Research Division of Materials Joining Process, Dep. of Energy Control of Processing

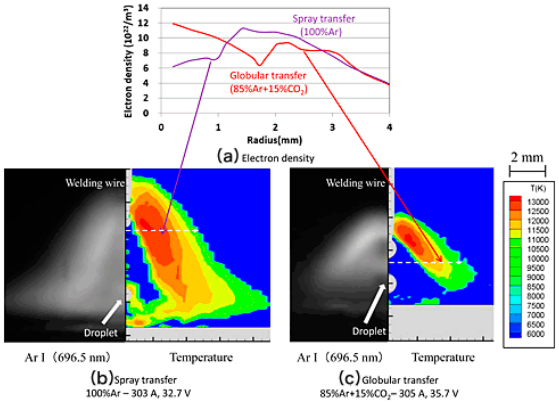
Research summary

The main research subject is the development of the high density energy source for processing advanced materials having special functions and properties. We undertake fundamental investigations of the properties of the high energy source interacting with materials, and we study advanced control techniques for optimizing the energy transport.

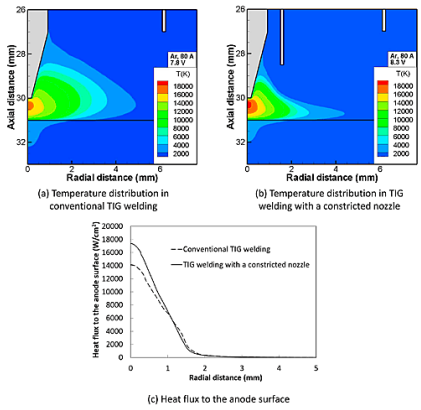
Major emphasis is placed on the generation, control and energy transport in arc plasmas, which are a high density energy source which have been applied to a variety of materials processing techniques such as welding, cutting, heating, high temperature processing, surface modification and the creation of powders.

Research subjects

(1) Generation and control of thermal plasmas, and their application to welding and joining processes
(2) Arc physics, molten pool behavior, and transport theory in fusion welding
(3) Development of new arc electrodes based on the analysis of electrode-plasma interaction
(4) Development of advanced high quality clean welding processes
(5) Development of new generation welding and joining processes employing atmospheric pressure plasma
(6) Control of arc discharge in lighting and electrical devices



Optical measurement of electron density and plasma temperature during spray transfer and globular transfer in gas metal arc welding process ((a) Electron density, (b) Spray transfer, (c) Globular transfer). An addition of CO_2 into shielding gas causes constriction of arc current toward the arc axis, which leads to globular transfer due to increase in arc pressure.



Numerical simulation on effects of constricted nozzle on arc phenomena in TIG welding process ((a) Temperature distribution in conventional TIG welding, (b) Temperature distribution in TIG welding with a constricted nozzle, (c) Heat flux to the anode surface). In TIG welding with a constricted nozzle, arc temperature increases due to constriction of arc. Consequently, larger heat flux to the anode surface is obtained compared with that of conventional TIG welding.

Major Papers

K. Tanaka, M. Shigeta, M. Tanaka and A. B. Murphy, "Investigation of the Bilayer Region of Metal Vapor in a Helium Tungsten Inert Gas Arc Plasma on Stainless Steel by Imaging Spectroscopy", J. Phys. D-Appl. Phys., 52, 35 (2019), 354003-(9 pages). doi

A. V. Nguyen, D. Wu, S. Tashiro and M. Tanaka, "Undercut Formation Mechanism in Keyhole Plasma Arc Welding", Weld. J., 98 (2019), 204-s-212-s. doi

B. Xu, S. Chen, S. Tashiro, F. Jiang, A. V. Nguyen and M. Tanaka, "Material Flow Analyses of High-Efficiency Joint Process in VPPA Keyhole Flat Welding by X-ray Transmission System", J. Clean Prod. (2019), in Press. doi

M. Shigeta and M. Tanaka, "Visualization of Electromagnetic-Thermal-Fluid Phenomena in Arc Welding", Jpn. J. Appl. Phys., 59 (2019), SA0805-(12 pages). [INVITED REVIEW PAPER] doi

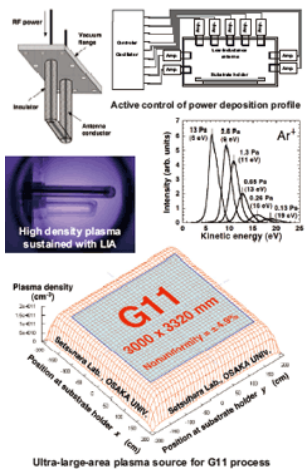
Research Division of Materials Joining Process, Dep. of Energy Transfer Dynamics

Research summary

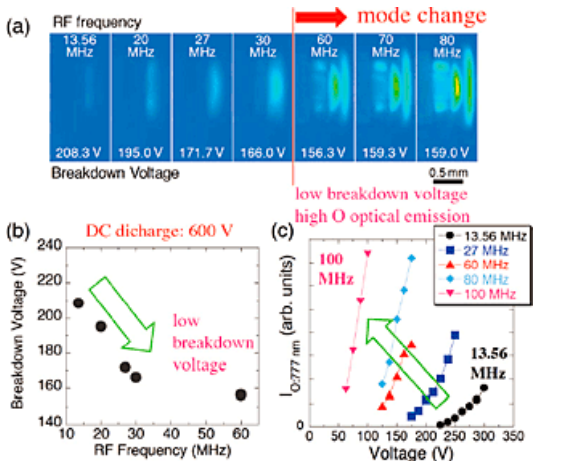
Our research activities encompass works on development of process control technologies of surface and interface for advancement of materials joining science and processing technologies through creation of novel process-energy sources (plasmas and particle beams), and span the range of applications from to functionalization of materials to their process control. These research activities are based on fundamental studies on energy transfer dynamics involved in a variety of materials processing with process-energy sources.

Research subjects

(1) Development of novel plasma sources and particle beams for advanced process technologies (CVD, PVD)
(2) Development of novel large-area, low-damage and high-density plasma sources for advanced process control of functional materials
(3) Development of novel large-area, low-damage and high-density plasma sources for advanced process control of functional materials
(4) Creation of softmaterial processing science for development of advanced green nanotechnologies with inorganic/organic flexible hybrid structures
(5) Studies on temporal and spatial control of discharge for development of innovative plasma sources for plasma medicine



Low-damage and ultra-large-area plasma source with multiple low inductance antenna modules



Development of innovative plasma source for plasma medicine
(a) ICCD images of atmospheric RF plasmas
(b) Frequency dependence of discharge breakdown voltage
(c) Frequency dependence of O optical emission intensity

Major Papers

G. Uchida, Y. Mino, T. Suzuki, J. Ikeda, T. Suzuki, K. Takenaka and Y. Setsuhara, "Decomposition and Oxidation of Methionine and Tryptophan Following Irradiation with a Nonequilibrium Plasma Jet and Applications for Killing Cancer Cells", Sci. Rep., 9 (2019), 6625/1-6625/17. doi

K. Takenaka, M. Endo, G. Uchida, Y. Setsuhara and A. Ebe, "Influence of Deposition Condition on Electrical Properties of a-IGZO Films Deposited by Plasma-enhanced Reactive Sputtering", J. Alloy. Compd, 772 (2019), 642-649. doi

K. Takenaka, M. Endo, H. Hirayama, G. Uchida, A. Ebe and Y. Setsuhara, "Low-temperature Formation of High-Mobility A-InGaZnO_x Films Using Plasma-Enhanced Reactive Processes", Jpn. J. Appl. Phys., 58 (2019), 090605/1-090605/5. doi

K. Takenaka, Y. Setsuhara, J.G. Han, G. Uchida and A. Ebe, "High Rate Formation of Silicon Nitride Thin Films Using Plasma-Assisted Reactive Sputtering Deposition", Thin Solid Films, 685 (2019), 306-311. doi

K. Takenaka and Y. Setsuhara, "Droplet-Vaporization Behavior during Plasma-Assisted Mist Chemical Vapor Deposition of Zinc Oxide Films", Plasma Sources Sci. Technol., 28 (2019), 065015/1-065015/8. doi

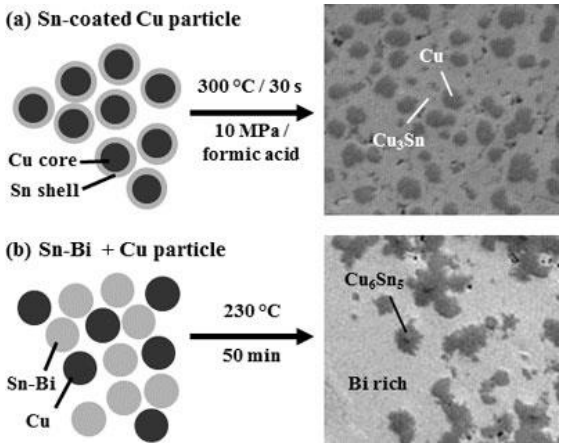
Research Division of Materials Joining Process, Dep. of Manufacturing Process

Research summary

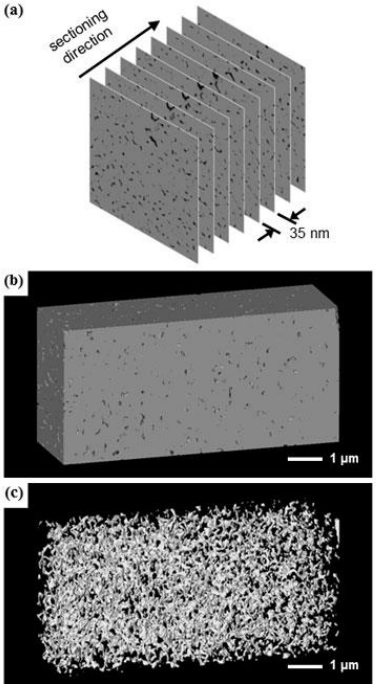
The main research objectives are to analyze the mechanisms of material process including joining by various energy sources, and to develop advanced processes with high efficiency and high productivity. Especially, for a micro joining process in electronics packaging, the creation of the functional joint materials, the development of novel advanced micro processes by various energy sources, and the enhancement of the highly reliable joints based on the control of interfacial structure and performance are performed to produce micro joints with superb functionality and high reliability. In addition, we are resolving the joining problems of newly-developed materials. And we are aiming to develop new appropriate material processes for these materials.

