

## Contents

### Part I

<b>1. Materials Science</b> .....	1
P1-1 Functional Polymer Research Project .....	2
Leader : Yasunari Maekawa	
P1-2 Advanced Catalyst Research Project .....	3
Leader : Tetsuya Yamaki	
P1-3 Positron Nano-Science Research Project .....	4
Leader : Atsuo Kawasuso	
P1-4 Semiconductor Analysis and Radiation Effects Research Project .....	5
Leader: Takeshi Ohshima	
P1-5 Biocompatible Materials Research Project .....	6
Leader : Mitsumasa Taguchi	
P1-6 Environmental Polymer Research Project .....	7
Leader : Noriaki Seko	
P1-7 Element Separation and Analysis Research Project .....	8
Leader : Hironori Ohba	
<b>2. Life Science</b> .....	9
P2-1 Ion Beam Mutagenesis Research Project .....	10
Leader : Yutaka Oono	
P2-2 Microbeam Radiation Biology Research Project .....	11
Leader : Tomoo Funayama	
P2-3 Medical Radioisotope Application Research Project .....	12
Leader: Noriko S. Ishioka	
P2-4 Radiotracer Imaging Research Project .....	13
Leader: Naoki Kawachi	
P2-5 Radiation and Biomolecular Science Research Project .....	14
Leader : Akinari Yokoya	
P2-6 Biomolecular Function Research Project .....	16
Leader : Motoyasu Adachi	
P2-7 Biomolecular Structure and Dynamics Research Project .....	17
Leader : Taro Tamada	
<b>3. Advanced Quantum-Beam Technology</b> .....	19
P3-1 Laser Compton Scattering $\gamma$ -ray Research Project .....	20
Leader : Ryoichi Hajima	
P3-2 Beam Engineering Section .....	22
Section Manager : Yasuyuki Ishii	

## Part II

<b>1. Materials Science</b> .....	23
1-01 Epitaxial Layer Thickness Dependence of Charge Collection in SiC Schottky Barrier Diodes .....	29
1-02 Experimental Study on Radiation Effects on Magnetic Tunnel Junctions 4 .....	30
1-03 Frequency Dependence of Single Event Transient (SET) Error Rate for Silicon on Insulator (SOI) Devices .....	31
1-04 Study on Radiation Resistance of Inverted Metamorphic Triple-junction Solar Cells .....	32
1-05 Irradiation Effects of Ni ions on AlGaN/GaN High Electron Mobility Transistors .....	33
1-06 Minority Carrier Traps in GaAs Devices with Embedded InAs Quantum Dot Layers .....	34
1-07 Study of the Thermal Recovery for Si:C S/D n-MOSFETs .....	35
1-08 Soft Error Tolerance of Redundant Flip-Flop by Heavy-Ion Beam Tests in 65 nm Bulk and FDSOI Processes .....	36
1-09 Proton Irradiation Effects on InAsSb Quantum-Well-Based Hall Sensors .....	37
1-10 Research of the Radiation Tolerance in Space Environment of General Electronic Devices .....	38
1-11 Fabrication of Quantum Registers and Array of Quantum Sensors in Diamond by Nano-Hole Ion Implantation .....	39
1-12 Investigation of Deep Levels in Diamond by Transient Charge Spectroscopy with Heavy Ion Microbeam .....	40
1-13 Preparation of Copper Nanocones in Ion-Track Membranes of Polyimides .....	41
1-14 Catalytic Activity of Pt Nanoparticles on a Glassy Carbon Substrate Pre-Irradiated with Ar Ions .....	42
1-15 Ion-Track Grafting of Vinylbenzyl Chloride into Poly(ethylene- <i>co</i> -tetrafluoroethylene) Films: Comparison between Different Ions .....	43
1-16 Improvement of HI Concentration Performance Using Crosslinked Radiation-Grafted Membranes .....	44
1-17 Development of Radiation-Grafted Cation-Exchange Membranes for Redox-Type Reactors in the IS Process .....	45
1-18 Prediction of Heavy-Ion Irradiation Effect on Organic Polymers Using Radiation Transport Simulation Code .....	46
1-19 Design and Fabrication of Near-Perfect Optical Absorbers Using Etched Ion Tracks .....	47

