[Title]			[Instructor]		
Advanced Condensed Matter Physics			Akira Ishikawa/ Atsushi Shohji		
[Code]	[Credits]	[Program]	[Semester]	[Hours]	[Language of instruction]
GTZ501	2	Advanced Material Science	1st Semester	Mon.／II	Japanese/English

[Outline and purpose]

This course, which is based on electrodynamics, quantum mechanics, statistical mechanics, condensed matter physics, and group theory, deals with quantum field theory, thermal-equilibrium and nonequilibrium statistical physics, and photonic phenomena in solid-state materials. The essence of the theories and experiments will be systematically lectured for deeper understanding of solid-state materials.

[Objectives]

1. to understand the overview of the interaction between light and matter
2. to understand the semiclassical theory of the interaction between light and matter
3. to understand the full-quantum theory of the interaction between light and matter
4. to understand group theory
5. to understand coupling of angular momentum in solid state materials
6. to understand conservation of angular momentum

[Requirements]

electrodynamics, quantum mechanics, solid state physics, statistical mechanics

[Evaluation]

homework/examination：100 %

[Textbooks]

[References]

Charles Kittel, “Quantum Theory of Solids” (John Wiley & Sons, Inc., NY, 1963)
Kenichi Asano, “Quantum Theory of Electrons in Solids” (University of Tokyo Press, Tokyo, 2019)
George F. Koster, John O. Dimmock, Robert G. Wheeler, and Hermann Statz, “Properties of the thirty-two point groups ” M.I.T press.

[Schedule]

1. Optical response (A. Ishikawa)
2. Interaction between light and atom (A. Ishikawa)
3. Interaction between light and semiconductor (A. Ishikawa)
4. Quantization of electromagnetic field and photons (A. Ishikawa)
5. Interaction between photon and matter (A. Ishikawa)
6. Stimulated and spontaneous emissions (A. Ishikawa)
7. Polariton (A. Ishikawa)
8. Coupling of angular momentum and Clebsch–Gordan coefficients (A. Shohji)
9. Selection roles of excitons and Raman scattering for semiconductors (A. Shohji)
10. LS coupling excitons (A. Shohji)
11. j-j coupling excitons (A. Shohji)
12. Energy shift and splitting of exciton states by external magnetic field (A. Shohji)
13. Spatial mode of light (A. Shohji)
14. Interaction between forbidden excitons and light with spatial modes (A. Shohji)
15. Summary of condensed matter physics

[Title]	[Instructor]
Advanced Quantum Devices	Keisuke Arimoto/ Kazuharu Uchiyama

[Code]	[Credits]	[Program]	[Semester]	[Hours]	[Language of instruction]
GTZ502	2	Advanced Material Science	2nd Semester	Tue.／Ⅱ	Japanese

[Outline and purpose]

In this program, bases of quantum mechanics and solid state physics are summarized, and then principles of devices which utilize quantum effects (e.g. semiconductor heterostructure devices) are lectured. The physical and engineering bases are provided for analysis and design of functionalities in novel devices and systems based on the interdisciplinary sciences of electronic and electromagnetic dynamics including quantum mechanical features through transport of signal and information in non-equilibrium open system as well as the underlying fundamental processes.

[Objectives]

Obtaining knowledge of the following items is the objective of this program.
(1) Fundamentals of quantum mechanics (e.g. states of electrons confined in quantum wells)
(2) Principles of functionality based on interaction in nanostructured devices including local environment

[Requirements]

Basic knowledges about quantum mechanics and solid-state physics are desirable.

[Evaluation]

Level of understanding is evaluated by small tests, reports and term-end examination.