Research subjects

(1) Development and evaluation of advanced micro joining process
(2) Elucidation of micro joining phenomena and defect suppression
(3) Control and analysis of microstructure at soldered interface
(4) Development of eco-friendly fluxless soldering process using a reducing atmosphere
(5) Formation of high heat-resistance joint using three-dimensional nanostructure



Micro joining process using a transient liquid phase bonding (TLPB) method
(a)TLPB process and microstructure of joint using Sn-coated Cu particles
(b)TLPB process and microstructure of joint using Sn-Bi solder particles + Cu particles



Microstructure of sintered joint using Ag nanoparticle paste
(a)Serial sectioning of Ag sintered layer by FIB/SEM system
(b)Reconstructed 3D image of Ag sintered layer
(c)Reconstructed 3D pore distribution into Ag sintered layer

Major Papers

R. Gao, S. He, Y.-A. Shen and H. Nishikawa, "Effect of Substrates on Fracture Mechanism and Process Optimization of Oxidation-Reduction Bonding with Copper Microparticles", J. Electronic Mater., 48, 4 (2019), 2263-2271. doi

Y.-A. Shen, S. Zhou, J. Li, C.-H. Yang, S. Huang, S.-K. Lin and H. Nishikawa "Sn-3.0Ag-0.5Cu/Sn-58Bi Composite Solder Joint Assembled Using a Low-Temperature Reflow Process for PoP Technology", Mater. Des., 183 (2019), 108144. doi

Y.-A. Shen, C. M. Lin, J. Li, R. Gao and H. Nishikawa, "Suppressed Growth of (Fe, Cr, Co, Ni, Cu)Sn_2 Intermetallic Compound at Interface between Sn-3.0Ag-0.5Cu Solder and $FeCoNiCrCu_{0.5}$ Substrate during Solid-state Aging", Sci. Rep., 9 (2019), 10210. doi

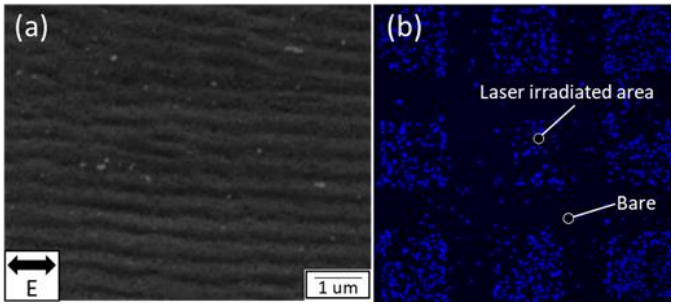
Research Division of Materials Joining Process, Dep. of Laser Materials Processing

Research summary

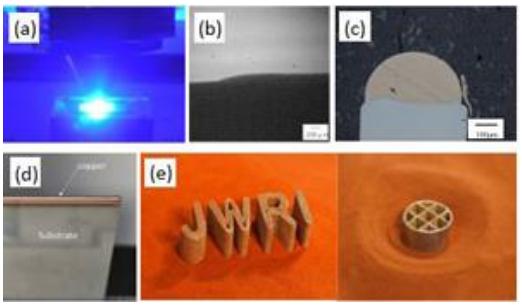
Fundamental studies are performed concerning welding, joining, cutting, surface modification and removal processing with laser beams, aimed at advanced fusion between laser science and production engineering. We focus on clarification of welding or joining mechanisms on the basis of the visualization of material processing phenomena with high-speed optical observation or X-ray transmission imaging techniques. Moreover, laser should be utilized with not only high thermal efficiency but also physicochemical effects induced by interaction between light and material. Thus we create innovative processes including laser direct joining of metal and plastic, put these processes to practical use and disseminate achievements of our research to the world.

Research subjects

(1) Development and evaluation of joining and welding processes for the advanced functional materials
(2) Development of additive manufacturing technologies with blue diode laser
(3) Creation of new function by surface modification with laser
(4) Fundamental studies on laser interaction with materials and fundamental studies of materials processing utilizing laser



PMMA film surface after femtosecond laser irradiation.
(a) SEM image with periodic nanostructures oriented to the direction perpendicular to the laser polarization vector (The period of the periodic nanostructure is about 230nm) on PMMA film surface.
(b) Fluorescence microscope image of cell cultivation test. Cells adhered to the periodic nanostructures surface rather than bare surface.



Copper cladding using blue diode laser (a)Blue diode laser (b) X ray observation of laser coating with blue laser (c) Cross section image (d) Surface image of pure copper coating layer (e) 3D object of pure copper by Blue diode laser

Major Papers

K. Koda, K. Takenaka, and M. Tsukamoto, "Laser-fluence Dependence of Microstructure Formed on Nickel by Backward Pulse Laser Deposition", Appl. Surf. Sci., 485 (2019) 128–132. doi

Y. Sato, M. Tsukamoto, T. Shobu, Y. Funada, Y. Yamashita, T. Hara, M. Sengoku, Y. Sakon, T. Ohkubo, M. Yoshida and N. Abe, "In Situ X-ray Observations of Pure-Copper Layer Formation with Blue Direct Diode Lasers", Appl. Surf. Sci., 480 (2019), 861-867. doi

K. Takenaka, M. Tsukamoto, M. Hashida, S. Masuno, H. Sakagami, M. Kusaba, S. Sakabe, S. Inoue, Y. Furukawa and S. Asai, "Ablation Suppression of a Tutanium Surface Interacting with a Two-Color Double-Pulse Femtosecond Laser Beam", Appl. Surf. Sci., 478 (2019), 882-886. doi

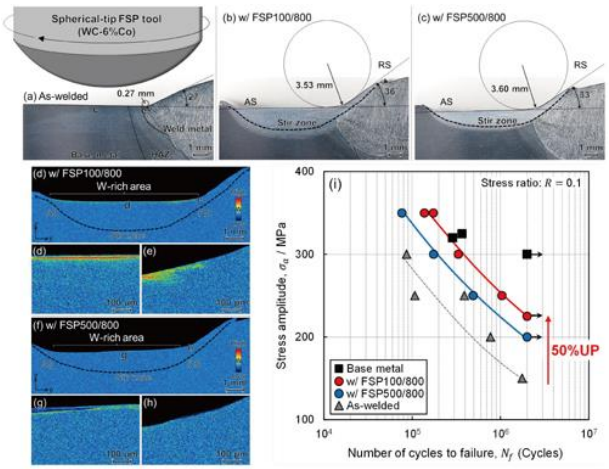
Research Division of Materials Joining Mechanism, Dep. of Welding Mechanism

Research summary

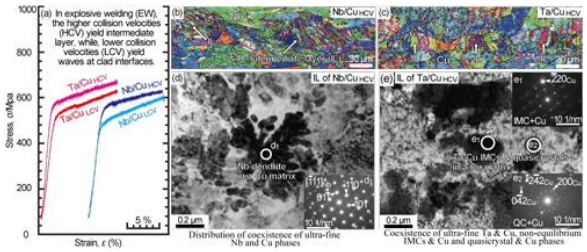
Mechanisms controlling the joint performance of structural and functional materials, which obtained by fusion welding, liquid-state/solid-state bonding, and solid-state bonding, are metallographically characterized to establish a scientific basis to produce joint materials featuring superior performance. The microstructures of the weld-deposited metal, the heat-affected zone of fusion-welded joints, and the interfacial region of solid-state bounded joint are thoroughly investigated utilizing various methods such as X-ray diffraction, electron-microscopy observation, elementary analysis, EBSP analysis, and numerical modeling and simulation. Formation processes of the microstructures and their relation to joint performance are discussed from the material scientific viewpoint.

Research subjects

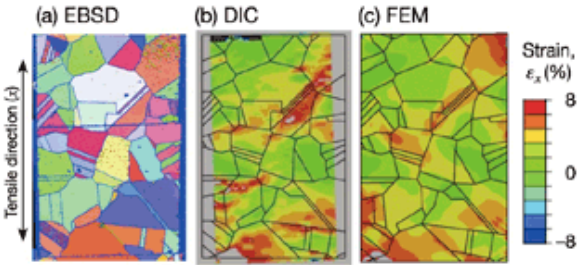
(1) Weld microstructure analyses of structural material such as steel
(2) Bonding mechanism of solid-state joining of metals and ceramics, and its application to microstructural control
(3) Application of welding and joining phenomena to development of advanced materials
(4) Synthesis of new functional materials at welding and joining interface
(5) Evaluation of the effect of microstructure on mechanical behavior of structural materials joints



Geometry modification and W-rich layer formation for weld toe of high-strength low-alloy steel joints using friction stir processing (FSP) with spherical-tip WC tool, resulting in fatigue strength improvement.



Designing high bending strength Nb/Cu and Ta/Cu clads produced by explosive welding (EW) with high micro-hardness intermediate layers (ILs) at their interfaces.



Measurement and simulation of deformation behavior at crystalline grain scale of austenitic stainless steel. (a) Orientation map obtained by electron backscatter diffraction (EBSD) technique. (b) Measurement of deformation by digital image correlation (DIC) method.

