◆Department of Metallurgy and Ceramics Science

1. Program Outline

This graduate school program provides study course to educate high skill experts having fundamental and application knowledge and technology, regarding research and development of metal and ceramics for creation of innovative structural and functional materials.

2. Course Outlines and Faculty

This course aims to build up the ability of followings;
to extract and appreciate the essence of scientific and technological problems;
to make use of expertise to solve the problems with creativeness;
to appreciate and systemize the international R&D trends for materials;
to logically explain, write and make discussion in both Japanese and English.

3. Guide to Study in Department of Metallurgy and Ceramics Science

- **Deepening the special knowledge with wide scope and literacy of science.**
- **Acquisition of the ability to set up creative issues and give the original solutions.**
- **Training the logical expression and communication in both Japanese and English.**
- **Cultivation of fundamental liberal arts.**

4. Graduation Requirements

Department of Metallurgy and Ceramics Science

【Master's degree】

- 34 credits or more from the Graduate school courses.
- Research Courses (研究科目群)
  (1) 4 credits from the Seminar Courses (講究科目)
  (2) 3 credits from the Graduate Research Courses (研究関連科目)
- Courses by Departments (専門科目群)
  (1) 12 credits or more from the Departmental Courses (専攻専門科目)

(2) 2 credits or more from the Courses in Other Departments (他専門科目)・2 credits or more from the Liberal Arts and General Education(G) (大学院教養・共通科目群)

- The student must complete a mater thesis research, submit a thesis for the degree and take and pass the final examination given after the submission of her/his thesis for the qualification.

【Doctoral degree】

(1) Seminar in each term must be taken.
(2) If the student enrolls the Integrated Doctoral Educational Program, one Off-Campus Project is required to complete.
(3) The candidate must complete and upload a thesis for the degree, and take the final examination and evaluation of his/her thesis.

The candidate who satisfies the above requirements and passes the final examination is awarded a Doctoral degree.

Students should consult with their own supervisors about the study plan.

4. Tables of Courses

Research Courses (研究科目群)

Course Number	Remarks* (See footnotes)	Course	Department Offering course**	Credit	Semester S: Spring A:Autumn	Opening year a: Annually e: Even o: Odd
24701 -24704	◎	Seminar in Materials Science and Technology I-IV	MCS	0-1-0		a
24801 -24806	◎	Seminar in Materials Science and Technology V-X	MCS	0-2-0		a
24705 -24708		Materials Research Methodology I-IV	MCS	0-1-0		a

Courses by Departments (専門科目群)

Course Number	Remarks (See footnotes)	Course	Department Offering course*	Credit	Semester S: Spring A:Autumn	Opening year a: Annually e: Even o: Odd
Departmental Courses (専攻専門科目)						
24042	B★□	Thermodynamics for Metallurgists	MCS	2-0-0	S	a
24002	B★□	Applied Diffraction Crystallography in Metals and Alloys	MCS	2-0-0	S	a
19066	I★□	Environmental Degradation of Materials	CMS	2-0-0	A	a
24010	A★□	Microstructure of Metals and Alloys	MCS	2-0-0	A	a
24006	B★□	Physical Chemistry of Melts	MCS	2-0-0	A	a
24008	A★□	Phase Transformation in Solids	MCS	2-0-0	A	a
24043	B★□	Advanced Metal Physics	MCS	2-0-0	A	a
24055	B★□	Transport Phenomena of Metallie Materials	MCS	2-0-0	A	a
96047	A★□	Science & Engineering of Solidification	MSE	2-0-0	S	e
96048	A★□	Characteristics & Applications of Intermetallic Alloys	MSE	2-0-0	S	e
96049	B★□	Lattice Defects & Mechanical Properties of Materials	MSE	2-0-0	A	e
96050	B★□	Diffusion in Alloys	MSE	2-0-0	A	e
97036	A★	Phase Diagram and Related Thermodynamics	IMS	2-0-0	S	e
97017	B★	Crystallography for Microstructural Characterization	IMS	2-0-0	A	a
96055	A★□	Advanced Course in Design and Fabrication of Micro/Nano Materials	MSE	2-0-0	A	o

