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NEWSLETTER

An Initiative of ISAJ

Inside This Issue

ISAJ Symposium 2023 Announcment

14^{th} ISAJ Symposium

Integrated Science for a Sustainable Society

November 10, 2023 (Friday)

Venue: Conference Hall (5th floor), CRIS building, Hokkaido University (north campus), Kita 20 Nishi 10, Sapporo, Japan

From Editor's Desk

Greetings and a warm welcome to this issue of ISAJ Newsletter in 2023! We apologize for our silence since our issue in the last year.

In this issue, we present you with two research articles and event report on 13th Annual ISAJ Symposium-2022. The Research articles are on thermoelectric energy harvesting and room temperature formability of pure magnesium by grain refinement. This issue also contains pictures of our 13th annual symposium held near the end of last year.

Under the Research Spotlight section, we present you an article discussing the concept, challenges and technologies innovations in the field of thermoelectric energy harvesting. This topic is of utmost importance today for environmental conservation. Author has briefly explained the working concept of thermoelectric harvesting devices and their performances. The article also discusses the challenges and applications of technology.

The second research article is also closely related to environmental conservation. Magnesium and its alloys being the lightest of all structural metals (for use in infrastructure, including transportation), its use in automobiles can save considerable fuel. The research article on room temperature formability of pure magnesium summarizes experimental investigation of grain size impacts on deformation twining, dislocation slip and grain boundary sliding. Author has concluded that with decrease in grain size, deformation twining decreases and dislocation slips becomes dominating phenomena which enhances the compressibility of pure magnesium. Mechanical behavior of pure magnesium with different grain size are also presented in this article.

ISAJ organized its 13th Annual Symposium on November 18 (Fri), 2022 in the main auditorium of Embassy of India, Tokyo. The symposium theme was "Frontiers of Materials, Life & Earth Sciences and Beyond". There were about 90 participants, including 12 plenary speakers, 8 invited speakers and 47 poster presenters. Five young researchers gave oral presentations in addition to the poster presentation. We present an overview of the Annual Symposium in the Event Report section of this issue. We also present results of a post-symposium questionnaire survey of the participants.

We hope you would find the present issue of our Newsletter interesting. We look forward to receiving your feedback. Any suggestions/ideas for improving the upcoming newsletters are welcome.

Editor(s)
Swapnil Ghodke
Mahendra Kumar Pal

Research Spotlight

Thermoelectric energy harvesting: Concept, challenges, and technology

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Currently a process development engineer (R&D) at Advanced Semiconductor Materials international (ASM), Japan. Prior to this, he worked as a designated assistant professor and postdoc at Nagoya University. During 2016-2019, he was a postdoc at Toyota Technological Institute, Nagoya. He received his PhD from Nagoya University with scholarship from JICA.
Dr. Swapnil is working on the development of non-toxic, low-cost, environmentally friendly, high-performance hybrid lead-free piezoelectric and thermoelectric materials for the device applications.

Introduction

Electrical energy plays an essential part in modern human society. Energy is generated by consuming non-renewable resources, which are also responsible for releasing greenhouse gasses into the atmosphere. Greenhouse gases can hamper the ecological balance by disrupting the ecosystem through global warming and climate change. The imbalance in demand and supply of these limited energy resources also forecasts a global energy crisis for the future generation. The solution to the above problems lies in alternative energy resources and/or new technologies with higher efficiencies of energy conversion.

Concept

Thermoelectric generators (TEGs), which are solid-state devices that can convert waste heat into useful electrical energy and wise versa without any moving mechanical parts or fluids, are emphasized as one of the potential technologies to reduce the carbon footprint and utilize the energy resources more efficiently.

The concept is very simple. When a temperature difference is applied across a substance that easily conducts electricity, such as a metal or a semiconductor, a voltage (thermal electromotive force) is generated across the substance. The thermoelectric effect is the mutual influence of this thermal energy and electrical energy, and one of them is a phenomenon called the "Seebeck effect" in which the temperature difference between two junctions is directly converted into a voltage.
The efficiency of energy conversion in TEGs is an increasing function of the dimensionless figure-of-merit,

$$\eta = \frac{T_H - T_C}{T_H} \frac{\sqrt{1+ZT}-1}{\sqrt{1+ZT}+\frac{T_C}{T_H}} \quad (1)$$

Here, T_H and T_C represent the temperature of the hot end and the cold end, $ZT = S^2\sigma T\kappa^{-1}$, where S, σ, T, and κ stand for the Seebeck coefficient, electrical conductivity, absolute temperature, and thermal conductivity of constituent thermoelectric materials, respectively. The efficiency of energy conversion in TEGs is directly proportional to electrical conductivity and Seebeck coefficient while inversely to thermal conductivity.