Major Papers

P. K. Parchuri, S. Kotegawa, H. Yamamoto, K. Ito and A. M. K. Hokamoto, "Benefits of Intermediate-Layer Formation at the Interface of Nb/Cu and Ta/Cu Explosive Clads", Mater. Des., 166 (2019), 107610. doi

P. K. Parchuri, S. Kotegawa, K. Ito, H. Yamamoto, A. Mori, S. Tanaka and K. Hokamoto, "Cladding of a Crack-Free W Plate on Cu Plates Using Explosive Welding at Higher Collision Velocity with Lower Collision Angle", Results Mater., 5, 100023 (2019), 1-7. doi

A. Sharma, J. S. Panchagnula, M. Kumar, K. Ito, P. K. Parchuri, S. Simhambhatla and S. Reddy, "Wire Arc Additive Manufacturing, Thermal Modelling, Build Direction, Mechanical Properties", J. Manufacturing Processes, 40 (2019), 46-58. doi

Y. Mikami, W. Sadakane and M. Mochizuki, "Numerical Simulation of Microscopic Residual Stress Evolution in Polycrystalline Aggregate Subjected to Weld Thermal Cycle", Weld. World, 64, 1 (2019), 105-114. doi

Research Division of Materials Joining Mechanism, Dep. of Joint Interface Structure and Formation Mechanism

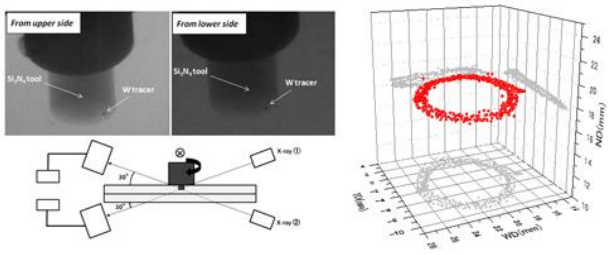
Research summary

In this department, based on the elucidation of the various phenomena at the joint interfaces of ferrous, nonferrous, non-metal materials at both macroscopic and microscopic levels, the interface formation mechanisms during various joining processes are clarified to create new interface control methods.

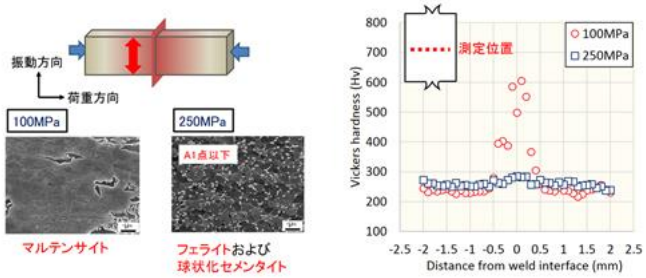
In addition, novel welding and modification processes are developed, mainly based on fusion welding methods and friction welding methods such as the friction stir welding, rotary friction welding and linear friction welding methods, which is the core of the fundamental technologies having a great potential to produce new values. These developments are going to be used and focused simultaneously in our society in order to create a new research field and elevate the continuous growth of industrial competitiveness of our country.

Research subjects

(1) Control of interface and elucidation of formation mechanism during friction welding (FSW, Friction welding, Linear friction welding)
(2) Development of novel joining and modification processes
(3) Elucidation of formation mechanism of weld interface and molten pool
(4) Analysis of joint interface structure
(5) Control of solid-liquid interface formation



Three-dimensional visualization of the material flow using a W tracer during the FSW.



SEM microstructures and Vickers hardness along the central axis of LFWed joints.

Major Papers

S.-J. Lee, T. M. Park, J.-H. Nam, W. S. Choi, Y. Sun, H. Fujii and J. Han, "The Unexpected Stress-Strain Response of Medium Mn Steel after Friction Stir Welding", Mater. Sci. Eng. A., 744 (2019), 340-348. doi

Y. Sun, H. Fujii, S. Zhu and S. Guan, "Flat Friction Stir Spot Welding of Three 6061-T6 Aluminum Sheets", J. Mater. Process. Technol., 264 (2019), 414-421. doi

Y. Aoki, R. Kuroiwa, H. Fujii, G. Murayama and M. Yasuyama, "Linear Friction Stir Welding of Medium Carbon Steel at Low Temperature", ISIJ Int., 59, 10 (2019), 1853-1859. doi

T. Nagira, X. C. Liu, K. Ushioda, Y. Iwamoto, G. Ano and H. Fujii, "Role of Annealing Twinning in Microstructural Evolution of High Purity Silver during Friction Stir Welding, Sci. Technol. Weld. Join., 24 (2019), 644-651. doi

H. Liu, K. Ushioda and H. Fujii , "Elucidation of Interface Joining Mechanism during Friction Stir Welding through Cu/Cu-10Zn Interfacial Observations", Acta Mater., 166 (2019), 324-334. doi

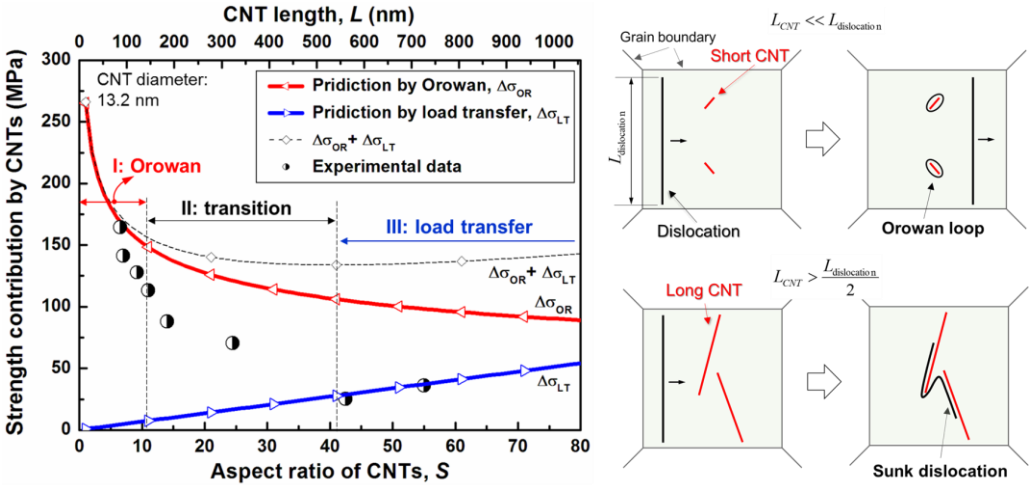
Research Division of Materials Joining Mechanism, Dep. of Composite Materials Processing

Research summary

From a viewpoint of the energy saving and environmental problem solutions, the research fields of this department focus on both of the effective reuse of resources and energy including renewable ones and reduction of life hazardous materials and air pollutions. In particular, by controlling the interfacial mechanics and high-performance of materials, atomic/nano-scale composite materials and processing designs for the environmentally benign are established, and applied to innovative industrial development.

Research subjects

(1) Titanium materials with high-strength and ductility via atomic-scale microstructure optimization by first principle calculation
(2) Nano-carbon materials reinforced metal matrix composites through interfacial mechanics
(3) Surface modification by 3D-nano structuring and application to novel biomaterials
(4) Direct bonding of plastic materials to metals by molecular structure control
(5) Ni-rich TiNi shape memory alloys with nano-precipitation and expansion ability evaluation in application to stent devices



Dependence of strength contribution by CNTs on the aspect ratio or length of CNTs and Interaction between matrix dislocations and CNTs with a small and large length in metal grains, MRS Bulletin, 44 (2019) 40-45.

Major Papers

A. Bahador, J. Umeda, S. Tsutsumi, E. Hamzah, F. Yusof, H. Fujii and K. Kondoh, "Asymmetric Local Strain, Microstructure and Superelasticity of Friction Stir Welded Nitinol Alloy", Mater. Sci. Eng. A., 767 (2019), 138344. doi

J. Umeda, K. Kondoh, H. Sannomiya, T. Luangvaranunt, M. Takahashi and H. Nishikawa, "Interfacial Reaction Behavior and Mechanical Properties of Pure Aluminum and Magnesium Alloy Dissimilar Materials Fabricated by Hot Press and Heat Treatment", Mater. Charact., 157 (2019), 109879. doi

X. Zhang, S. Li, B. Pan, D. Pan, L. Liu, X. Hou, M. Chu, K. Kondoh and M. Zhao, " Regulation of Interface between Carbon Nanotubes-Aluminum and Its Strengthening Effect in CNTs Reinforced Aluminum Matrix Nanocomposites", Carbon, 155 (2019), 686-696. doi

B. Chen, K. Kondoh, J. Umeda, S. Li, L. Jia and J. Li, "Interfacial In-Situ Al_2O_3 Nanoparticles Enhance Load Transfer in Carbon Nanotube (CNT)-reinforced Aluminum Matrix Composites", J. Alloy. Compd, 789 (2019), 25-29. doi

K. Kondoh, R. Ikemasu, J. Umeda, S. Kariya and A. Khantachawana, " Microstructural and Mechanical Properties of α-Titanium Sintered Material via Thermal Decomposition of Additive Chromium Oxide Particles", Mater. Sci. Eng. A., 739, 2 (2019), 491-498. doi

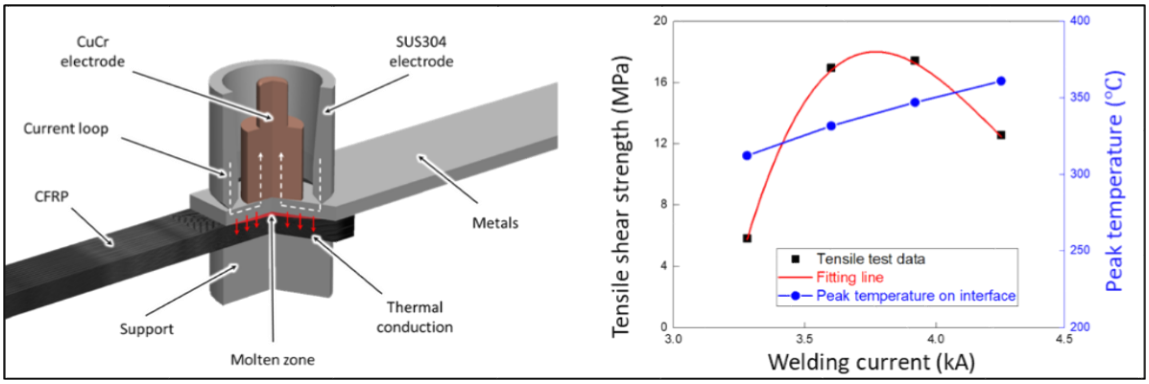
Research Division of Materials Joining Assessment, Dep. of Joining Mechanics and Analyses