24047	B/I★	Degradation of Infrastructure	MCS	1-0-0	A	o
24051	B/I★	Science of Materials	MCS	1-0-0	A	e
24501	A	Special Lecture on Metallurgical Engineering A I	MCS	1-0-0	S	o
24502	A	Special Lecture on Metallurgical Engineering A II	MCS	1-0-0	S	e
24034	A	Characterization of Nano-materials	MCS	2-0-0	A	a
24045	B	Advanced Metallurgical Engineering Laboratory	MCS	0-0-4	A	a
24050	B	Advanced Course in Wettability Control of Solid Surface	MCS	2-0-0	S	o
24053	B	Advanced Course of Nano-Bionics	MCS	2-0-0	S	e
71052	B	Nuclear Materials Science	NE	2-0-0	A	e
24521	I	Materials Off-Campus Project I	MCS	0-0-4	S	a
24522	I	Materials Off-Campus Project II	MCS	0-0-4	A	a
24056	B#	Specific interdisciplinary Subject in Materials Science and Engineering A*	MCS	0-2-0	S	a
24057	B#	Specific interdisciplinary Subject in Materials Science and Engineering B*	MCS	0-2-0	A	a
28011	□	Interdisciplinary Energy Materials Science	ACEEES	2-0-0	A	a
Courses in Other Departments (他専攻科目)						
		Special subjects in other departments in addition to the above subsidiary subjects				

Footnotes:

B: Basic, A: Applied, I: Interdisciplinary

- Subjects marked with ◎ should be compulsorily mastered by getting the credit.
- Subjects marked with ★ are given in English biannually and acceptable for the credits of International Graduate Program. (One cannot get both credits of these subjects alternately given in Japanese and English)
- Subjects marked with □ are acceptable for the credits of ACEEES.
- Subjects marked # can only be registered by the students of the ACEEES, In order to promote interdisciplinary research on campus, students are required to take/register courses provided by designated other majors/programs rather than their own majors/programs.
- Students admitted to enroll the ACEEES should read the indication in the URL as follows; HP http://www.gakumu.titech.ac.jp/kyoumu/curriculum/guide.html

* MCS: Dept. Metallurgy and Ceramics Sciences
CMS: Dept. Chemistry and Materials Science
MSE: Dept. Materials Science and Engineering
IMS: Dept. Innovative Material Science
NE: Dept. Nuclear Engineering
ACEEES: Academy for Co-creative Education of Environment and Energy Science

Liberal Arts and General Education(G) **(大学院教養・共通科目群)**

	Remarks
International Communication(G) **((大学院国際コミュニケーション科目)** **Interdisciplinary Courses**(G) **(大学院総合科目)** **Interdepartmental Courses**(G) **(大学院広域科目)** **Arts and Humanities**(G) **(大学院文明科目)** **Carrier Development Courses**(G) **(大学院キャリア科目)** **Courses for Developing Creativity**(G) **(大学院創造性育成科目)** **Courses for International Students**(G) **(大学院留学生科目)**	Refer to VI.Liberal Arts and General Education

5. Syllabus of Course Subjects

24042

Thermodynamics for Metallurgists

Spring Semester (2-0-0) (Even Years)

Assoc. Prof. Kenichi Kawamura

[Aims]

Thermodynamics is a powerful tool for the material processing and design. This lecture provides the understanding of the thermodynamics from the basics to the applications, and extends to the defect chemistry in solid oxide.

[Outline]

1. Introduction
2. Basics of thermodynamics
3. Gibbs energy
4. Phase diagram and rule
5. Activity
6. Chemical reaction
7. Thermodynamic table
8. Measurement for thermodynamic data
9. Crystal defects
10. Solid state ionics
11. Application of solid state ionics I
12. Application of solid state ionics II

24002

Applied Diffraction Crystallography in Metals and Alloys

Spring Semester (2-0-0) (Odd Years)

Prof. Yoshio Nakamura

[Aims]

Fundamentals of crystallography and structural characterization by diffraction technique are introduced especially to students who study metallurgy.

