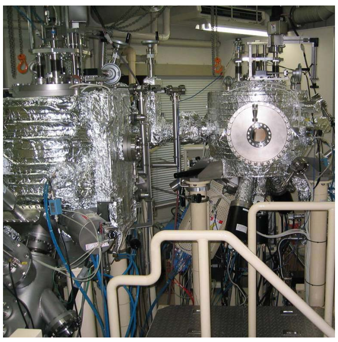


1-4 Multi-Ion Vapor Deposition System

Building No. 2, Room 104

This is a thin-film deposition system equipped with magnetron sputtering cathodes. This deposition system also consists of an electron cyclotron resonance ion source for Ar milling and surface modification. In addition, a Freeman ion source enables ion implantation and dynamic mixing of samples, and its maximum acceleration voltage is 50 kV.

ULVAC: MB98 (1999)



1-5 Multi-Layer Chemical Vapor Deposition Reactor

Building No. 2, Room 111

This is an apparatus for fabricating thin films by chemical vapor deposition (DVD) using electron cyclotron resonance (ECR) plasma. The high density and high ionization rate of the plasma in this equipment enables a high deposition rate, excellent step coverage, and low-temperature synthesis of thin films.

Sumitomo Metal Industries, Ltd.: ES-037 (1988)

1-6 Three Cathode-Equipped Compact Sputtering System

Building No. 2, Room 111

This sputtering system is composed of a main deposition chamber and a load lock chamber that are used for the preparation of thin films. Three kinds of sputtering targets can be installed. RF power is applied to the target in order to produce Ar plasma. The substrate can be rotated during sputter deposition for film uniformity.

IZUMI-TECH: IZU-SP008 (2012)

1-7 Hot Working (Forging) Simulator

Building No. 2, Room B06A

Heat treatment under various conditions, high-temperature tensile/compressive deformation, powder sintering, and material phase transformation measurement can be performed using this equipment.

Fuji Electronic Industrial Co., Ltd.: Thermecmastor-Z (2009)

1-8 Spark Plasma Sintering: SPS-1050

Building No. 2, Room B01

This is a powder consolidation machine that uses the spark plasma sintering method. The raw material powder is filled in the conductive mold and is compressed by the top and bottom punches. A large pulsed current flowing through the moldgenerates heat for the sintering. Owing to the rapid heating effect, the grain growth can be suppressed and fine-structured compact specimens can be obtained.

Sumiseki Materials Co., Ltd: DR.SINTER Model SPS-1050 (1992)

1-9 Spark Plasma Sintering: SPS-3.20, Mark IV

Building No. 2, Room B04

This is a powder consolidation machine that uses the spark plasma sintering method. The raw material powder is filled in the conductive mold and is compressed by the top and bottom punches. A large pulsed current flowing through the mold generates heat for the sintering. Owing to the rapid heating effect, grain growth can be suppressed and fine-structured compact specimens can be obtained. Compared with the SPS-1050, a larger current (10000 A) and a higher load (20 ton) can be applied in this equipment; this is useful for preparing large compact specimens.

SPS SYNTEX INC: DR.SINTER Model SPS-3.20 Mark IV (2005)

1-10 Electron Beam Melting Furnace

Building No. 2, Room B05

This device is used for melting refractory materials using an electron beam on a water-cooled copper hearth (φ100 × t10 mm) under high vacuum conditions (10^{-4} Pa).

JEOL Ltd.: (1995)

1-11 Gas Atomization

Building No. 3, Room 307

This device can make rapidly-quenched metal powder in air or in an inert atmosphere. The molten metal is pulverized and quenched by a high-pressure gas stream. After atomization, the powder is collected in a vacuum chamber that is isolated from air. Thus, easily oxidized metal powders such as titanium- and zirconium-based alloys can be produced safely.

Makabe Giken Co,.Ltd.: RQM-P-100 (1998)

1-12 High-Frequency Induction Tilt Casting

Building No. 3, Room 307

This device can prepare a master alloy ingot by tilt-casting into a mold by high frequency induction heating under inert gas atmosphere. The amount of an alloy that can be prepared at one time is about 70 g in terms of iron. By selecting the optimum crucible material, the maximum temperature can be reached up to 1500 °C.