Research summary

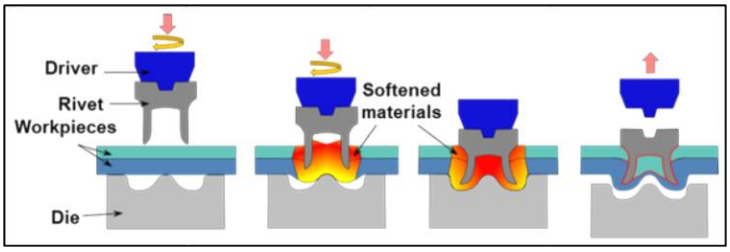
The mathematical and numerical modelling is a basis of AI and one of the most efficient approaches to look into various detail phenomena involved in joining & welding & additive manufacturing processes. In addition, assessment to residual stress/strain and defects in various types of joints between dissimilar materials is being studied through both the advanced measuring technology and numerical computational approaches.

Research subjects

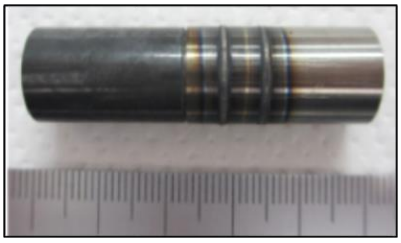
(1) Computational and experimental study of nonlinear thermo-mechanical-metallurgical phenomena in multi-materials solid-state joining, fusion welding and additive manufacturing.
(2) Field Measurement and FEM (M-FEM) for identification of internal residual stress and fracture criteria of materials and various types of joints.
(3) AI for full manufacturing processes including metal forming, joining, welding and assembling of structures.



Digital twin of coaxial one-side resistance Digital twin of coaxial one-side resistance spot welding



A novel friction self-piercing riveting (F-SPR) process



Zircaloy-SiC/SiC joint by laser

Major Papers

S. Ren, Y. Ma, S. Saeki, Y. Iwamoto and N. Ma, "Numerical Analysis on Coaxial One-Side Resistance Spot Welding of Al5052 and CFRP Dissimilar Materials", Materials and Designs (2019), 1-10. doi

Y. Ma, B. Yang, M. Lou, Y. Li and N. Ma, "Effect of Mechanical and Solid-State Joining Characteristics on Tensile-Shear Performance of Friction Self-Piercing Riveted Aluminum Alloy AA7075-T6 Joints", J. Mater. Process. Technol., 278 (2019), 116543(10pages). doi

H. Serizawa, N. Nakazato, Y. Sato, M. Tsukamoto, J. S. Park and H. Kishimoto, "Experimental Studies on Joinability of Zircaloy and SiC/SiC Composite with Titanium Powder", IJCES, 1 (2019), 56-62. doi

Y. Li, Y. Wei, X. Luo, C. Li and N. Ma, "Correlating Particle Impact Condition with Microstructure and Properties of the Cold-Sprayed Metallic Deposits", J. Mater. Sci. Technol. 40, 1 (2019), 185-195. doi

B. Vicharapu, H. Liu, H. Fujii, K. Narasaki, N. Ma and A. De, "Probing Residual Stresses in Stationary Shoulder Friction Stir Welding Process", Int. J. Adv. Manuf. Technol. (2019), 91-98. doi

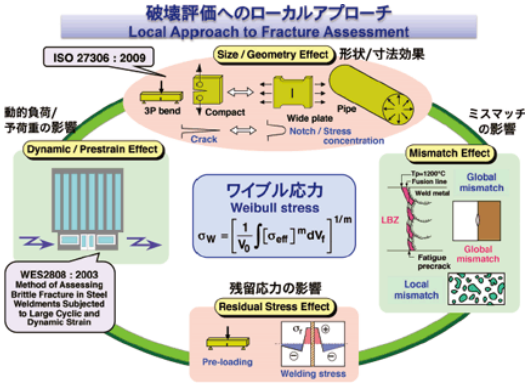
Research Division of Materials Joining Assessment, Dep. of Structural Integrity and Failure Assessments

Research summary

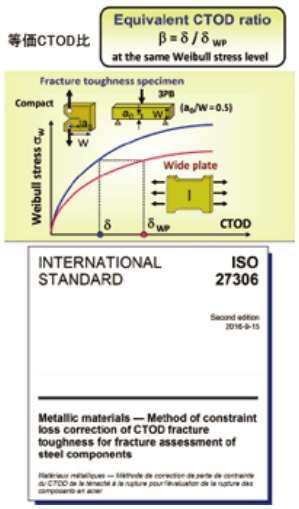
The welding & joining design should use the properties and qualities of materials to their best advantage in service conditions. A need has been increased for more creative joint design and manufacturing in the industry. This department focuses on the development of a procedure for fitness-for-service assessment, in particular fracture assessment of metallic structures constructed by joining & welding. The methodology is founded on the local approach to fracture, which enables the transferability analysis between the strength of fracture toughness specimen and the performance of structural component. With this procedure, the critical allowance of flaw and damage in service conditions is predicted. The results are published as national and international standards or guidelines for user friendliness.

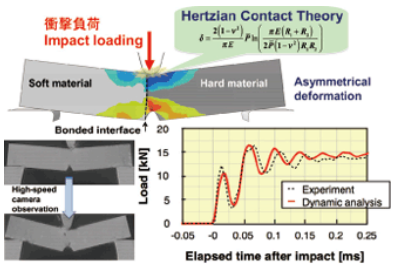
Research subjects

(1) Structural integrity assessment by the Weibull stress approach
(2) Development of fitness-for-service assessment procedure for welded structures in service
(3) Interface strength evaluation of dissimilar joints
(4) Fracture performance assessment under dynamic loading
(5) Science of go/no-go of dynamic crack propagation



Structural integrity assessment of weld structures by the Weibull stress criterion





Dynamic analysis of stress-strain fields in Charpy specimen of dissimilar joints

Development of international fracture assessment standard, ISO 27306, for steel structures

Major Papers

Y. Takashima, Y. Ito, F. Lu and F. Minami, "Fracture Toughness Evaluation for Dissimilar Steel Joints by Charpy Impact Test", Weld. World, 63, 5 (2019), 1243-1254. doi

Y. Takashima, T. Kawabata, R. Deguchi, S. Yamada and F. Minami, "Increase in Micro-Cracks Beneath Cleavage Fracture Surface in Carbon Steel ESSO Specimens", Theor. Appl. Fract. Mec., 101 (2019), 365-372. doi

F. Yanagimoto, T. Hemmi, Y. Suzuki, Y. Takashima, T. Kawabata and K. Shibanuma, "Contribution of Grain Size to Resistance against Cleavage Crack Propagation in Ferritic Steel", Acta Mater., 177 (2019), 96-106. doi

G. An, J.-U. Park, M. Ohata and F. Minami, "Fracture Assessment of Welded Joints of High-Strength Steel in Pre-Strained Condition", Appl. Sci., 9 (2019) doi

T. Kawabata, F. Tonsho, Y. Nishizono, N. Nakamura and Y. Takashima, "Controlling Factors for Roughness Increases on Cleavage Fracture Surfaces and Crack Branching in Polycrystalline Steel", Theor. Appl. Fract. Mec., 100 (2019), 171-180. doi

Research Division of Materials Joining Assessment, Dep. of Joining Design and Dependability

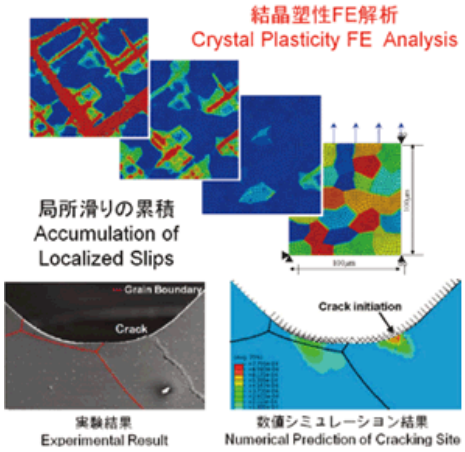
Research summary

In evaluating the reliability of the structures, this department investigates not only the conventional optimization for the safety and the durability in constructing steel structures but also the reliability (Dependability) including the maintenance, the repair/reinforcement and the evaluation of lifetime considering cultural science and social science. Moreover, making researches on the procedure to safely break up the structures completing the lifetime, the circulating loop in which the members or the units are reused is concretized.

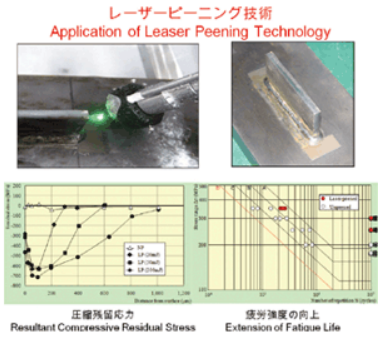
The department purposes to establish the evaluating methods to satisfy the high accuracy and the high quality in cutting, processing and assemblage for "products of steel structures" based on the dependability in the circulating loop containing the maintenance, the repair/reinforcement and the evaluation of lifetime.