1-20	Atomistic Transformation Processes Due to the correlation of Implanted N-Ions with Ti Thin Films	48
1-21	Development of Hydrogen Permselective Membranes by Radiation-induced Graft Polymerization into Porous PVDF Films	49
1-22	Synthesis, Characterization, and Alkaline Stabilities of Radiation Grafted 4-Vinylimidazolium-Based Anion Conducting Polymer Electrolyte Membranes	50
1-23	Anisotropic Swelling of Hydrogel Nanowires Fabricated by Single Particle Nanofabrication Technique (SPNT)	51
1-24	Nitrogen Doping in Carbon-Based Cathode Catalysts Using Electron Beam Process	52
1-25	Utilization of Ion Implantation for Synthesis of Nitrogen-doped Carbon Material with Catalytic Activity	53
1-26	Formation Mechanism of Nanometer-sized Pores in Polymer-derived Silicon Carbide Film by Pyrolysis	54
1-27	Design of Functional Interfaces of Fuel Cell Materials	55
1-28	Oxygen Reduction Activity of Iron and Nitrogen Doped Carbon Films	56
1-29	Photoluminescence Properties of Ion-implanted Phosphorous- and Boron-codoped Si Nanocrystals	57
1-30	Synthesis of New-structured Multi-walled Carbon Nanotubes inside Silicon Carbide Nanotubes	58
1-31	Improvement on Hydriding Characteristics for Hydrogen Storage La-Ni Based Alloy by Ion Beam	59
1-32	Vacancy-Induced magnetism in ZnO probed by Spin-Polarized Positron Beam	60
1-33	Lattice Structure Transformation and Change in Surface Hardness of Ni <sub>3</sub> Ta Intermetallic Compounds Induced by Energetic Ion Beam Irradiation	61
1-34	Amorphization of NiTi Intermetallic Compounds Induced by Energetic Ion Bombardment	62
1-35	Clustering of Metal Atoms by High Energy Ion Implantation in Silica Glass and the Effects on Magnetic and Optical Properties	63
1-36	Depth-Directional Magnetic Modification for Bulk FeRh by High Energetic Ion-Irradiation	64
1-37	Synergetic Effect of He, H and Displacement Damages on Irradiation Hardening and Microstructures of F82H	65
1-38	Helium Effects on Hardening Behaviors of Ni Metal and Austenitic Stainless Steel Irradiated up to 200 dpa	66
1-39	Simultaneous Irradiation Effect of He and H with Displacement Damage on Swelling Behavior of T91 Steel	67

1-40	Morphology Change of CeO <sub>2</sub> Thin Film Induced by He Precipitation .....	68
1-41	Evaluation of Irradiation Resistance of ODS Ferritic Steel for Fast Reactor Application .....	69
1-42	Void Swelling Resistance of High-Nickel Alloy during Irradiation .....	70
1-43	Proton Irradiation Effect on Mössbauer Effect of the Fe <sub>65</sub> Ni <sub>35</sub> Alloy .....	71
1-44	Effect of Damage Depth Profile on Hydrogen Isotopes Dynamics in Tungsten ...	72
1-45	Effects of Ion Irradiation on Hardness and Microstructure of Pure Tungsten .....	73
1-46	Irradiation-Induced Microstructural Changes of Highly-Crystalline SiC Fibers ..	74
1-47	Gamma Ray Irradiation Effect of Ceramics .....	75
1-48	Evaluation Trial for the Lifetime of Charge Stripper Foils in the 3-GeV RCS of J-PARC .....	76
1-49	Radiation Resistance Test of Insulation for JT-60SA In-vessel Coils .....	77
1-50	Radiation Tolerance Test of the Rotation Target for the J-PARC Beam Scraper and the ILC Positron Source .....	78
1-51	Survey of Consumer Electronic Parts in the 3D Scanner with Radiation Resistance .....	79
1-52	Degradation Behavior of Surface-mounted LED by Gamma Irradiation .....	80
1-53	Irradiation Test of Semiconductors Components on the Shelf for Nuclear Robots Based on Fukushima Accidents .....	81
1-54	Development of Radiation-Resistant Braided Aramid Fiber Bar .....	82
1-55	Element Distributions Measurement in Incinerated Ash Using Micro-PIXE Analysis .....	83
1-56	Distribution of Zr Inside an Adsorbent for the Extraction Chromatography Technology .....	84
1-57	Alpha-ray Degradation of Adsorbents for MA Recovery .....	85
1-58	Gamma-ray Degradation of HDEHP Adsorbents for MA Recovery .....	86
1-59	The Hydrogen Gas Generation by Electron-beam Irradiation from ALPS Adsorbents Solidified by Several Inorganic Materials .....	87
1-60	The Hydrogen Gas Generation by Gamma-ray Irradiation from ALPS Adsorbents Solidified by Several Inorganic Materials .....	88
1-61	Hydrogen Generation from Cement Solidified Sample Loading Carbonate by Gamma Irradiation .....	89