Makabe Giken Co,.Ltd.: VF-HMF100 (2007)

1-13 Single Roll Melt Spinning

Building No. 2, Room B06A

This device is used for ultra-rapid cooling of molten metals in a vacuum or an inert gas atmosphere. An alloy is melted in the quartz nozzle and spun by the high-speed rotating copper roller. The melting temperature of the alloy must be below 1200 °C. This machine can also be used as a copper mold casting machine.

NISSIN GIKEN Corporation: NEV-A04 (1999)

2. Performance Evaluation Station

2-1 Magnetic Property Measurement System

Building No. 2,Room 107

This measurement system can be used to characterize the magnetic properties of magnetic materials (mainly thin-film samples). The maximum magnetic field is 2 T. The magnetoresistance effect, Hall effect, and magnetization can be measured.

TAMAKAWA CO.,LTD: TM-VSM2614HGC-KIT (2014)

2-2 X-ray Diffractometer (Micro-Area Type)

Building No. 2, Room 103

This X-ray diffractometer can analyze fine precipitation in specimens using a micro X-ray collection device, CBO-f.

Rigaku: UltimaIV/MAJ (2009)

2-3 X-ray Diffractometer (Horizontal Sample Setting Type)

Building No. 2, Room 103

A high-performance detector (D/teX Ultra) enables a high-speed analysis, up to 100 times compared with a conventional scintillation counter. In addition, a trace element analysis can be performed. Texture measurement can be performed using the multi-purpose sample stage.

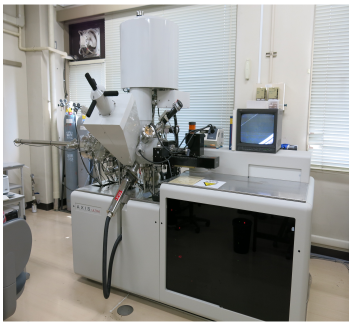
Rigaku: UltimaIV/SG (2012)

2-4 X-ray Photoelectron Spectrometer (XPS)

Building No. 2, Room 106

The composition of a sample can be analyzed by measuring the energy and intensity of photoelectrons generated under irradiation of X-rays. The position of peak energy determines the chemical state, and the surface with a depth of several nanometers can also be analyzed. The sample transfer container system enables the analysis of chemically-treated samples without exposure to the atmosphere.

SHIMAZDU Co.: KRATOS AXIS-Ultra DLD (2009)

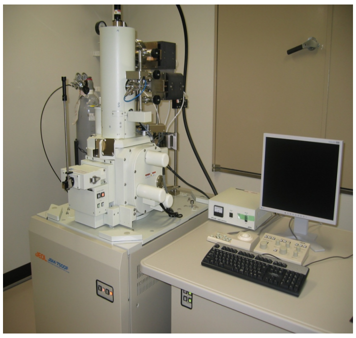


2-5 Field Emission Scanning Electron Microscope (FE-SEM)

Building No. 2, Room 217

High-resolution observations on the order of 1 nm in secondary electron images can be achieved by using the FE electron gun. This equipment can analyze complex surfaces, such as tensile-fractured surfaces. Insulation materials can be observed using various observation modes without pre-treatment.

JEOL: JSM-7500F (2009)



2-6 Field Emission Electron Probe Micro-Analyzer (FE-EPMA)

Building No. 2, Room 106

FE-EPMA with a small probe of 40 nm and a high resolution of 3 nm enables high-precision composition analysis using a wavelength dispersive X-ray spectrometer, which can detect elements from boron to uranium. The attached EBSD system analyzes the crystal orientation of specimens.

JEOL: JXA-8530F (2009)

2-7 Scanning Electron Microscope (Tungsten Filament) (W-SEM)

Building No. 2, Room 107

This thermionic-emission gun with a tungsten filament provides high-resolution secondary electron images (SEI) and back-scattered electron (BSE) images of metallic and inorganic materials. The chemical compositions of samples can be determined using the attached EDX system. The maximum size of a specimen that can be installed in the analysis chamber is 200 mm in diameter and 80 mm in thickness.