Research subjects

(1) Soundness diagnosis of structural members and joints
(2) Development of simulation technology of mechanical behavior
(3) Development of fatigue life assessment tool (crack nucleation, propagation)
(4) Development of measurement technology of deformation and crack
(5) Development of life extension technology for structural members and joints
(6) Assessment of Weldability and Quality of New and Functionally Graded Materials



Numerical simulation of mechanical fatigue phenomena



Development of life extension technology for steel structures

Ultra-dynamic and cyclic loading test for large structures
Soundness diagnosis of structure members by ultra-dynamic structural testing system （Speed 1,200mm/sec, Load 1,200kN, Stroke 500mm）

Major Papers

S. Tsutsumi and R. Fincato , "Cyclic Plasticity Model for Fatigue with Softening Behaviour below Macroscopic Yielding", Mater. Des., 165 (2019), 107573. doi

S. Tsutsumi, R. Fincato and H. Momii , "Effect of Tangential Plasticity on Structural Response under Non-Proportional Cyclic Loading", Acta. Mech. 230, (2019), 2425-2446. doi

R. Gadallah and S. Tsutsumi, "Critical Investigation on the Effect of Steel Strength on Fatigue Crack Growth Retardation Including a Single Tensile Overload", Theor. Appl. Fract. Mec., 104 (2019), 102326. doi

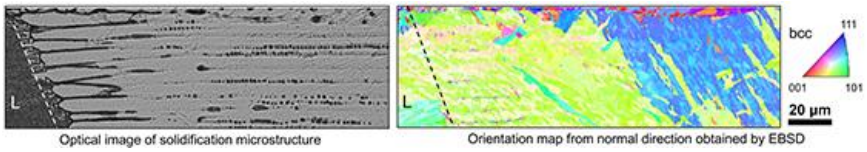
Research Division of Materials Joining Assessment, Dep. of Reliability Evaluation & Simulation

Research summary

Development of innovative manufacturing technology is required to manufacture high-performance machine products and structures of the next-generation. Department of Reliability Evaluation & Simulation conducts research and education for elucidation and control of the factors on weldment properties by high accurate evaluation based on material science and engineering. In order to create innovative and attractive technique of welding & Joining as a final aim, our department are working on elucidation of metallurgical phenomenon such as solidification and transformation, and on developing the prediction method for the microstructures and the properties of weldments.

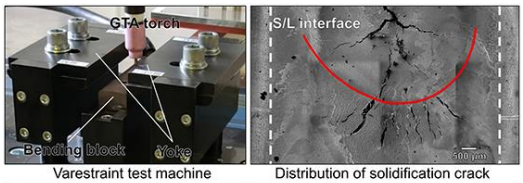
Research subjects

(1) Effect of solidification on microstructural formation and mechanical properties of high strength steel weld metal
(2) Investigation of controlling factor of weld hot cracking susceptibility and establishment of the prediction technology of weld hot cracking
(3) Clarification of influential factors of corrosion resistance of stainless steel dissimilar weld
(4) Analysis of solidification/transformation behavior and accurate evaluation of hot crack susceptibility by using In-situ observation method
(5) Investigation of peritectic reaction mechanism on carbon steel during welding process

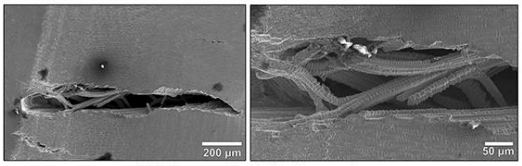


Optical image of solidification microstructure　Orientation map from normal direction obtained by EBSD

Observation of solidification microstructure by liquid Sn quenching

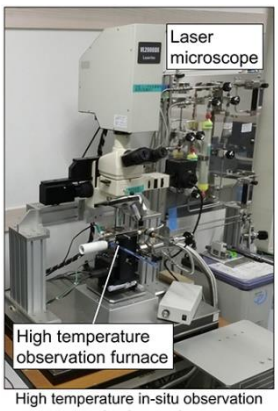


Varestraint test machine　Distribution of solidification crack

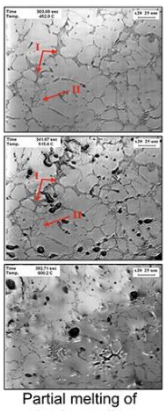


SEM image of solidification crack

Evaluation of solidification crack susceptibility by Trans-Varestraint test



High temperature in-situ observation system using laser microscope


Partial melting of aluminum alloy

High temperature in-situ observation by laser microscope

Major Papers

S. Ueda, K. Kadoi, S. Tokita and H. Inoue, "Relationship between Alloy Element and Weld Solidification Cracking Susceptibility of Austenitic Stainless Steel", ISIJ Int., 59, 7 (2019), 1323-1329. doi

K. Kadoi, M. Hiraoka, K. Shinozaki and T. Obana, "Ductility-dip Cracking Susceptibility in Dissimilar Weld Metals of Alloy 690 Filler Metal and Low Alloy Steel", Mater. Sci. Eng. A., 756 (2019), 92-97. doi

C. Cheng, K. Kadoi, S. Tokita, H. Fujii, K. Ushioda and H. Inoue, "Effects of Carbon and Chromium on Microstructure Evolution and Mechanical Properties of Friction Stir Weldment in Medium-carbon Steel", Mater. Sci. Eng. A., 762 (2019), 138060. doi

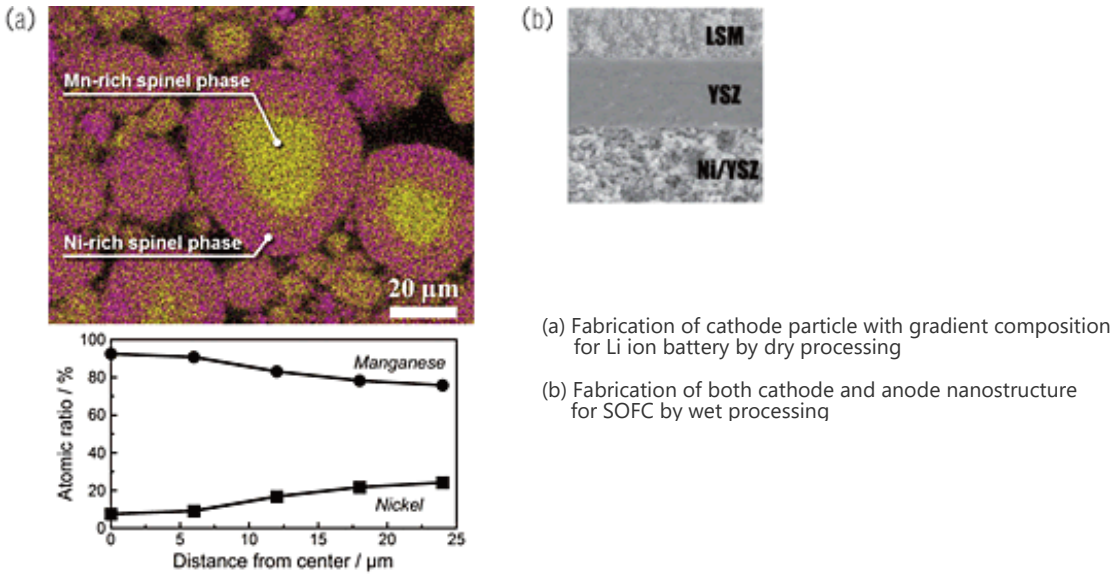
Smart Processing Research Center, Dep. of Smart Coating Processing

Research summary

This department deals with smart coating processing based on nanoparticle processing, which leads to advanced manufacturing technology as well as safe, security, environmental and energy issues. By making use of new properties of nanoparticles, nanoporous or multi-component films can be created without any heat assistance. Nano and microscale design of particles will lead to high reliability and functional coating films with various kinds of coating processes. Smart coating on the surface of particles will make key materials for new areas such as DDS (Drug Delivery System) or Fuel Cells.

Research subjects

(1) Development of solid-state processing in water vapor for functional fine-particle synthesis
(2) Low temperature synthesis of composite oxide nanoparticles by mechanochemical method
(3) Development of Li ion battery electrodes by controlling their composite structure
(4) Wet processing for composite nanoparticles and their applications for fuel cells
(5) Development of fuel cell electrodes for PEFC and SOFC
(6) Development of low thermal conductivity materials using composite particles
(7) Development of 3D direct-assembly process of nanoparticles
(8) New recycling process of composite materials by bonding and disassembling of their interface



(a) Fabrication of cathode particle with gradient composition for Li ion battery by dry processing

(b) Fabrication of both cathode and anode nanostructure for SOFC by wet processing

Major Papers

T. Kozawa, A. Kondo, K. Fukuyama, M. Naito, H. Koga, Y. Shimo, T. Saito, H. Iba, Y. Inda, T. Oono, T. Katoh and K. Nakajima, "Bulk-type All-Solid-State Batteries with Mechanically Prepared $LiCoPO_4$ Composite Cathodes", J. Solid State Electrochem., 23, 4 (2019), 1297-1302. doi

T. Kozawa, K. Fukuyama, A. Kondo and M. Naito, "Wet Mechanical Route to Synthesize Morphology-Controlled $NH4MnPO_4{\cdot}H_2O$ and Its Conversion Reaction into $LiMnPO_4$", ACS Omega., 4 (2019), 5690-5695. doi

H. Bai, J. Hu, Y. Duan, T. Kozawa, M. Naito, J. Zhang and S. Dong, "Surface Modification of $Li_{1.3}Al_{0.3}Ti_{1.7}(PO_4)_3$ Ceramic Electrolyte by Al_2O_3-doped ZnO Coating to Enable Dendrites-Free All-Solid-State Lithium-Metal Batteries", Ceram. Int., 45, 12 (2019), 14663-14668. doi