1-62	Effect of Seawater on Corrosion of SUS316L in HAW under $\gamma$ -ray Irradiation	90
1-63	Radiolytic Hydrogen Absorption Behavior of Explosive Bonded Zr/Ta/R-SUS304 Joint in Nitric Acid Solution under Gamma-ray Irradiation	91
1-64	Effects of Gamma-ray Irradiation on the Inhibitive Effects of the Sodium Pentaborate against the Corrosion of Carbon Steel in the Diluted Seawater	92
1-65	Electrochemical Properties of Stainless Steel in Zeolites Containing Diluted Artificial Seawater under Gamma-rays Irradiation	93
1-66	Studies on Radiolysis Behavior of Simulated Carbonate Slurry under Co-60 Gamma-ray Irradiation	94
1-67	Gas Retention Behavior of Carbonate Slurry under Gamma-ray Irradiation	95
1-68	Radiation-Induced Degradation of 2-Chlorophenol in Zeolite/Water Mixture	96
1-69	Microfabrication of Biocompatible Hydrogels by Proton Beam Writing	97
1-70	Crosslinking Mechanisms of Polysaccharides in Ionic Liquids by Ionizing Radiation	98
1-71	Grafted Polymer-based Cationic Catalyst for Biodiesel Fuel Production	99
1-72	A New Modification Method for Introducing of Functional Unit and Its Practical Application	100
1-73	Research for Antivirus and Deodorizing Material with Electron Beam-Induced Graft Polymerization	101
1-74	Surface Modification of PA66 by Radiation Grafting	102
1-75	Vanadium Recovery from Seawater by Radiation-Grafted Adsorbents Based on Polyethylene Terephthalate Fiber	103
1-76	Modification of Porous PTFE Filters with Highly Hydrophilic Properties by Radiation Grafting Techniques	104
<b>2.</b>	<b>Life Science</b>	<b>105</b>
2-01	Development of Live-Cell Imaging System for Long-Term Analysis of Bystander Cell Populations Irradiated with Heavy-Ion Microbeams	109
2-02	Interphase Death Was Related to Growth Inhibition after Gamma-ray and Carbon-ion Irradiation in Human Neural Stem Cells but not in Glioblastoma Cells	110
2-03	Analysis of Gamma-ray Induced Bystander Effect between Human Lung Normal and Cancer Cells	111
2-04	Effects of High Concentration Verteporfin and Ion Beams on the Expression of p53 in Human Cultured Retinal Endothelium	112

2-05	LET Dependency of Survival Parameters by Carbon Ion Irradiation in Normal Human Dermal Fibroblasts .....	113
2-06	Combining Carbon-ion Beam and NHEJ Repair Inhibitor NU7026 Efficiently Kills Cancer Cells .....	114
2-07	Epigenetic Modifier as a Potential Radiosensitizer for Heavy-ion Therapy on Malignancy (IV) .....	115
2-08	Analysis of Mechanisms for the Induction of Radiation-Induced Adaptive Response by Bystander Response .....	116
2-09	Analysis of Biological Effect on 3D Cultured Tissue Induced by Heavy-ion Microbeam Irradiation .....	117
2-10	What Kinds of Secrete Factor(s) Can Induce Bystander Lethal Effect in Normal Human Fibroblasts Irradiated with Ar-Ion Microbeams? .....	118
2-11	Analysis of Bystander Effect Induced by Peroxynitrite in Glioma Cells .....	119
2-12	<i>In vivo</i> 3D Analysis after Localized 26.7-MeV/u $^{12}\text{C}^{6+}$ -ion Beam Irradiation in Japanese Medaka, <i>Oryzias latipes</i> .....	120
2-13	Dose and Particle Dependence of Fluorescent Dots in DNA Sheet Observed with Fluorescence Imaging of Oxidative Damage of Guanine Induced by Heavy Ion Irradiation at TIARA .....	121
2-14	Sensitizing Activity Mechanism of Porphyrin Boron and/or Fluorine Compounds for Carbon Irradiation in C6 Glial Tumor Cells .....	122
2-15	Detection of Transcripts of the Apoptosis Related Genes in the Heavy-Ion Irradiated Silkworm Eggs during Early Development .....	123
2-16	Effects of Region-Specific Carbon-Ion Irradiation on Locomotion in <i>C. elegans</i> .....	124
2-17	Detection Methods of Irradiated Raw Bovine's Liver to Sterilize the Inside of "GYU-REBA-SASHI" .....	125
2-18	Estimation of Damage Localization in DNA Irradiated with $^4\text{He}^{2+}$ , $^{12}\text{C}^{6+}$ , and $^{60}\text{Co}$ $\gamma$ -rays in Aqueous Solution .....	126
2-19	A Study on Ion-beam-induced Mutations in Rice under Cross-ministerial Research Program, "SIP" .....	127
2-20	Ion Beam Breeding of Rice for the Mutation Breeding Project of the Forum for Nuclear Cooperation in Asia (FNCA) .....	128
2-21	Mutagenesis of the Oil-producing Algae by Ion Beam Irradiation .....	129
2-22	Development of Low Temperature-Flowering Chrysanthemum Variety 'Ryujin' and 'Touma' .....	130
2-23	Determination of Ion Beam Irradiation Conditions for Callus of Tulip .....	131