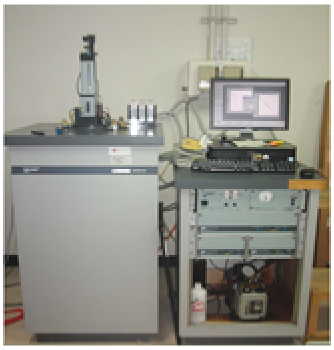
Hitachi High Technologies: S-3400N (2008)

2-8 Superconducting Quantum Interference Device (SQUID) Magnetometer

Building No. 2, Room 107

Quantum Design's MPMS magnetometry provides users with a superconducting quantum interference device, SQUID, which has a sensitivity $\leq 10^{-6}$ emu under a temperature range of 2–400 K and a magnetic field control below 5 T. AC magnetic measurements can also be performed in a frequency range of 0.01–1500 Hz.

Quantum Design: MPMS-5S (1997)



2-9 Instron Tensile Test

Building No. 3, Room 211

This is a universal mechanical testing machine to investigate the tensile and compressive properties of materials at room temperature. By measuring the stress–strain curve of the material, the yield stress, elongation, fracture strength, and Young's modulus can be determined. It consists of two testing machines, one for low loads (5 kN) and another for high loads (50 kN). The former is suitable for evaluating ribbon samples and the latter for bulk samples. The strain can be measured more accurately by using an external strain gauge.

Instron: 4204 (1991)

2-10 Differencial Scanning Calorimetry (DSC)

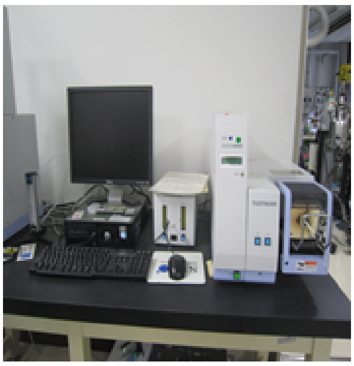
Building No. 3, Room 301

This device is a high-performance differential scanning calorimeter in which the temperature program can be precisely reproduced. The lowest temperature can reach the cryogenic temperature range, and the maximum controlled cooling rate exceeds the glass-forming critical cooling rate of metallic glass. Ultra-high-speed scanning of 750 °C/min in a measurement range of -170–750 °C can be performed in the double furnace system. In addition, because the endothermic and calorific values are directly measured, the sensitivity does not depend on the temperature. The accuracy and reproducibility of temperature and calorific values are excellent.

Perkin Elmer: DSC8500 (2010)

2-11 Conventional Type Thermal Analysis Measurement System (DTA, DSC, TMA)

Building No. 2, Room 215

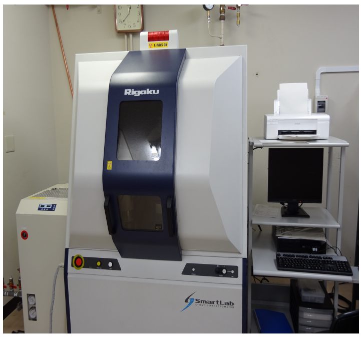


Differential thermal analysis (DTA), differential scanning calorimetry (DSC), and thermomechanical analysis (TMA) between the sample and reference are monitored against time or temperature, while the temperature of the sample is programmed in a specified atmosphere. A aluminum, platinum, or alumina crucible can be used while monitoring the DTA and DSC properties of the sample. The system delivers an extended temperature range from ambient temperature to 1300°C for DTA, to 1200 °C for DSC and to 1500 °C for TMA. The cooling unit can be used to measure the DSC in a temperature ranging from -150°C to 500 °C.

SIISeiko Instruments Inc.: EXSTAR 6000 series, TMA/SS 6200, TG/DTA 6300, DSC 6200 6300 (2007)

2-12 Multi-purpose X-ray Diffractometer

Building No. 2, Room 103



X-ray diffraction is the non-destructive analysis of multi-component mixtures. This method helps analyze unknown materials and perform material characterization in fields such as metallurgy, mineralogy, and condensed matter physics. Crystalline phase identification of the constituents is performed by comparing the diffraction patterns to a known standard or to a database such as the Powder Diffraction File (PDF). The fundamental physics of X-ray diffraction is based on the high-accuracy measurement of interplanar spacings and corresponding intensity profiles. Rigaku SmartLab is a high-resolution X-ray diffractometer (XRD), which provides rapid and accurate measurements on X-ray scattering profiles of powders, thin films, and bulk crystals. In particular, the SmartLab system is capable of utilizing thin-film metrology, small angle scattering, and in-plane scattering together with operando measurements.