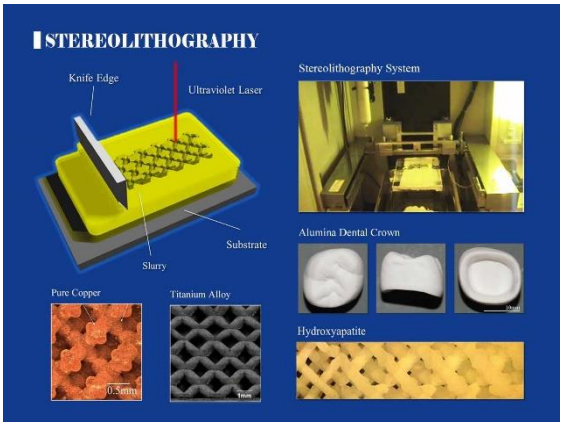
Smart Processing Research Center, Dep. of Nano/Micro Structure Control

Research summary

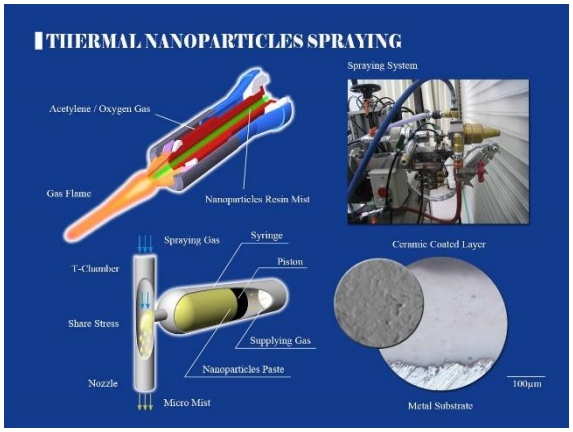
Additive Manufacturing (AM) was newly developed as novel process to create three dimensional (3D) structures through two dimensional (2D) layer laminations. Metal and ceramic nanoparticles were dispersed into resin paste to use for our original process. In lithography techniques, a high power laser beam was scanned on the spread paste for 2D layer drawing and 3D structure forming. In deposition techniques, the paste was introduced into high temperature plasma or gas flame for 2D cladding and 3D patterning. Created electric devices, biological implants and energy modules will contribute to sustainable development.

Research subjects

(1) Stereolithographic Additive Manufacturing of Metal and Ceramic Parts Using Nanoparticles Pastes
(2) Structural Fabrication of Photonic Crystals with Diamond Structures for Terahertz Wave Control
(3) Modulation of Micro Porous Structures in Biological Ceramic Implants for Artificial Metabolism
(4) Manufacturing of Micro Metal Lattices for Effective Controls of Heat Flow and Stress Distributions
(5) Advance Development of Thermal Nanoparticles Spraying for Additive Manufacturing Technique
(6) Fine Separator Formation in Solid Oxide Fuel Cells by Using Thermal Nanoparticles Spraying
(7) Fine Ceramic Coating with Thermal Conductivity and Corrosion Resistance for Heat Exchanger Tubes
(8) Layer Laminations by Fine Particles Spraying and Sintering to Create Functionally Graded Structures



Laser Scanning Stereolithography of Additive Manufacturing to Fabricate Bulky Metal and Ceramic Components with Micro Geometric Patterns



Thermal Spraying Using Fine Particle Pastes to Laminate Metal and Ceramic Coated Layers with Functional Nano/Micro Structures

Major Papers

S. Kirihara, "Stereolithographic Additive Manufacturing of Ceramic Components with Micropatterns for Electromagnetic Wave Control", Ceram. Mod. Thecnol., 1, 2 (2019), 84-90. doi

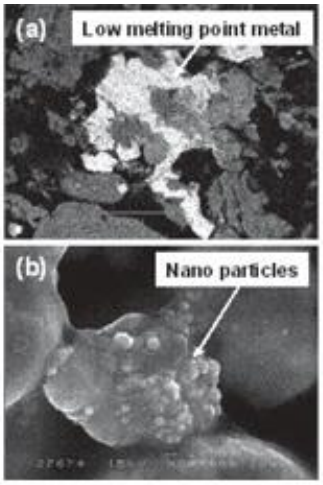
Smart Processing Research Center, Dep. of Smart Green Processing

Research summary

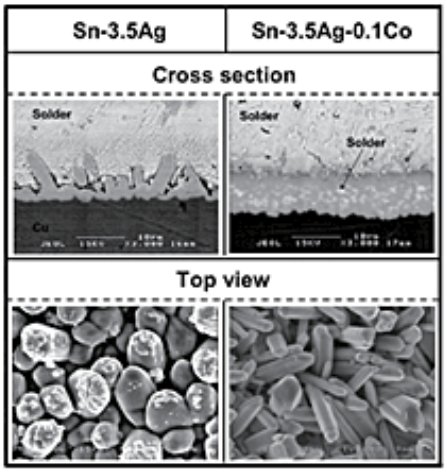
The aim of this division is to develop the environmentally conscious smart technology to reduce the environmental impact in manufacturing, waste treatment and recycle processing. Especially, the research focuses on the following topics; substitution of materials to toxic free and eco-materials in electronics assembly, the use of low environmental impact materials in joining process, enhancement of reliability of fine-pitch high density packaging, and design for reuse. Also low temperature joining, substitution of rare materials and precious metals to popular substances, and development of low energy consumption new smart joining process which can make highly reliable joint are the targets of research in smart green processing department.

Research subjects

(1) Promotion of toxic-free manufacturing of fine pitch high density packaging in electric equipments and electronics
(2) Interfacial reaction between lead-free solder and materials
(3) Improvement of joint lifetime by controlling microstructures at interface
(4) Nano-particle assisted smart bonding
(5) High reliability of Cu filler conductive adhesive bonding
(6) Low temperature joining of metallic glasses



Addition of various particles into electrical conductive adhesives to improve the performance of electrical conductive adhesive
(a) With low melting point metal
(b) With nano-particles



Influence of Co addition to Sn-3.5Ag solder on intermetallic compound at solder/Cu interface

Major Papers

S. Zhou, Y.-A. Shen, T. Uresti, V. C. Shunmugasamy, B. Mansoor and H. Nishikawa, "Improved Mechanical Properties Induced by In and In & Zn Double Additions to Eutectic Sn58Bi Alloy", J. Mater. Sci. -Mater. Electron., 30, 8 (2019), 7423-7434. doi

S. Zhou, C.-H. Yang, Y.-A. Shen, S.-K. Lin and H. Nishikawa, "The Newly Developed Sn-Bi-Zn Alloy with a Low Melting Point, Improved Ductility, and High Ultimate Tensile Strength", Mater., 6 (2019), 100300. doi

Z. Jin, Y.-A. Shen, S. He, S. Zhou, Y. C .Chan and H. Nishikawa, "Novel Polarity Effect on Intermetallic Compound Thickness Changes during Electromigration in Cu/Sn-3.0Ag-0.5Cu/Cu Solder Joints", J. Appl. Phys., 126, 18 (2019), 185109. doi

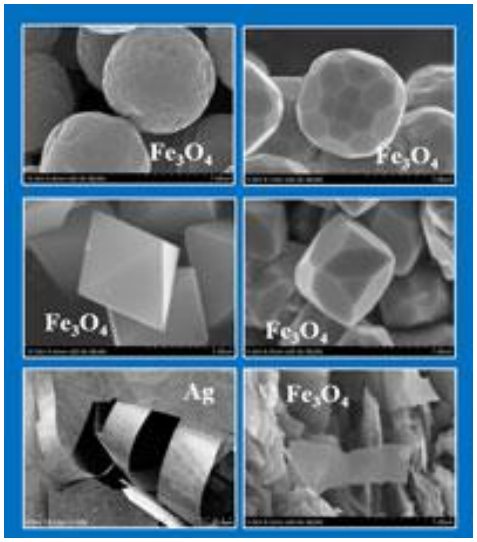
Smart Processing Research Center, Dep. of Life-Innovation Materials Processing

Research summary

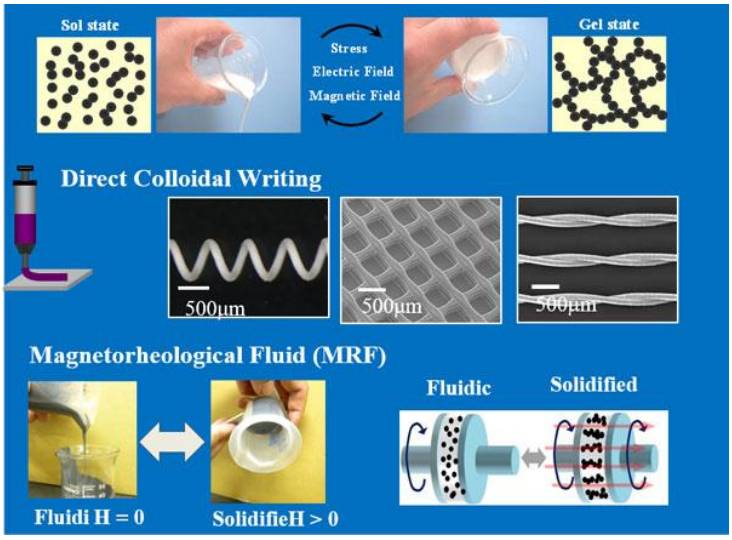
This department focuses on developments of new materials and their processing technologies that contribute to the life-innovation, aiming to realize a sustainable and healthy society from the viewpoint of advanced process science. In particular, we will develop functional materials including magnetorheological fluids that have human-friendly power transmission for next-generation rehabilitation robots. In addition, we will explore processing methods for the life-innovation materials, based on nanostructural controls of various joint configurations including solid-liquid interfaces.

Research subjects

(1) Synthesis of Fine Particles using Solution as Reaction Field and their Function Search
(2) External Stimulus Response of Fine Particle Dispersion System and its Applications
(3) Development and Applications of Directed Patterning of Fine Particles on Soft Matters
(4) Development and Applications of Advanced Assembling Technology of Fine Particles



Nano / micro materials synthesized though wet-chemical route in this laboratory, aiming for material developments.