[Textbooks]

[References]

Jasprit Singh, “Electronic and Optoelectronic Properties of Semiconductor Structures” (Cambridge University Press)

[Schedule]

1 Basics of quantum mechanics and classical/quantum statistical mechanics
2 Electronic states in solids
3 Quantum size effect
4 Band structure
5 Electron and current densities in nano-structures
6 Effective mass approximation
7 Transition probability and optical properties (absorption/emission) of materials
8 Phenomena and observations as the basis of functionality
9 Construction of quantum mechanical functionality
10 Thermodynamics basis for transport processes in non-equilibrium open system
11 Dynamics of environment as the basis of functionality
12 Phenomenology and mathematics for functionalities
13 Quantum optical devices based on laser and optical processes
14 Optoelectronics devices and quantum mechanical features
15 Summary and assessment

[Title]	[Instructor]
Advanced Photonics	Tetsuo Harimoto / Masaru Sakai

[Code]	[Credits]	[Program]	[Semester]	[Hours]	[Language of instruction]
GTZ503	2	Advanced Material Science	1st Semester	Fri.／II	Japanese

[Outline and purpose]

To pursue understanding of optics and related basic principles investigated with optoelectronics and optical devices.

[Objectives]

To acquire following basic knowledge of optics and photonics as they relate to forefront research of novel opto- and photo-electronic devices.

(1) Wave-particle duality of light
(2) Propagation, interference, and diffraction of light
(3) Optical semiconductors
(4) Nonlinear optics
(5) Basic principles of the laser

[Requirements]

Wave theory, Electromagnetics, Elementary quantum mechanics, Mathematics.

[Evaluation]

Homework / Examination : 80%
Audit attitude : 20%

[Textbooks]

[References]

1. A. Yariv, Photonics: Optical Electronics in Modern Communication, Oxford Univ. Pr., ISBN: 0195179463
2. A. Furusawa, Quantum optics and quantum information science, Saiensu-sha Co., Ltd. Publishers, ISBN:4901683233 (in Japanese)
3. M. Matsuoka, Quantum Optics, Shokabo Co., Ltd., ISBN:4785320935 (in Japanese)

[Schedule]

1. Light wave and Maxwell's equations
2. Propagation of light in materials
3. Total internal reflection and evanescent field
4. Polarization of light and polarization conversion
5. Lens and image formation
6. Gaussian beam optics
7. Light interference, multilayers and anti-reflective coating
8. Basic laser principles
9. Generation of ultrashort laser pulses
10. Amplification of lasers
11. Control and detection of ultrashort and high intensity laser beams
12. Lasers devices: laser diode, all-solid-state lasers, and high-power lasers
13. Applied laser technologies: high-accuracy measurement and nanotechnology
14. Applied laser technologies: fine processing and nuclear fusion
15. Summary and assessment

[Title]	[Instructor]
Lectures on Advanced Electronics	Hatsuhiro Kato / / Kaoru Ijima

[Code]	[Credits]	[Program]	[Semester]	[Hours]	[Language of instruction]
GTZ504	2	Advanced Material Science	2st Semester	Mon.／II	Japanese

[Outline and purpose]

As a fundament of device properties and its circuitization, the technique such as Kirchhoff's law is lectured to analyze electronics circuits. The integration of devices and the design concept for making them to work as a system are also discussed. We shall promote understanding of applications and programs that can serves for an effective use of the system, control of experiment equipment and efficient analysis of experiment data.

[Objectives]

1) Confabulation of basic circuits and analyzing their characteristics.
2) Design of memory system by regarding the bit configuration and the interface.
3) Program concept for the basic application exploiting advantages of system characteristics.

[Requirements]

Semiconductor materials, Electromagnetism, Basics of programming

[Evaluation]

1) Examinations in occasions and/or term ends (50%)
2) Report and its illustration details (50%)

[Textbooks]

[References]

Simon. M. Sze, Physics of Semiconductor Devices, Wiley (ISBN:0-471-05661-8)

[Schedule]

(Element technology)
1. Circuit network and analysis method
2. Passive element
3. Active devices (saturation region)
4. Transient response
5. Calculation of network (input/output impedance)

(Integration Technology)
6. Material properties and lithography technology
7. Elemental technology 1 (current mirror and sense amplifier)
8. Element technology 2 (frequency characteristic)
9. SRAM memory cells and block configuration
10. System design and its evaluation

(System Technology)
11. System and its control
12. Experimental system and the numerical calculation system
13. Program technology 1 (OS and software)
14. Program Technology 2 (Practical System)
15. Summary and Evaluation

[Title]	[Instructor]
Advanced Quantum Material Science	Masanori Nagao / Tetsuya Sato/ Kosuke Hara

[Code]	[Credits]	[Program]	[Semester]	[Hours]	[Language of instruction]
GTZ505	2	Advanced Material Science	1st Semester	Thu.／II	Japanese/English

[Outline and purpose]

This course deals with electrical transport properties of solid-state materials, solar cell materials, and gas-based microfabrication technologies including lithography as well as property changes upon miniaturization. The contents cover dye sensitized solar cell and electrical transport properties, as the basis for material characterization, and fabrication and testing for electronic devices.