[Outline]

1. Symmetry description of crystal
2. How to describe structure of crystals
3. Crystal symmetry and physical properties
4. Ordered structure and modulated structure
5. Diffraction from ideal and imperfect crystals
6. X-ray and Electron diffraction techniques for structural analysis and characterization

19066

Environmental Degradation of Materials

Autumn Semester (2-0-0)(Odd Years)

Prof. Atsushi Nishikata and Assoc. Prof. Eiji Tada

[Aims]

Based on electrochemistry and surface chemistry, the class offers analytical methods to be applied for degradation mechanisms and its prevention of infrastructural and functional materials in various environments.

[Outline]

1. Electrochemistry of Corrosion
   - 1.1 Basics of electrochemistry, Electrochemical equilibrium, Standard electrode potential, Potential-pH diagram
   - 1.2 Kinetics of electrochemistry, Butler-Volmer equation, Exchange current density, Overpotential
   - 1.3 Mixed potential theory, Corrosion potential, Corrosion current, Polarization curve
   - 1.4 Anodic dissolution mechanism: Anodic dissolution of metals and alloys
2. Practical Corrosion and Degradation of Materials
   - 2.1 Forms of corrosion, Classification of corrosion, Evaluation methods
   - 2.2 Determination of corrosion, Measurement of corrosion rate
   - 2.3 Passivity and passive films, Characteristics of passive films
   - 2.4 Degradation of stainless steel, Localized corrosion, Pitting and crevice corrosion
   - 2.5 Stress corrosion cracking (SCC), Environmental brittlement (HE, CF)
3. Environmental Degradation of Materials
   - 3.1 Novel corrosion resistant materials
   - 3.2 Degradation of electronic devices and materials
   - 3.3 Degradation of infrastructure and its evaluation
   - 3.4 Novel methods for evaluation and measurement of materials degradation

24010

Microstructures of Metals and Alloys

Autumn Semester (2-0-0) (Odd Years)

Prof. Tatsuo Sato

[Aims & Outline]

Characteristics and formation mechanisms of various microstructures of metals and alloys produced during fabrication processes such as cast/solidification, plastic deformation and heat treatments are comprehensively introduced. The fundamental correlation between microstructures and mechanical properties is discussed. The topics on the advanced materials are also introduced.

24006

Physical Chemistry of Melts

Autumn Semester (2-0-0) (Odd Years)

Prof. Masahiro Susa and Assoc. Prof. Yoshinao Kobayashi

[Aims]

This lecture mainly centers upon thermodynamics of metal, its oxide melts and metal production process. The term of ‘melts’ essentially means what the term of ‘liquid’ does and is often used, in particular, when one refers to the state of substances which are melted at high temperatures. In this usage, for example, liquid iron is a kind of melt but liquid water is not. Many metallic materials are produced via the state of melts and thus understanding of physico-chemical properties of melts is essential to metallic materials process designing and its optimization. This lecture ranges from fundamental to applied thermodynamics relevant to metals. The final goal is to learn how to use the concept of activity and how to utilize thermodynamic laws and functions, through many exercises. Moreover, this lecture consequently aims to understand the thermodynamic treatment on the practical production process.

[Outline]

1. Basic Thermodynamics
   First law, Internal energy and enthalpy, Second law, Entropy, Third law, Gibbs energy and chemical potential, Chemical equilibria and phase rule, Ellingham diagram
2. Activity
   Law of mass action and concept of activity, Raoultian and Henrian standard activities, Henrian activities by mole fraction and mass% expressions, Interaction parameters, Basicity
3. Solution theory, interaction parameter, solubility product, the Gibbs-Duhem equation, impurities capacity

24008

Phase Transformations in Solids

Autumn Semester (2-0-0) (Even Years)

Prof. Masao Takeyama

[Aims]

Physical and mechanical properties of metals and alloys are directly associated with their microstructures, so it is very important to understand how to control the microstructures through phase transformations. This course of lectures covers the fundamental mechanisms of solid/solid phase transformations and microstructure evolution in ferrous and other materials.