Development of stimuli responsive colloidal dispersions and their applications to 3D printing technology and functional fluids materials (magnetorheological fluid).

Major Papers

H. Abe, T. Naka, K. Sato, Y. Suzuki and M. Nakano, "Shape-Controlled Syntheses of Magnetite Microparticles and Their Magnetorheology", Int. J. Mol. Sci., 20, 15 (2019), 3617-1-3617-11. doi

H. Abe, A. Kondo and K. Sato, "Free-polymer-induced Gelation of Non-aqueous Colloids for Direct", Ceram. Mod. Thecnol., 1, 2 (2019), 99-103. doi

K. Sato, C. Iwata, N. Kannari and H. Abe, "Highly Accelerated Oxygen Reduction Reaction Kinetics in Colloidal Processing-Derived Nanostructured Lanthanum Strontium Cobalt Ferrite/gadolinium-Doped Ceria Composite Cathode for Intermediate-Temperature Solid Oxide Fuel Cells", J. Power Sources, 414 (2019), 502-508. doi

K. Fukui, Y. Nakamura, H. Abe and Y. Suzuki, "Hydrothermal Synthesis and Electrochemical Capacitor Application of Urchin-Like $NiCo_2O_4$ Particles: Effect of Urea Concentrations", J. Ceram. Soc. Jpn., 127, 11 (2019), 843-848. doi

Hitachi Zosen Advanced Welding Technology Joint Research Chairs

Research summary

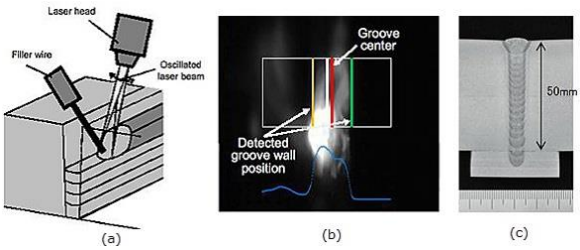
This research chair has been developing welding technology to realize international competitive manufacturing for wide range of thick-plate structures by fusing advanced technologies owned by JWRI and Hitachi Zosen Co. It aims to realize smart manufacturing factory.

The high power laser technology for thick plate welding developed in this chair has reached a practical level at the factory. Now, we are developing the foundation of the digital welding technology required at next generation like process simulation technology and waveform controlled the high heat input digital submerged arc welding technology.

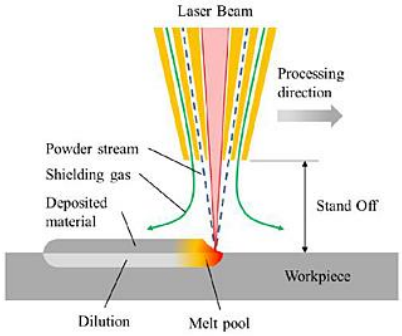
Furthermore, as a new development of laser welding technology, we will promote the development of three dimensional overlay welding technology that realizes high wear resistance by utilizing blue laser etc.

Research subjects

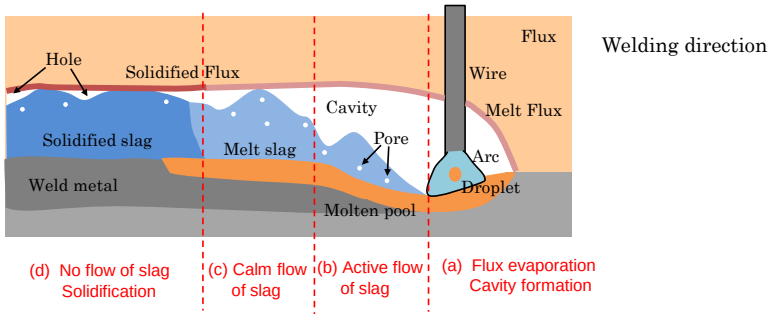
(1) Development of Laser Welding Technology for Thick Plate
(2) Development of High Efficiency SAW Technology
(3) Development of Overlay Welding Technology using Additive Manufacturing
(4) Smart Welding & Manufacturing System



Laser Multi-layer Welding Technology for Thick Plate
(a) Schematic diagram of welding process
(b) Schematic diagram of gap sensing system
(c) Groove shape and cross section of weld



Overlay Welding Technology using Additive Manufacturing



SAW Phenomena

Major Papers

T. Fujimoto, M. Hirano, E. Fujimoto, Y. Abe, M. Nakatani, M. Shigeta and M. Tanaka, "Effects of the Shielding Gas Flow on the Blowhole Generation for Aluminum Alloys Laser Welding", The 72nd IIW Annual Assembly & Int. Conf., Bratislava, Slovakia (2019.7.8-13)

Y. Abe, M. Nakatani, T. Fujimoto, M. Shigeta and M. Tanaka, "Investigation of Welding Condition for Narrow Gap Submerged Arc Welding", The 72nd IIW Annual Assembly & Int. Conf., Bratislava, Slovakia (2019.7.8-13)

Osaka Fuji "Advanced Functional Processing" Joint Research Chairs

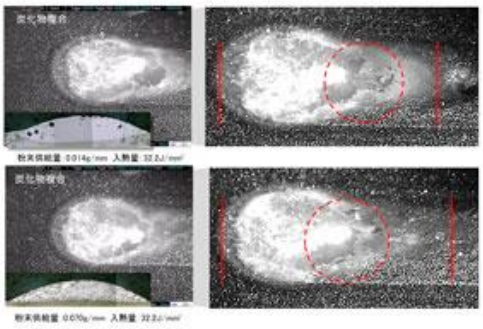
Research summary

This research chair aims to develop advanced functional processing technics by combining laser processing technology and materials knowledge in JWRI and advanced functional manufacturing technologies of Osaka Fuji Corporation.

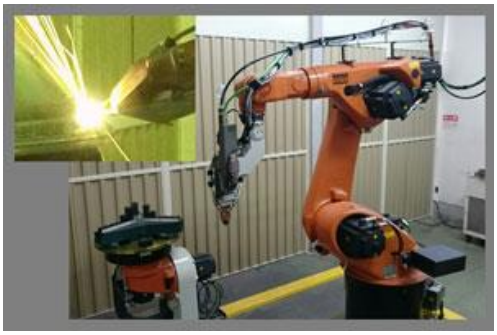
The main purpose is to develop the surface functioning of various materials by laser cladding method, low weldability materials. Finally, these fruits are applied to the next generation of manufacturing technology for various industrial fields.

Research subjects

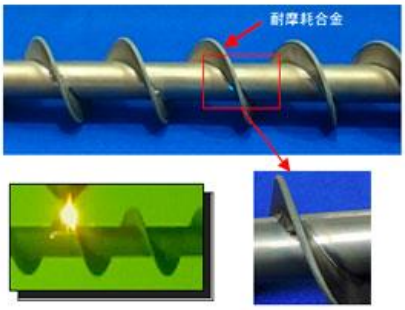
(1) Development of highly functional surface by laser cladding
(2) Development of functional surfaces of small or thin parts
(3) Development of hybrid technology of laser and conventional surfacing technologies
(4) Fundamental research of laser additive manufacturing technology



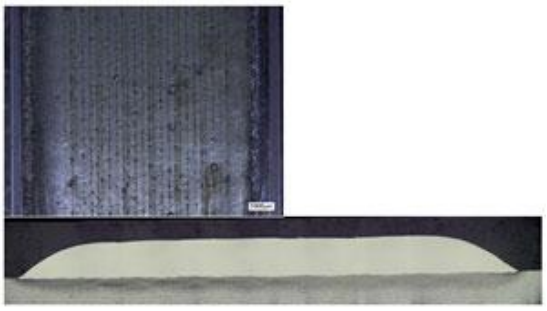
Dynamic observation of molten pool behavior for analysis of blow halls formation using high-speed camera



Experimental apparatus for laser cladding



Example of laser cladding on edge of screw



Wide, flat cladding layer which was provided by beam control

Major Papers

Y. Sato, M. Tsukamoto, T. Shobu, Y. Funada, Y. Yamashita, T. Hara, M. Sengoku, Y. Sakon, T. Ohkubo, M. Yoshida and N. Abe, "In Situ X-ray Observations of Pure-Copper Layer Formation with Blue Direct Diode Lasers", Appl. Surf. Sci., 480 (2019), 861-867. doi

K. Morimoto, M. Tsukamoto, S. Masuno, E. Hori, Y. Sato, S. Kato, K. Azumi, Y. Hayashi and N. Abe, "High Quality Welding of Pure Copper Plate with High Intensity Blue Diode Laser", 38th Int. Congress on Applications of Lasers & Electro-Optics (ICALEO 2019), Orlando, FL, USA (2019.10.7-10)

E. Hori, M. Tsukamoto, S. Masuno, K. Morimoto, Y. Sato, S. Kato, K. Azumi, Y. Hayashi and N. Abe, "Influence of Laser Wavelength on Weld Quality in Bead-On-Plate Welding of Pure Copper with High Intensity Blue Diode Laser", 38th Int. Congress on Applications of Lasers & Electro-Optics (ICALEO 2019), Orlando, FL, USA (2019.10.7-10)

K. Morimoto, M. Tsukamoto, S. Masuno, K. Azumi, Y. Hayashi and N. Abe, "Influence of Laser Wavelength on Melt Pool Behavior in Welding of Thin Pure Copper Plate with Blue Diode and Fiber Lasers",Lasers in Manufacturing （LiM2019）, Munich, Germany (2019.6.24-27)

Development Base on Development of Interdisciplinary and International Researchers for Creation of Life Innovation Materials

Research summary

The Project, Development Base on Creation of Life Innovation Materials for Interdisciplinary and International Researcher Development, has started from 2016 as inter-university cooperative research project (Joining and Welding Research Institute, Osaka Univ., Institute for Materials Research, Tohoku Univ., Laboratory for Materials and Structures, Tokyo Institute of Tech., Institute of Materials and Systems for Sustainability, Nagoya Univ., Institute of Biomaterials and Bioengineering, Tokyo Medical and Dental Univ., Research Organization for Nano & Life Innovation, Waseda Univ.) This development base promotes the joint research for development of life innovation materials for applications in the environment and medical fields through the inter-university cooperative researches by the 6 research institutes at 6 universities.