2-24	Re-Development of New Variety of <i>Salvia</i> by Ion Beam Breeding	132
2-25	The Pyrimidine (6-4) Pyrimidone Photoproducts Cause T to G Mutations in Arabidopsis	133
2-26	Evaluation System of DNA Lesions Caused by Ion beam Irradiation Using the Polymerase Chain Reaction	134
2-27	Lethal Effects of Gamma Rays and Carbon Ion Beam Radiations in <i>Bacillus Subtilis</i>	135
2-28	Exploration of <i>Sinorhizobium</i> Mutants Showing High Salt Tolerant Using the Ion Beam Mutation Breeding	136
2-29	Functional Analysis of <i>pprA</i> and <i>pprI</i> Genes That Are Involved in Radiation/Desiccation Response in the Radioresistant Bacterium <i>Deinococcus grandis</i>	137
2-30	Genome Sequence Analysis of High Ethyl Caproate Producing Sake Yeasts Generated by Ion Beam Breeding -the Third Report-	138
2-31	Mutation Breeding of Microalga Strains Resistant to Hyper-salinity Stress	139
2-32	Noninvasive Analysis of the Effect of GSH and DTT on Cadmium Translocation in Oilseed Rape Using PETIS	140
2-33	Investigation on a Detection Method Using Secondary Electron Bremsstrahlung for a Gas Region Intersecting a Therapeutic Carbon Beam via Monte Carlo Simulations	141
2-34	Development of Cherenkov Light Imaging System for Study of Radiocesium Dynamics in Plants	142
2-35	A Method to Quantitative Visualization of Root Secretion by Using $^{11}\text{CO}_2$ and a Positron-emitting Tracer Imaging System	143
2-36	PET Imaging of Cancer Using Cu-64 Ions	144
2-37	Large-Scale Production of At-211 by Using TIARA-AVF Cyclotron	145
2-38	Medical Radioisotope Production with Accelerator Neutrons by 50 MeV Deuterons	146
2-39	Effects of Wakosil and Nicotine on Trace Elements Distribution in Lung Microvascular Endthelial Cells	147
2-40	Analysis of Intracellular Boron Distribution of Cultured Cells Using Micro Particle Induced Gamma-ray Emission	148
2-41	Analysis of Multiple Myeloma Cell line Using In-Air Micro-PIXE	149
2-42	Co-localization of Iron Binding on Silica with p62/sequestosome1 (SQSTM1) in lung Granulomas of Mice with Acute Silicosis	150

2-43	Elemental Localization within Poplar Stem Using Micro-PIXE (Particle Induced X-ray Emission) .....	151
2-44	Fluoride Varnish Remaining After Physical Stress .....	152
2-45	Protamine-Hyaluronic Acid Particles as a Drug Delivery System Utilizing Radiotherapy .....	153
<b>3.</b>	<b>Advanced Quantum-Beam Technology</b> .....	<b>155</b>
3-01	Continuous Ion Beam Induced Luminescence Analysis for Identification of Organics in Microscopic Targets .....	158
3-02	Analysis of Multiple Ion Scattering in $\beta$ -FeSi <sub>2</sub> Films with Equivalent Domains Epitaxially Grown on Si(111) .....	159
3-03	In-situ Measurement of Li-distribution in Li Ion Battery .....	160
3-04	Measurements of Neutron Energy Spectra of Thermal Energy Region in High Energy Quasi-monoenergetic Neutron Fields Using a Bonner Sphere Spectrometer .....	161
3-05	Measurement of Neutron-production Double-differential Cross Sections in Most-forward Direction for 65- and 80-MeV Proton Incidences .....	162
3-06	Development of Active Control System of the Cyclotron Magnetic Field for Stable Microbeam Irradiation .....	163
3-07	Status Report on Technical Developments of the TIARA AVF Cyclotron .....	164
3-08	Status Report on Technical Developments at Electrostatic Accelerators .....	165
3-09	Investigation of Phosphor Screens for Real-time Tuning of the Large-area Ion Beam Profile .....	166
3-10	Effect of Incident Beam Angle for Beam Size Reduction in the Several-hundred keV Ion Microbeam System .....	167
3-11	Development of Metal <sup>68</sup> Ge Source for Generation of Spin-polarized Positron Beam Using Carbon-sealed Capsule .....	168
3-12	Development of Production Technique of Track-etched Porous Membranes Using Continuous Ion Irradiation .....	169
3-13	Proton Beam Irradiation with a Beam Chopper Regulation at the HY Port of TIARA .....	170
3-14	Development of Flexible Mach-Zehnder Interferometer Embedded in PDMS by Proton Beam Writing .....	171
3-15	Micro-structuring of Epoxy Resists Containing Nanoparticles by Proton Beam Writing .....	172
3-16	Development of Micromachining Technique Using Heat-resistance Materials .....	173
3-17	Local Modifications of Semiconductor Surface by Fast Cluster-Ion Irradiation .....	174
3-18	Ion Irradiation Effect on Magnetic Properties of FeRh Thin Films with Energetic Carbon Single and C <sub>60</sub> Cluster Ion Beam .....	175