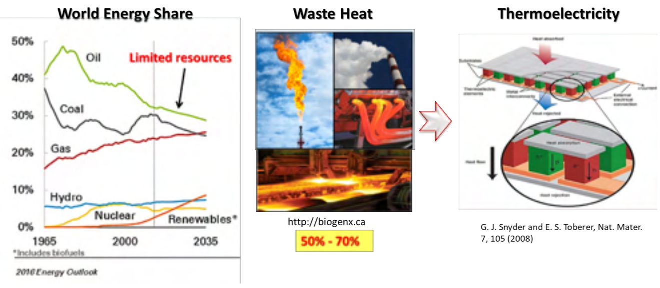

Fig. 1 Consumption of nonrenewable resources for global energy need, waste from of energy in heat, and TEG and energy harvesting technology.

Challenges and Strategies for High-Performance Materials

A high-performance thermoelectric material should possess high power factor $S^2\sigma$ along with low lattice thermal conductivity. This means a material must be a good conductor of electricity and a poor conductor of heat. Theoretically, all the physical quantities are strongly coupled with each other, which makes it more challenging to obtain a high-performance thermoelectric material. Since early 1900s, extensive research has been carried out for obtaining high-performance thermoelectric materials found out that semimetals could be used for practical applications by improving their thermoelectric properties through novel strategies such as reducing lattice thermal conductivity through grain boundary scattering, nanostructuring, composite effect, quantum dot superlattices, amorphous structures, modulation doping, and nanoporous structures.

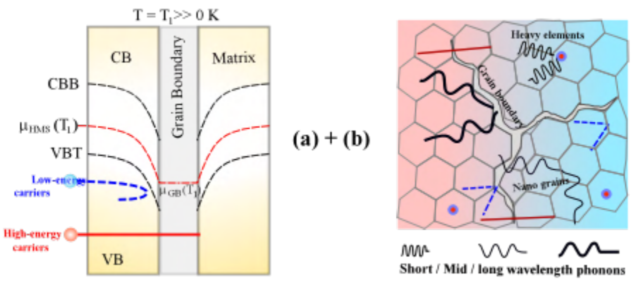

Fig. 2 Strategy of energy filtering and phonon scattering strategy for high-performance TEG [Ghodke et al. *ACS Appl. Mater. Interfaces* 2019, **11**, 34, 31169–31175].

Numerous state-of-art thermoelectric materials have been reported with ZT more than unity in different temperature range; SnSe (ZT = 2.6), PbTe (ZT 1.8), BiSbTe (ZT 1.86), ZnSb (ZT 1.3), Cu_2Se (ZT ¿ 2), Mg_2Si (ZT 1.3), TAGS (ZT 1.5), MnSi (ZT 1.15). Using these materials, the equivalent efficiency of energy conversion from waste heat to electrical energy in practical applications varies in the range of 5% to 15% depending on the applied temperature range.

The Applications: Mars Rovers to IoT Devices

TEGs became very famous when NASA in the 1970s utilized this technology in radioisotope thermoelectric generators for deep space missions and interplanetary explorations (Mars rovers). Along with technological advancements, TEG technology has been used for energy harvesting in automobiles, power plants, or industries.

Fig. 3 TEG concept tested for efficient exhaust in automobile by BMW, and RTEG used by NASA for Mars Rover.

In recent years with the growth of IoT devices and wireless technology, TEGs have come into use for day-to-day life applications in form of wearable battery-free devices. Here, the human body heat as a source is used to generate electric power for such devices as digital watches, health monitoring patches, etc. Autonomous power sources for sensors generally do not require large amounts of power and can be sustained from ambient sources with stable power supply, solely on TEGs.

Fig. 4 An overview of wearable thermoelectric generator and applications. [*Adv. Mater.* 2021, 2102990].

Research Highlight

Enhancement of room-temperature formability of pure magnesium by grain refinement

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Currently a postdoctoral researcher at the NIMS Japan (Research Centre for Structural Materials). He was previously a Research Fellow at Tohoku University (Institute for Materials Research). He received his doctorate from Tohoku University, in September 2016.