Research subjects

(1) Environmental and sustainable materials
(2) Biomedical and healthcare materials
(3) Base materials and technology

6 universities cooperative research project

(1) Joining and Welding Research Institute, Osaka Univ.
(2) Institute for Materials Research, Tohoku Univ.
(3) Laboratory for Materials and Structures, Tokyo Institute of Tech.
(4) Institute of Materials and Systems for Sustainability, Nagoya Univ.
(5) Institute of Biomaterials and Bioengineering, Tokyo Medical and Dental Univ.
(6) Research Organization for Nano & Life Innovation, Waseda Univ.

Research subjects

(1) Environmental and sustainable materials
(2) Biomedical and healthcare materials
(3) Base materials and technology

Cooperation system of the six research institutes at six universities

Major Papers

G. Alkan, L. Mancic, S. Tamura, K. Tomita, Z. Tan, F. Sun, R. Rudolf, S. Ohara, B. Friedrich and O. Milosevic, "Plasmon Enhanced Luminescence in Hierarchically Structured Ag@ $(Y_{0.95}Eu_{0.05})_2O_3$ Nanocomposites Synthesized by Ultrasonic Spray Pyrolysis", Adv. Powder Technol. (2019), 1409-1419. doi

Z. D. Dai, X. Z. Song, X. L. Kang, J. K. Cao, H. Abe, S. Ohara and Z. Q. Tan, "Controlled Synthesis of TiO_2 Nanosheets with Exposed (001) Facets for Enhanced Photocatalytic Activity", IOP Conf. Ser. : Mater. Sci. Eng., 479, 1 (2019) 012120. doi

Center to Create Research and Educational Hubs for Innovative Manufacturing in Asia

Summary

From FY 2013-FY 2018, the project called "Center for the Project to Create Research and Educational Hubs for Innovative Manufacturing in Asia" were implemented to establish new joining and welding technologies, to create global research networks, and to cultivate global leaders in the region.

From FY 2018 namely the second phase, based on the research network established through former activities, the project will continue aiming to strengthen and obtaining higher international competency both in institution wide and in university wide through high quality international collaborative research by having organic cooperation with ASEAN Campus Programme and with Global Knowledge Partners promoted by Osaka University.

As in detail, two pillars are set as follows: 1) Strengthen International Collaborative Research: Increase number of international co-authored papers by implementing international collaborative research with overseas universities, establish international joint laboratory, 2) Conduct practical Global Leader Training: Implement Inbound & Outboud Coupling Internship (CIS) both overseas and domestic which is composed of students from different majors and cultural background.

Activities

(1) Strengthen International Collaborative Research: Increase number of international co-authored papers by implementing international collaborative research, establish international joint laboratory

(2) Conduct practical Global Leader Training: Implement Inbound & Outboud Coupling Internship (CIS) both overseas and domestic which is composed of students from different majors and cultural background.

Table.1 Some major international joint research topics in FY 2019 (Excerpt)

Partner	Research Topics
Shanghai Jiao Tong University	Coaxial one-side resistance spot welding (COS-RSW) of Al and CFRP
Shanghai Jiao Tong University	Friction self-piercing riveting of high strength aluminum alloy AA7075-T6
University of Technology Malaysia	Synthesis of copper matrix composites with TiB2 particles
University of Technology Malaysia	Microstructure control of high oxygen concentration dual phase Ti via hot extrusion

Table.2 Some major papers issued in FY 2019 (Excerpt)

	Papers
1	A. Bahador, Shota Kariya, Junko Umeda, Esah Hamzah, and Katsuyoshi Kondoh, Tailoring Microstructure and Properties of a Superelastic Ti–Ta Alloy by Incorporating Spark Plasma Sintering with Thermomechanical Processing, /Materials Engineering and Performance (IF=1.5)/*//*, Vol. 28, PP:3012-3020 (2019).
2	A. Bahador, Junko Umeda, Seiichiro Tsutsumi, Farazila Yusof, Esah Hamzah, and Katsuyoshi Kondoh, Asymmetric Local Strain, Microstructure and Superelasticity of Friction Stir Welded Nitinol Alloy, /Journal of Materials Science Engineering A/(IF=4),Vol. 767, (2019).
3	A. Bahador, Junko Umeda, Esah Hamzah, Farazila Yusof, Xiaochun Li and Katsuyoshi Kondoh, *Synergetic Strengthening Mechanisms of Copper Matrix Composites with TiO**_2 **Nanoparticles*, */Journal of Materials Science Engineering A (IF=4)/*/,/ Vol. 772, pp:138797,(2020).
4	Sendong Ren, Yunwu Ma, Shuhei Saeki, Yoshiaki Iwamoto, Ninshu Ma, Numerical analysis on coaxial one-side resistance spot welding of Al5052 and CFRP dissimilar materials. Materials &Design, 2020. 188: p. 108442.
5	Yunwu Ma, Bingxin Yang, Ming Lou, Yongbing Li, Ninshu Ma, Effect of mechanical and solid-state joining characteristics on tensile-shear performance of friction self-piercing riveted aluminum alloy AA7075-T6 joints. Journal of Materials Processing Technology, 2020, 278, 116543

Table. 3 List of Coupling Internship in FY 2019

Location	Host Company	Partner University
Thailand	OTC Daihen	Kasetsart Univ.
Vietnam	IHI Infrastructure Asia	Hanoi Univ. of Science and Tech.
Myanmar	J&M Steel Solutions	Yangon Tech. Univ.
Indonesia	Cilegon Fabricators	Indonesia Univ.
Aioi, Japan	IHI Aioi Works	Indonesia Univ.(Indonesia)
Kobe, Japan	Daihen Corporation	King Mongkut Univ. of Tech. Thonburi (Thailand)

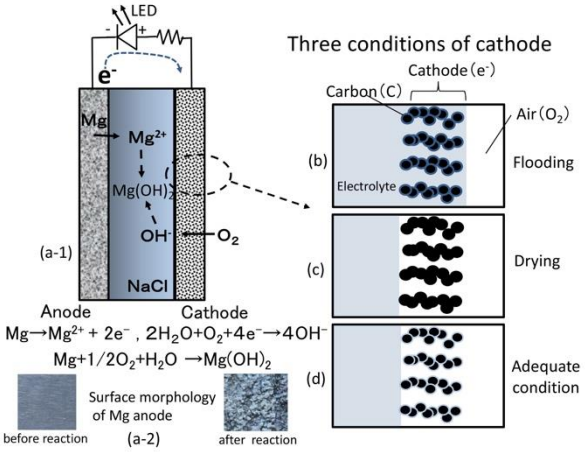
R&D Project for Environmental Resources and ECO Joining

Research summary

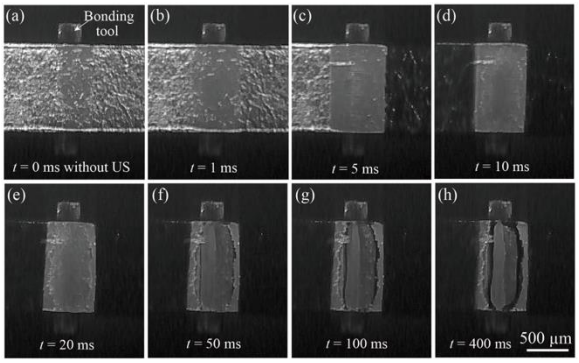
We study concerning the energy system/environmental resources and ECO-joining in this project. An environment harmony energy device, for example, Mg-air battery is being developed to prepare lighting for blackouts due to natural disasters of earthquakes and typhoons. It is, also, very important to improve energy efficiency and to save resources by establishing bonding technologies adequate for manufacturing ecological products without toxic substances. Micro-joining processes for advanced electronic assembly such as wire and ribbon bonding have been studied. These micro-joining processes can be applied as a low temperature bonding method to ECO electronic packaging. This is applied to rapid bonding of dissimilar materials. Also, the study of joint-defect detection is necessary to repair and restore the concrete infra-structures. We have conducted the defect detection, using a laser Doppler technique and AI (artificial intelligence) deep learning system. Establishment of the way to sustainable human society overcoming global environmental problems is the final purpose of the R&D project.

Research subjects

(1) Cathode materials design of Mg-air battery
(2) Improvement of structures of Mg-air battery for establishing the long lift and high power
(3) Development of Mg-air battery for charging smartphones
(4) Solid state micro joining (ultrasonic joining) for power electronic packaging
(4) Interfacial nanostructures between wide-gap semiconductors and their electrodes.
(5) Study of joint-defect detection of infra-structures, using the laser Doppler technique and AI deep learning system
(6) Study of separation and collection of toxic substances
(7) Study of sustainable system for cleating environmental resources.



Schematic illustrations of structures and working principle of Mg-air battery. (a-1) Overall structures of Mg-air battery and chemical reactions, (a-2) Surface morphology of Mg anode, (b) Carbon cathode when flooding is produced, (c) When drying condition, (d) Adequate condition. Carbon cathodes should have hydrophilic and hydrophobic characteristics.



In-situ observation results (video captures) of the bonding interface between Al ribbon and silica substrate taken at F_{rate} = 10^3 fps. The bonding condition was F_b = 7 N and P_u = 4 W. (a) t = 0 ms, (b) t = 1 ms immediately after introducing ultrasonic vibration, (c) Apparent bonded area increases at t = 5 ms, (d) Apparent bonded area decreases at t = 10 ms due to Al ribbon warping; (e) t = 20 ms, (f) Central belt zone begins to be observed at t = 50 ms, (g) t = 100 ms, (h) t = 400 ms.

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