Rigaku: SmartLab 3XG (2012)

2-13 Single-Crystal X-ray Diffractometer

Building No. 2, Room 103

Single-crystal X-ray diffraction is most commonly used for the precise determination of a unit cell, including the positions of atoms in a unit cell. The obtained structural information on the distribution of constituent atoms, bond distances, and angles enables us to understand the physico-chemical properties of each material. Applications of single-crystal diffraction include material identification, crystal solution and refinement, determination of unit cells and bond distances and angles, and site ordering. A classical four-circle goniometer with a scintillation counter (Rigaku AFC7R) and a modern single crystal diffractometer with an imaging plate (IP) (Rigaku R-AXIS) are installed at the Cooperative Research and Development Center for Advanced Materials together with a powerful high-frequency 18kW X-ray generator (ultraX 18). The four-circle goniometer system is also equipped to handle high temperatures which allows us to analyze the atomic structural changes at high temperatures in detail.

Rigaku: AFC-7R and R-AXIS IV++ with UltraX 18 (2012)

2-14 Micro X-ray Diffractometer

Building No. 2, Room 103

The characterization of microstructural examinations requires an X-ray diffraction (XRD) analysis in the small area of a large sample. This micro X-ray diffraction (μXRD) analysis utilizes a narrow X-ray beam to perform localized X-ray diffraction measurements of a very small area. This method uses a powerful high-frequency 18 kW X-ray generator (ultraX 18) and dedicated incident beam collimators that reduce the emitted X-rays. The μXRD technique is usually applied to several diffraction investigations including the characterization of small spots on samples with strong composition gradients. This technique is also useful in the analysis of contaminations, inclusions, petrological samples, used test pieces of alloy samples, and patterned wafers.

Rigaku: RINT-2000 with UltraX 18 (2016)

2-15 Vibrating Sample Magnetometer (VSM)

Building No. 2, Room B-05

Magnetic properties of bulk, powder, and thin-film materials can be measured with high sensitivity in a temperature range of 77 K to 1200 K using this magnetometer. The maximum applicable magnetic field is 1.5 T and the magnetization range is 10^{-3} to 10^{2} emu. Magnetization curves at an arbitrary temperature, thermal magnetization curves under a constant magnetic field, temperature changes during magnetization, spontaneous magnetization, and Curie and Neel temperatures can also be obtained. The measurement of magnetostriction by using Strain-Gauge under applying magnetic field is also possible.

Toei Scientific Industrial: VSM-5 (1995)

2-16 Laue X-ray Back Scattering by Digital CCD Camera

Building No. 2, Room 110

The constituent instruments of this system are 1) X-ray generator, 2) Laue back scattering optical system, 3) Sample stage, 4) Cooling-type CCD digital camera, 5) PC, and 6) Orientation-analyzing software. A tungsten target is used as the X-ray tube and the maximum load power is 3 kW. A four-axis goniometer is commonly used in the electric discharge machine. Diffraction spots can be immediately obtained on the PC using the CCD digital camera.

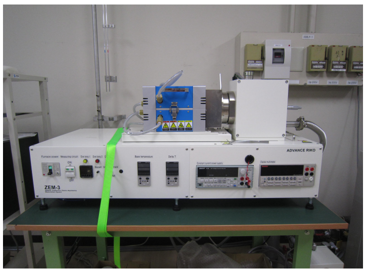
Rigaku: RASCO-IIBLA (2014)

2-17 Seebeck Coefficient/Electrical Resistivity Measurement System

Building No. 3, Room 308

The Seebeck coefficient and electrical resistivity can be measured by the steady direct-current method and by the four-point probe method. The operating temperature ranges from room temperature to 1000 ºC. The available sample shape is a rod or a prism with a length of 5～2 mm.

Advance Riko: ZEM-3 (2015)



3. Crystal Preparation Station

3-1 Solidification Control Equipment from Liquid Phase

Building No. 2, Room B04

This equipment can obtain single crystals of metals, semiconductors, and oxide and fluoride compounds by the Czochralski process or by the vertical Bridgeman process. The state of melted materials can be monitored in-situ. The materials are melted by a high-frequency induction heating system or by a resistance heating system under an arbitrary atmosphere.