[Outline]

1. Introduction -Basics for studying phase transformations-
   1-1 Thermodynamics and Phase diagrams
   1-2 Diffusion
   1-3 Diffusional Transformations in solids
   1-4 Diffusionless Transformations in solids
2. Microstructures and Phase transformations in Ferrous Materials
   2-1 Phase transformations in iron
   2-2 Pearlite
   2-3 Bainite
   2-4 Martensite
3. Microstructures of Other alloys
   3-1 Titanium and titanium alloys
   3-2 Nickel base alloys
4. Phase transformations in Intermetallics
   4-1 Order/disorder transformations
   4-2 Ordering and Phase Separation

24043

Advanced Metal Physics

Autumn Semester (2-0-0)

Prof. Ji Shi

[Aims & Outline]

This course is designed to introduce first-year graduate students to the fundamentals and recent developments in solid state physics, especially in relation to metals and alloys. Emphasis is placed on the electronic structures of solids and related properties. Starting from introductory quantum mechanics, the course covers following topics: atomic structure, bonds in metallic and nonmetallic solids, band structure and semiconductors, transition metals and ferromagnetism, physics and applications of thin solid films.

24055

Transport Phenomena of Metals and Alloys

Autumn Semester (2-0-0) (Even Years)

Assoc. Prof. Miyuki Hayashi

[Aims]
The lecture focuses on the basic transport phenomena such as flow pattern of liquid, mass and heat transport in liquid and solid and reaction rate at the interface between different phases, which can be seen in the metal smelting, the production process of electrical materials and so on.
[Outline]

1. Introduction
2. Mass transport
    1) Fick's law of diffusion
    2) Shell mass balances and boundary conditions
    3) Steady-state diffusion
    4) Nonsteady-state diffusion
3. Momentum transport
    1) Newton's law of viscosity
    2) Navier-Stokes equation
    3) Laminar flow and turbulent flow
    4) Friction factors
4. Energy transport
    1) Fourier's law of heat conduction
    2) Shell energy balances and boundary conditions
5. Dimensional analysis
    1) Buckingham's pi theorem
    2) Dimensionless numbers for forced convection and free convection
    3) Dimensionless number for heat conduction
6. Macroscopic balances
    1) Isothermal systems
    2) Nonisothermal systems
    3) Bernoulli equation

96047

Science and Engineering of Solidification

Spring Semester (2-0-0) (Even Years)
Prof. Shinji Kumai
[Aims & Outline]
The present lecture provides a fundamental knowledge of solidification, from the scientific to the engineering point of view, covering the recent development and future prospects. Basic concepts of driving force for solidification, undercooling, local equilibrium, and interface non-equilibrium are described. A detailed explanation is also made about dendritic and eutectic growth, as well as of peritectic, monotectic and behavior of third phase.

96048

Characteristics and Applications of Intermetallic Alloys

Spring Semester (2-0-0) (Even Years)
Assoc. Prof. Yoshisato Kimura
[Aims & Outline]
Intermetallic compounds provide very different physical and chemical properties due to a wide variety of their ordered crystal structures. Starting from fundamental characteristics of intermetallic compounds strongly depending on their ordered structures, advanced applications both for structural and functional are covered with considering strategies for the material design.

96049

Lattice Defects & Mechanical Properties of Materials

Autumn Semester (2-0-0) (Even Years)

Prof. Susumu Onaka and Prof. Masaharu Kato

[Aims & Outline]

Lattice defects and their role on mechanical properties of solid materials are lectured. Topics such as linear elasticity (stress, strain, Hooke's law) and dislocation theory are included.

96050

Diffusion in Alloys

Autumn Semester (2-0-0) (Even Years)

Prof. Masanori Kajihara

[Aims]

Evolution of microstructure occurs in many alloy systems at elevated temperatures. Such a phenomenon is usually controlled by diffusion. On the basis of Fick's first and second laws, diffusion can be described mathematically. In the present lecture, various mathematical methods describing diffusion will be explained in detail.