[Objectives]

1. to understand the electrical transport properties of solid-state materials
2. to understand the fundamental principles of plasma discharges
3. to understand the gas- and surface-phase chemical reactions
4. To be able to explain the principle of solar cells.
5. To be able to select materials with suitable physical properties for solar cells.

[Requirements]

Physical Chemistry, Quantum Chemistry, Electromagnetism, Solid State Physics or Semiconductor Physics

[Evaluation]

examination : 25 %
homework : 25 %
audit attitude : 25 %
presentation : 25 %

[Textbooks]

[References]

1) Michael A. Lieberman, *Principles of Plasma Discharges and Materials Processing, 2nd Edition,* Wiley-Inter science , ISBN: 978-0-471-72001-0

[Schedule]

1. Basis of electrical transport properties
2. Metal
3. Semiconductor and insulator
4. Superconductor
5. Other topics of electrical transport properties
6. What is discharges and plasma?
7. Principles of plasma discharges
8. Interaction of the plasma and the solid surface
9. Fabrication of thin films and nanostructure using plasma processes
10. Characterization of thin films and nanostructure
11. Principles of operation of solar cells
12. Output characteristics and efficiency limiting factors of solar cells
13. Semiconductor and metallic materials used in solar cells
14. Transparent conducting and optical materials used in solar cells
15. Fabrication processes of materials used in solar cells

[Title]	[Instructor]
Advanced Functional Materials	Isao Tanaka / Takahiro Takei / Eiichi Kondoh

[Code]	[Credits]	[Program]	[Semester]	[Hours]	[Language of instruction]
GTZ506	2	Advanced Material Science	2nd Semester	Tue.／I	English／Japanese

[Outline and purpose]

Synthesis and crystal growth techniques for solid state materials are acquired on the base of phase equilibrium in this course. Also crystal chemistry and characterization for solid state materials are acquired. For various synthesis processes, the mechanism and their theories are acquired.

[Objectives]

1. to understand relationship between defect concentration and physical properties by lattice defect formation in crystalline materials
2. to understand formation mechanism in various synthesis processes for solid state materials
3. to gain ability to use binary phase diagrams

[Requirements]

inorganic chemistry, solid state chemistry, materials engineering, physical chemistry, electronic physical properties

[Evaluation]

homework/ examination：70%
audit attitude：10%
presentation：20%

[Textbooks]

Anthony R. West, Solid State Chemistry and Its Applications, Second Edition, JOHN WILEY & SONS, LTD, ISBN:978-1-119-94294-8

[References]

[Schedule]

1. Function and property by crystal defects
2. Non-stoichiometry and lattice defects in oxides
3. Defect concentration and defect equilibrium
4. Relationship between defect concentration and electrical conductivity
5. Interim summary I
6. Synthesis of inorganic materials by solid state reaction
7. Sol-gel synthesis of inorganic materials
8. Synthesis by hydrothermal and solvothermal reactions
9. Thin film preparation by gas phase reaction
10. Solid-liquid interface & Interim summary II
11. Phase rule and phase diagram
12. Phase diagram and microstructures
13. Solid-liquid interface and its equilibrium
14. Basic theories of solution chemistry and phase diagram
15.Nucelation and crystal growth . Summary

[Title]	[Instructor]
Structure and Chemistry of Crystalline Solids	Junji Yamanaka / Satoshi Watauchi / Yonezaki Yoshinori

[Code]	[Credits]	[Program]	[Semester]	[Hours]	[Language of instruction]
GTZ507	2	Advanced Material Science	2st Semester	Thu.／II	Japanese/English

[Outline and purpose]

There are three important purposes in this lecture:
1. For a better understanding of physical properties of crystals, the concepts of symmetry operations are lectured from the viewpoint of group theory.
2. To investigate physical properties of crystals, a bulk crystal is very useful. The concepts of nucleation mechanism are also lectured.
3. We will also learn reciprocal space, electron diffraction, and transmission electron microscopy.