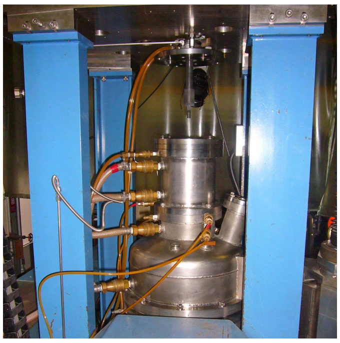
Celec: 89026 (1990)

3-2 Crystal Growth Equipment with Horizontal Magnetic Field Application System

Technical Center Ⅱ, Room 105

This equipment can obtain single crystals of metals, semiconductors, and oxide and fluoride compounds by the Czochralski process or by the vertical Bridgeman process in horizontal magnetic fields (maximum of 0.4 T). The materials are melted by a resistance heating system with a double zone-type carbon heater under an arbitrary atmosphere.

Celec (1989)

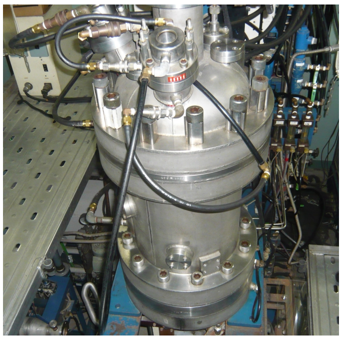


3-3 Crystal Growth Equipment for Bridgman Method

Technical Center II, Room 105

This equipment can obtain single crystals of metals and semiconductors by the vertical Bridgeman process. The charged materials are melted by a resistance heating system with a double zone-type carbon heater under an arbitrary atmosphere.

Kokusai Electric Inc.: 301-551 (1991)

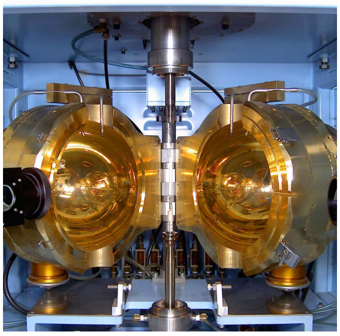


3-4 IR Image Furnace for Floating Zone Melting

Building No. 3, Room 208.

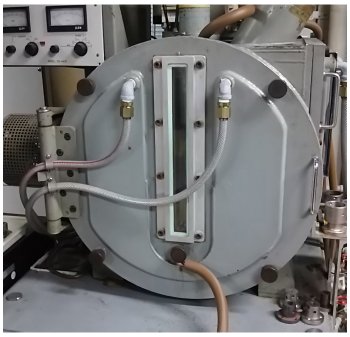
This equipment can obtain highly purified single-crystalline materials by the floating zone melting method using an infrared (IR) beam focused from a halogen lamp. It can melt materials under an arbitrary atmosphere and can be used to obtain single crystals of metals, alloys, intermetallic compounds, and oxides. The equipment can obtain highly purified materials because the materials are melted without the use of a reaction container.

Asukaru: FZ-SS35WV (1989)



3-5 Electron Beam Furnace for Floating Zone Melting

Building No. 3, Room 208.

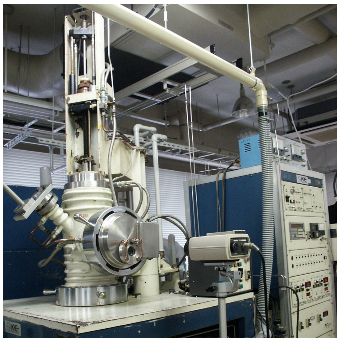


This equipment can obtain highly purified single-crystalline materials by the floating zone melting method using electron beams. The charged materials can be heated up to 3000 °C in vacuum.

JEOL: JEBS-3B (1974)

3-6 Crystal Growth Furnace with HF-Inductive Heating System

Building No. 3, Room 208.

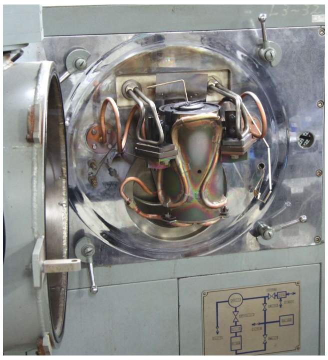


This equipment can obtain single-crystals of metals, semiconductors, and oxide and fluoride compounds using a high-frequency (HF)-inductive heating system. The charged materials are melted either by the Czochralski process, the vertical Bridgeman process within a crucible, or the floating zone melting without a crucible.