[Outline]

1. Introduction
2. Fick's first law
3. Fick's second law
4. Analytical solution of diffusion equation
5. Application of analytical solution to various problems
6. Boltzmann-Matano analysis
7. Darken's analysis
8. Migration of interface

97036

Phase Diagram and Related Thermodynamics

Spring Semester (2-0-0) (Even Years)

Prof. Hideki Hosoda and Assoc. Prof. Tomonari Inamura

[Aims & Outline]

The phase diagrams are the key and the map for seeking and creating new metal-base materials. This lecture provides comprehensive understanding of alloy phase diagram in the binary and ternary systems through studying the phase reaction, phase rule, Gibbs free energy and related topics. Practice is provided in each class to develop understanding.

97017

Crystallography for Microstructural Characterization

Autumn Semester (2-0-0)

Prof. Toshiyuki Fujii

[Aims & Outline]

This class offers methods of determining the crystal structure and characterizing the microstructure of metals. Students will learn about the basic crystallography, stereographic projection, x-ray and electron diffraction, and electron microscopy. Quizzes are given out to the students in every class.

96055

Advanced Course in Design and Fabrication of Micro/Nano Materials

Spring Semester (2-0-0) (Odd Years)

Assoc. Prof. Masato Sone

[Aims]
Fundamentals of design and fabrication of micro/nano materials are introduced especially to students who study materials chemistry.
[Outline]

1. Principle & classification of micro/nano materials
2. Fabrication method, properties and applications of nano particle
3. Fabrication method, properties and applications of nano tube
4. Designs & Fabrication method of molecular machine
5. Bottom up method of nanotechnology
6. Top down method of nanotechnology
7. Problems of nanotechnology into industry

24047

Degradation of Infrastructure

Autumn Semester (1-0-0) (Odd Year)
Prof. Hiroshi KIHIRA, Dr. Tomonori TOMINAGA, Dr. Takanori NISHIDA and Dr. Takuyo KONISHI
[Aims]
Infrastructures as social capital founded in the period of high growth in Japan are being faced with severe degradation without appropriate maintenance and updating through the years of low growth and economic stagnation. The potential danger is eminent. On the other hand, developing and emerging countries in Asia urgently needs growing equipment of infrastructure. In this lecture, industrial experts in the front line of the field of material and civil engineering will introduce the present situation of degradation of infrastructure and the development of countermeasure technology in Japan, Europe and United States, as well as give a perspective of upcoming technologies in this field.

24051

Science of Materials

Autumn Semester (1-0-0) (Even Years)
Dr. Shiro TORIZUKA, Dr. Toshiyuki KOYAMA, Dr. Akihiro KIKUCHI, Dr. Eiji AKIYAMA
[Aims]
This course aims at introducing various materials in the aspect of science through many topics drawing attentions in developing high performance materials in the field of infrastructure, energy and environmental conscious materials, combined with computational simulation. The following four topics related to innovative materials and creation process are selected to provide fundamental knowledge and broad interest in the science of materials.

1. Cutting edge of ultra steels with high performance
2. Thermodynamics and kinetics for computational materials design
3. Evolution of superconductive materials
4. Development of anti-corrosion materials

24501, 24502

Special Lecture on Metallurgical Engineering A Ⅰ (Odd Years)

Special Lecture on Metallurgical Engineering A Ⅱ (Even Years)

Spring Semester (1-0-0)

This course aims to provide a wide perspective and depth of technologies related to metallurgical engineering which covers a broad spectrum of materials and processes by introducing fundamental research and industrial development of state-of-the-art.

24034

Characterization of Nano-materials

Autumn Semester (2-0-0)

Prof. Yoshio Nakamura and Prof. Ji Shi

[Aims & Outline]

This course provides fundamentals on characterization of nanomaterials and nanostructured materials. This class will be given at Tsinghua University.

24045

Advanced Metallurgical Engineering Laboratory

Autumn Semester (0-0-4)

[Aims & Outline]

The present lecture provides a chance to understand the physical, chemical and mechanical properties of metallic materials through the basic experiments, which include age hardening of aluminum alloys. Heat treatment of ferrous alloys, tensile properties, corrosion behavior, steel making, and so on.

24050

Advanced Course in Wettability Control of Solid Surface

Spring Semester (2-0-0) (Odd Years)

Prof. Akira Nakajima

[Aims]

Wettability has been a research subject at the border between physics and chemistry, and is an important property of solid surface from both fundamental and practical aspects. This course provides fundamentals on surface wettability control for the understanding of surface phenomena and the designing surface functions of solids. Topics include environmental purification and energy saving by surface functional materials.

