Materials joining technologies and interface science for integration of novel structured metallic and inorganic materials†

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1. Research Activities of JWRI, Osaka University

Since the foundation originally as "*Welding Research Laboratory*" in 1969 at Osaka University, the Joining and Welding Research Institute (JWRI) has devoted research activities to better understanding of fundamental mechanisms involved in joining and welding science and development of industrial technologies in wide scales of structures ranging from huge constructions including nuclear power plants, ships and tall buildings to micro and nano-scales including microelectronic devices and nanoparticles, as key technologies for manufacturing functional structures.

With a variety of high-energy-density beams (arc discharge, lasers and electron beams) as well as other types of heat source including frictional heat, JWRI has carried out investigations on welding and joining, creation of advanced materials and composites, highly functional surface modifications, and development of novel technologies including space welding.

Since the restructuring of the JWRI in 1996, the JWRI has consisted of three divisions (the research division of Materials Processing System, the research division of Materials Joining Mechanism, and the research division of Functional Assessment) and the Smart Processing Research Center.

2. Research Division of Materials Processing System

This division is oriented to provide scientific bases for generation, conversion, transfer of processing energy sources and interaction with materials for well-controlled multi-functional processes and development of high-quality energy sources suitable for various materials processing.

In particular, the division has made great contributions to development of various advanced materials processing systems with concentrated and dispersed energy sources, which are expected to have wide application fields in the future. Major emphasis is placed on the developments of advanced monitoring and estimating techniques for material processing and the systematization of the functional materials processing technology through interpretation of phenomena relating to the high energy involved in the processing.

3. Research Division of Materials Joining Mechanism

This division has devoted research activities for investigation of the physical and chemical properties of high performance joints and composites produced by welding and joining, and the control of the joint microstructure by highly-controlled material processing.

The results of these investigations have been applied to the designing and development of optimum materials for joining and welding. Investigation is also made of the modification of the joint microstructure by well-controlled materials processing using laser and thermal energies.

4. Research Division of Functional Assessment

The structures studied in this division are not only large-size welded structures including ships, bridges, and nuclear reactors, but also microelectronic and nano structures, which have specific structures and functions, and frontier structures used in space and in the deep sea. The researches progress under the balance between social usefulness and the conservaton of environment and resources.

5. Smart Processing Research Center

The Smart Processing Research Center was established in 2003 by consolidating two centers, i.e., the Research Center for Ultra High Energy Density Heat Source, and the Research Center for Materials Recycling and Integration, to develop advanced processes for nano and micro-structured materials, thereby contributing to the establishment of next

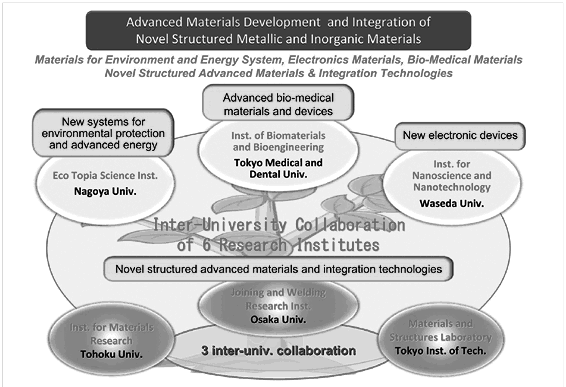

Fig. 1. Cooperation of the six Research Institutes.

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generation manufacturing that can encourage industries to minimize any negative impact on the environment.

To establish the advanced science and technology in the global research field of welding and joining processes, JWRI is making continuous and significant efforts to obtain instructive and informative R&D results by intelligent innovation.

6. Development Base of Advanced Materials Development and Integration of Novel Structured Metallic and Inorganic Materials

The project, Development Base of Advanced Materials Development and Integration of Novel Structured Metallic and Inorganic Materials (**Fig. 1**), started in 2010 as inter-university cooperative research project (Joining and Welding Research Institute, Osaka Univ., Institute for Materials Research, Tohoku Univ., Materials and Structures Laboratory, Tokyo Institute of Tech., Eco Topia Science Institute, Nagoya Univ., Institute for Nanoscience and Nanotechnology, Waseda Univ., Institute of Biomaterials and Bioengineering, Tokyo Medical and Dental Univ.). This development base promotes the joint research for development of new functional materials by integration of novel structured metallic and inorganic materials for applications in the specific fields including environment&energy, electronics, and biomedical materials through the inter-university cooperative researches.

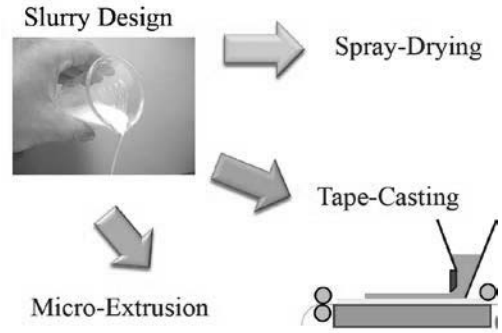

Fig. 2. Nano-particle based technologies.