3-19	Ion Induced Luminescence Measurement from Alumina Irradiated with Swift Carbon Cluster Ion Beams .....	176
3-20	Transmission Secondary Ion Mass Spectrometry of Peptides Using 5 MeV C <sub>60</sub> <sup>+</sup> Ions .....	177
3-21	Secondary Ion Emission from a Hafnium Oxide Film Target upon Sub MeV C <sub>60</sub> Ion Impacts .....	178
3-22	Development of Nanomaterials and Visualization of Ion Tracks through Interactions between Cluster Ion Beams and Organic Materials .....	179
3-23	Production and Destruction of Swift MeV/atom Carbon Cluster Ions in Collisions with Target Gases .....	180
3-24	Study on Interaction of Swift Cluster Ion with Matter .....	181
3-25	Kinetic Energy Distributions of 4-MeV C <sup>+</sup> and C <sup>4+</sup> Ion Beams Guided by a Cylindrical Glass Channel .....	182
3-26	Analysis of Linear Energy Transfer Effects on the Scintillation Properties of Ce-doped Gd <sub>2</sub> SiO <sub>5</sub> (GSO) .....	183
3-27	Periodical Calibration of Ionization Chamber System for <sup>60</sup> Co Gamma Ray High Dose Rate at Radiation Processing .....	184
3-28	Dose Dependence of Photo-stimulated Luminescence from G2000 Glass Material .....	185
3-29	Elements of Low Atomic Numbers in Lithium Oxide Ceramics under Irradiation .....	186
3-30	Calibration of Analytical Sensitivity for Heavy Elements on Micro Beam PIXE System in TIARA .....	187
3-31	Three-dimensional Distribution Measurement of Cesium in Clay Particles by Micro-PIXE-CT .....	188
3-32	Characteristics of Electron Spin Resonance Signal of Quartz from Sediments and Adjacent Bedrocks .....	189
3-33	Provenance Changes Associated with Variations in East Asian Summer Monsoon Precipitation Pattern Recorded in the Inner Shelf Deposit of East China Sea during the Middle to Late Holocene .....	190
3-34	ESR Dating of the Itoigawa-Shizuoka Tectonic Line Located at the Dondoko-sawa Outcrop in Japan South Alps Using Radiation Defect Centers .....	191
<b>4.</b>	<b>Status of Quantum-Beam Facilities .....</b>	<b>193</b>
4-01	Utilization Status at TIARA Facility .....	194
4-02	Operation of the AVF Cyclotron .....	195
4-03	Operation of Electrostatics Accelerators in TIARA .....	196

4-04	Operation of the Electron Accelerator and the Gamma-ray Irradiation Facilities .....	198
4-05	Utilization Status of the Electron Accelerator and the Gamma-ray Irradiation Facilities .....	199
4-06	Radiation Monitoring in TIARA .....	200
4-07	Radioactive Waste Management in TIARA .....	201
4-08	Facility Use Program in Takasaki Advanced Radiation Research Institute .....	202
<b>Appendices</b> .....		203
Appendix 1 Publication list .....		204
Appendix 2 Type of Research Collaboration and Facilities Used for Research .....		225
Appendix 3 Examples of Typical Abbreviation Name for Organizations in National Institutes for Quantum and Radiological Science and Technology and Japan Atomic Energy Agency .....		227