[Objectives]

To image structural features from point group notations
To understand the nucleation mechanism based on the thermodynamics
Comprehension of electron diffraction.

[Requirements]

Basic knowledge on physical chemistry and solid state chemistry.
Completion of undergraduate course covering basic physics.
Completion of undergraduate course covering basic chemistry.

[Evaluation]

Examinations: 80%
Reports (homework) & mini-exam. : 20%

[Textbooks]

[References]

Basic Solid State Chemistry Second Edition, WILEY (ISBN: 0471987565)
Transmission Electron Microscopy, A Textbook for Materials Science, Springer Science+Business Media, 2009, (ISBN: 978-0-387-76502-0)

[Schedule]

1 Application of group theory to crystallography, Sets
2 Groups
3 Symmetry elements and Symmetry operations
4 Lattice, space groups
5 Phase equilibria
6 Nucleation
7 Surface energy
8 Equilibrium shape of crystal
9 Principle of growth
10 X-ray diffraction and electron diffraction
11 Reciprocal space and electron diffraction
12 Basic Mechanical Structure of TEM
13 Practical use of TEM for inorganic materials
14 Recent topics about TEM
15 Examinations and commentaries

[Title]	[Instructor]
Advanced Special Lectures I	

[Code]	[Credits]	[Program]	[Semester]	[Hours]	[Language of instruction]
GTZ601	1	Advanced Material Science	Intensive	／	Japanese

[Outline and purpose]

The lecture indicates the state of the art of material science.

[Objectives]

To acquire the interdisciplinary knowledge on material science based on the knowledge of science in the undergraduate level

[Requirements]

The basic knowledge of material science for the undergraduate level

[Evaluation]

Presentation or report 100%

[Textbooks]

Not specify

[References]

Introduce or distribute it, if necessary

[Schedule]

The lecture contents will be announced through the Campus Networking System (CNS).

[Title]	[Instructor]
Advanced Special Lectures II	

[Code]	[Credits]	[Program]	[Semester]	[Hours]	[Language of instruction]
GTZ602	1	Advanced Material Science	Intensive	／	Japanese

[Outline and purpose]

The lecture indicates the state of the art of material science.

[Objectives]

To acquire the interdisciplinary knowledge on material science based on the knowledge of science in the undergraduate level

[Requirements]

The basic knowledge of material science for the undergraduate level

[Evaluation]

Presentation or report 100%

[Textbooks]

Not specify

[References]

Introduce or distribute it, if necessary

[Schedule]

The lecture contents will be announced through the Campus Networking System (CNS).

[Title]			[Instructor]		
Seminar in Advanced Material Science IA			all academic supervisors		
[Code]	[Credits]	[Program]	[Semester]	[Hours]	[Language of instruction]
GTZ603	1	Advanced Material Science	1st Semester		Japanese

[Outline and purpose]

It is necessary to review the related literatures, to consider the theme of research, including foreign journals of the related field. This program provides information on approaching those literatures. Other than that, the way of communication and collaboration on research group is also studied through the seminar.

[Objectives]

To direct one's study through the knowledge from this seminar

[Requirements]

General knowledge of material science relating research at undergraduate course

[Evaluation]

Integrated evaluation：100%

[Textbooks]

Not specify

[References]

Introduce or distribute it, if necessary

[Schedule]

Contents that advising teacher designates

[Title]	[Instructor]
Seminar in Advanced Material Science IB	all academic supervisors

[Code]	[Credits]	[Program]	[Semester]	[Hours]	[Language of instruction]
GTZ604	1	Advanced Material Science	2nd Semester		Japanese

[Outline and purpose]

It is necessary to review the related literatures, to consider the theme of research, including foreign journals of the related field. This program provides information on approaching those literatures. Other than that, the way of communication and collaboration on research group is also studied through the seminar.