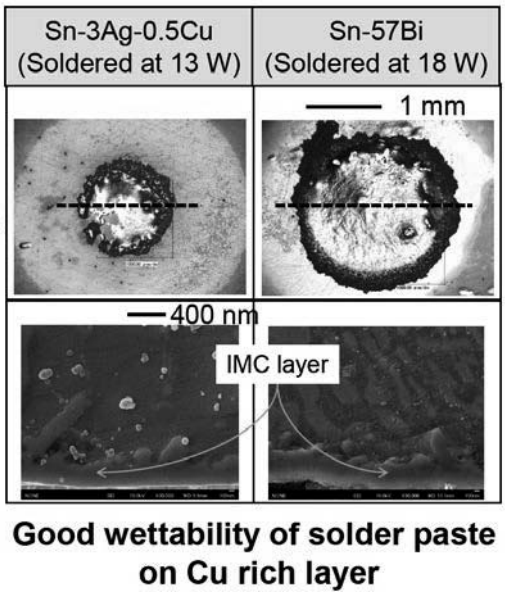

Fig. 3. Soldering technologies.

7. Global Collaborative Research Center for Computational Welding Science (CCWS)

The JWRI proposed the concept of computational welding science as early as the 1970's. It is one of the world pioneers in this field and has organized an international symposium on "Theoretical Prediction in Joining and Welding" in 1996. In further development of computational welding science, JWRI conducted a project on "Development of Highly Efficient and Reliable Welding Technology" which has been supported by the New Energy and Industrial Technology Development Organization (NEDO). One of the main objectives of this project is to establish a framework of the computational welding science which covers the entire aspects of welding, i.e. Welding Process, Welding Metallurgy and Welding Mechanics. This framework has been further developed to meet various demands from the industry.

8. Research Activities for the Project "*Advanced Materials Development and Integration of Novel Structured Metallic and Inorganic Materials*"

In the present project, research and development activities are underway in the following fields of investigations; 1) Development of Materials for Environment and Energy System, 2) Development of Electronics Materials, 3) Development of Bio-Medical Materials, 4) Development of Novel Structured Advanced Materials and Integration Technologies.

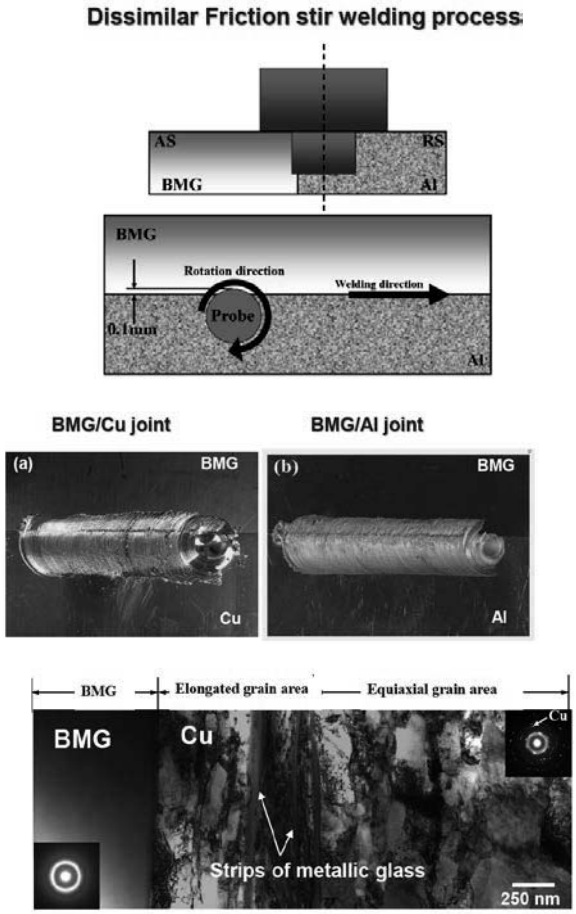

Fig. 4. Friction stir welding of bulk metallic glasses.

In the research field for Environment and Energy System, JWRI is to contribute to develop Environment and Energy Systems with metallic glasses and advanced ceramics via nano-assembly technologies (nano-particles, slurry and casting, **Fig. 2**), micro-assembly technologies, dissimilar materials joining technologies based on laser welding and nano-surface modification with advanced plasma processing.

For development of Electronics Materials, the JWRI is to contribute to develop device fabrication technologies via soldering technologies (**Fig. 3**) and plasma processing technologies. For the development of Bio-Medical Materials, JWRI is to make approaches via nano-particle technologies and bio-ceramics coating with advanced surface modification technologies.

Furthermore, in the field of Development of Novel Structured Advanced Materials and Integration Technologies, a variety of research activities are to be carried out for the establishment of scientific and technological bases of joining of metallic glasses and advanced ceramics materials. (**Fig. 4**)