[Outline]

1. Introduction
2. Fundamentals of solid surface
3. Surface energy and contact angle (1)
4. Surface energy and contact angle (2)
5. Surface structure and wettability (1)
6. Surface structure and wettability (2)
7. Sliding of liquid droplets (1)
8. Sliding of liquid droplets (2)
9. Dynamic wettability
10. Anti-snow adhesion
11. Materials for wettability control and their coating technology
12. Superhydrophobicity
13. TiO_2 photocatalyst
14. Research proposal presentation (students)

24053

Advanced Course of Nano-Bionics

Spring Semester (2-0-0) (EVEN Years)

Assoc. Prof. Toshiyuki IKOMA

[Aims]

This course provides complex phenomena/theories of material surfaces in biological tissues, based on surface designs and applications for biomedical devices, and advanced technologies of tissue engineering for bone, cartilage, nerve, and cornea, based on the expression of cell function on bioceramics from inorganic and organic interfacial

interactions.
[Outline]
1. History of biomedical devices
2. Biomimetic materials
3. Structure of bio-minerals
4. Surface design of biomaterials
5. Interfacial interaction of materials and cells
6. Methodology of drug delivery carriers
7. Preparation and application of nanoparticles
8. Biological reaction of nanoparticles
9. Detection of biomolecules based on materials
10. Microfluidics for diagnostics
11. Materials science for collagen
12. Scaffolds for tissue engineering
13. Application of bioceramics (I): bone and cartilage
14. Application of bioceramics (II): nerve and cornea
15. Toward to application of biomedical devices

71052

Nuclear Materials Science

Autumn Semester (2-0-0) (Even Years)

Prof. Toyohiko YANO

[Aims]

This is the only lecture concerning materials issues, including nuclear fuels and incore materials, of nuclear fission and fusion reactors. The basis is materials science. The topics including are: manufacturing methods of nuclear fuels, structures of fuels and fuel elements, moderators, control materials, blanket materials, and structural materials. Another emphasis is put on fundamentals of radiation damage and irradiation effects of nuclear reactor materials.

[Outline]

1. Components of LWR, HWR, LMFBR reactors and material selection
2. Radiation Damage of Materials
3. Physical and Chemical Properties of U, UO_2, and PuO_2
4. Fabrication Process of Nuclear Fuels
5. Fission and Fusion Reactor Materials

24521, 24522

Materials Off-Campus Project I, II

Spring and Autumn Semesters (0-0-4)

[Aims & Outline]

This course is designed to experience the research and/or production in the material companies. The knowledge of metallurgy studied in Tokyo Tech is expected to utilize in the companies during this internship program.

24056, 24057

Specific interdisciplinary Subject in Materials Science and Engineering A, B

Spring and Autumn Semesters (0-2-0)

Prof. Masao TAKEYAMA・Prof. Ji SHI・Prof. Jeffrey S. CROSS

Microstructure design is a key concept to impart specific physical/mechanical properties into substrates, and bring about technology breakthroughs relating to fundamental energy and environmental issues. This exercise/drill course utilizes a self-study approach on this subject for students seeking to broaden their knowledge on materials and to help acquire sufficient problem-solving skills to conduct research on structural and functional materials in

metallurgy and ceramics science.

24701-24704

Seminar in Materials Science and Technology I-IV

Spring and Autumn Semesters (0-1-0)

24801-24806

Seminar in Materials Science and Technology V-X

Spring and Autumn Semesters (0-2-0)

[Aims and scope]

Colloquium on topics relating to each specialty by means of reading research papers and books, and Discussion with each supervisor and course coordinator

24705-24708

Materials Research Methodology I - IV

Spring and Autumn Semesters (0-1-0)

[Aim & Outline]

These lectures aim to give students research methodology on materials science and engineering. Through Parts I and II students will understand the background and objectives of their master thesis researches mainly based upon industrial and scientific trends and will be able to explain them logically. Through Parts III and IV students will achieve competency for oral presentation and thesis-writing.