[Objectives]

To direct one's study through the knowledge from this seminar

[Requirements]

General knowledge of material science relating research at undergraduate course

[Evaluation]

Integrated evaluation：100%

[Textbooks]

Not specify

[References]

Introduce or distribute it, if necessary

[Schedule]

Contents that advising teacher designates

[Title]			[Instructor]		
Seminar in Advanced Material Science IIA			all academic supervisors		
[Code]	[Credits]	[Program]	[Semester]	[Hours]	[Language of instruction]
GTZ605	1	Advanced Material Science	1st Semester		Japanese

[Outline and purpose]

It is necessary to review the related literatures, to consider the theme of research, including foreign journals of the related field in addition to the Seminar I. This program provides information on approaching those literatures. Other than that, the way of communication and collaboration on research group is also studied through the seminar.

[Objectives]

To direct one's study through the knowledge from this seminar

[Requirements]

General knowledge of material science relating research at undergraduate course

[Evaluation]

Integrated evaluation : 100%

[Textbooks]

Not specify

[References]

Introduce or distribute it, if necessary

[Schedule]

Contents that advising teacher designates

[Title]			[Instructor]		
Seminar in Advanced Material Science IIB			all academic supervisors		
[Code]	[Credits]	[Program]	[Semester]	[Hours]	[Language of instruction]
GTZ606	1	Advanced Material Science	2nd Semester		Japanese

[Outline and purpose]

It is necessary to review the related literatures, to consider the theme of research, including foreign journals of the related field in addition to the Seminar I. This program provides information on approaching those literatures. Other than that, the way of communication and collaboration on research group is also studied through the seminar.

[Objectives]

To direct one's study through the knowledge from this seminar

[Requirements]

General knowledge of material science relating research at undergraduate course

[Evaluation]

Integrated evaluation：100%

[Textbooks]

Not specify

[References]

Introduce or distribute it, if necessary

[Schedule]

Contents that advising teacher designates

[Title]			[Instructor]		
Research Work in Advanced Material Science IA			all academic supervisors		
[Code]	[Credits]	[Program]	[Semester]	[Hours]	[Language of instruction]
GTZ607	2	Advanced Material Science	1st Semester		Japanese

[Outline and purpose]

Research studies on advanced material science for master’s thesis.

[Objectives]

To direct one's study through the knowledge from this seminar

[Requirements]

General knowledge of material science relating research at undergraduate course

[Evaluation]

Integrated evaluation：100%

[Textbooks]

Not specify

[References]

References that advising teacher designates

[Schedule]

Contents that advising teacher designates

[Title]			[Instructor]		
Research Work in Advanced Material Science IB			all academic supervisors		
[Code]	[Credits]	[Program]	[Semester]	[Hours]	[Language of instruction]
GTZ608	2	Advanced Material Science	2nd Semester		Japanese

[Outline and purpose]

Research studies on advanced material science for master’s thesis.

[Objectives]

To direct one's study through the knowledge from this seminar

[Requirements]

General knowledge of material science relating research at undergraduate course

[Evaluation]

Integrated evaluation：100%

[Textbooks]

Not specify

[References]

References that advising teacher designates

[Schedule]

Contents that advising teacher designates

[Title]			[Instructor]		
Research Work in Advanced Material Science IIA			all academic supervisors		
[Code]	[Credits]	[Program]	[Semester]	[Hours]	[Language of instruction]
GTZ609	2	Advanced Material Science	1st Semester		English／Japanese

[Outline and purpose]

Research studies on advanced material science for master’s thesis.

[Objectives]

To direct one's study through the knowledge from this seminar

[Requirements]

General knowledge of material science relating research at undergraduate course

[Evaluation]

Integrated evaluation：100%

[Textbooks]

Not specify

[References]

References that advising teacher designates

[Schedule]

Contents that advising teacher designates

[Title]			[Instructor]		
Research Work in Advanced Material Science IIB			all academic supervisors		
[Code]	[Credits]	[Program]	[Semester]	[Hours]	[Language of instruction]
GTZ610	2	Advanced Material Science	2nd Semester		Japanese

[Outline and purpose]

Research studies on advanced material science for master’s thesis.

[Objectives]

To direct one's study through the knowledge from this seminar

[Requirements]

General knowledge of material science relating research at undergraduate course

[Evaluation]

Integrated evaluation：100%

[Textbooks]

Not specify

[References]

References that advising teacher designates

[Schedule]

Contents that advising teacher designates