Kokusai Electric Inc.: DP-20MP (1981)

3-7 Tungsten Resistivity Element Furnace for Vacuum Heating

Building No. 3, Room 208.



This furnace can be used to heat and melt samples at a high temperature (up to 1900 °C) using a tungsten mesh heater in vacuum.

ULVAC: FHW-50-special specification (1971)

3-8 High-Frequency Induction Furnace

Multi-Use laboratry, Room 104

This furnace is capable of melting quantities of various metals (1 kg in the case of iron) in a high vacuum of 2.0×10^{-3} Pa. The charged metals are melted in an appropriate crucible in vacuum or an inert gas atmosphere; they are then cast into a mold by inclining the crucible. The furnace can be used to prepare ingots of raw metals, mother alloys, and metallic glasses.

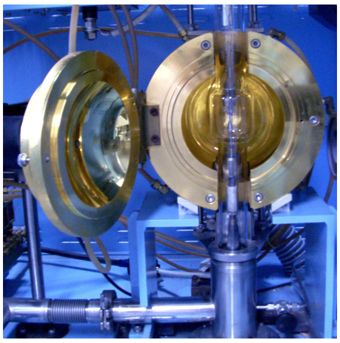
DIAVAC: VMF-1-11 (2004)

3-9 High-Temperature Floating Zone Furnace for Composite Ceramics

Building No. 2, Room B08.

This equipment can be used to heat and melt samples at a high temperature (up to above 2000 °C) using a xenon lamp heating system without a crucible. The equipment is used extensively for single-crystal growth and ceramic synthesis at a high melting temperature.

Asukaru: FZ-20065XHVG (1998)



3-10 Conventional-Type Arc-Melting Furnace

Building No. 3, Room 203.

The arc-melting furnace can melt charged materials and fabricate polycrystalline material ingots. The material is melted by means of an electrical arc, which is generated conventionally by a power of 2 to 6 kW. It is used extensively to melt and cast metals, alloys, intermetallic compounds, and some oxides, by increasing the temperature to above 3,000 °C.

DIAVAC: ACM-01 (1986)

3-11 Arc-Melting Furnace with Horizontal Traveling Hearth

Building No. 3, Room 203.

This arc-melting furnace exhibits a performance similar to that of a conventional furnace (such as the one listed in 3-10). In addition, the furnace is attached with a system that shifts the copper hearth horizontally at a speed of 5–60 mm/h. Therefore, it can fabricate long rod-shaped specimens with elongated and coarsened grains.

DIAVAC: ACM-S-6 (1985)

3-12 Programmable Furnace with $MoSi_2$ Heater

Building No. 3, Room 116.

This furnace, which is equipped with a $MoSi_2$ heater, can heat up to a maximum temperature of 1600 °C in air. The furnace can also be used for the synthesis of complex oxides by reaction sintering and for the fabrication of various sintered compacts.

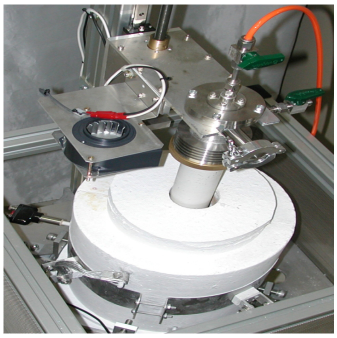
NECCO: 850-M-120×120 (1998)

3-13 Programmable Furnace for Flux Growth

Building No. 3, Room 117.

This furnace is used for the flux growth of single-crystalline compounds. It can be used to prepare fine single-crystals by controlling heat under a flowing gas atmosphere.

IZUMI TEC: IZU-KGSS-1500 (2008)



3-14 μ -PD Apparatus for Small-Diameter Crystal Growth

Building No. 3, Room 208.

The materials charged in a crucible are melted by a high-frequency induction heating system. The bottom of the crucible has a hole with a size of several millimeters, and the charged material is drawn down slowly after contacting a seed crystal. Thus, the apparatus can form a single-crystalline material on a thin stick with a diameter of several millimeters. The cross-section of the stick-shaped single-crystal can be controlled by changing the shape of the hole at the bottom of the crucible.

TDK: μPD-HT (2006)