He specializes in alloy design, processing, microstructure, and mechanical characterization of metallic materials such as steel, titanium alloys, magnesium, and their alloys.

His current research focuses on the development of high-performance steels and magnesium through composition optimization and/or thermo-mechanical processing.

Introduction

The increased greenhouse gas emissions are known to contribute to recent climate changes. One of the ways to address the issue is to make light weight structures. For instance, a vehicle weight reduction by 10% can lead to a 6 - 8% improvement in fuel economy (reduction in greenhouse gas emission) [1]. Among the commonly used materials for automotive materials, Magnesium and its alloys are the most promising candidate for lightweighting, since magnesium is 75% lighter than steel and 33% lighter than aluminium. It also shows high specific strength and damping capacity [2]. The room-temperature formability of magnesium is inferior to that of aluminium, limiting its widespread application. Its poor formability is due to its hexagonal crystal structure, which has only two independent easier slip systems (basal slip) at room temperature, which is insufficient for continuous deformation according to the Von Mises criterion [3]. Furthermore, twinning is more visible in magnesium during compression, and the formation of such twins has a negative effect on formability [4]. Recently, it was reported that the formability and compressibility of magnesium can be improved by grain refinement [5]. However, it is still unclear how the grain size affects deformation mechanisms during compression in pure magnesium, which is the objective of this work.

Commercially pure magnesium (99.96 %) was extruded at various temperature between 100 – 400° C. The schematic of extrusion process is shown in Fig.1 [6].

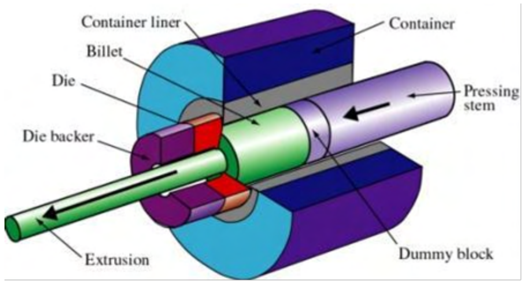

Figure. 1. Schematic illustration of extrusion process [6].

The microstructures were imaged with scanning electron microscopy (SEM) and electron back-scattering diffraction (EBSD). The representative microstructures after extrusion are shown in Figs. 2(a-c). The microstructure of the extruded sample is shown in Fig.2. The microstructure consisted of grain in equiaxed shape. The deformed structures such as shear bands and twins were not observed; hence, the initial microstructures were fully recrystallized. This was likely attributed to dynamic recrystallization during hot extrusion process. Note, the grain size of the sample extruded at 350° C is larger than the sample extruded at a lower temperature 160° C. The dependence of the average grain size on the extrusion temperature is shown in Fig.2(d). We can see that with decrease in the extrusion temperature, the average grain size is decreased.

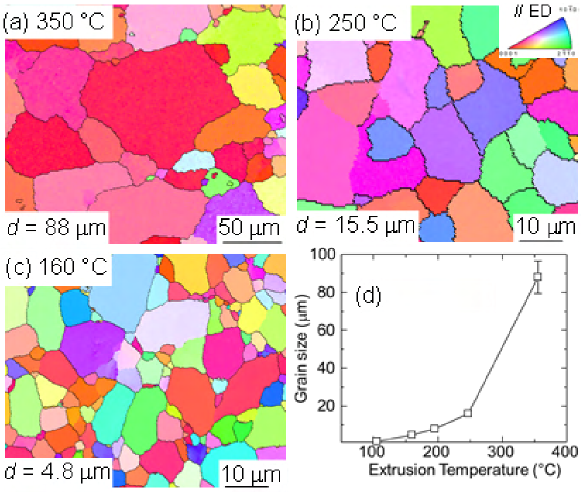

Figure. 2. (a–c) Grain orientation map of the as extruded pure magnesium and (d) Grain size as function of extrusion temperature.

From the hot extruded samples, cylindrical samples with a 10 mm height and a 5 mm diameter were machined. These cylindrical samples were then subjected to compression testing at room temperature with an initial strain rate of 1×10^{-5} s^{-1}. The compression test was performed until a fracture occurred or a 50% reduction in height (i.e., 5 mm in compression). The load-displacement data recorded during compression was used to calculate the nominal stress-strain curves, where nominal stress equals the applied force/cross-sectional area of the sample and nominal strain equals the change in length/original length of the sample. The nomical stress-strain curves of compressed sample with grain sizes of 88 μm, 15.5 μm and 4.8 μm are plotted in Fig. 3.

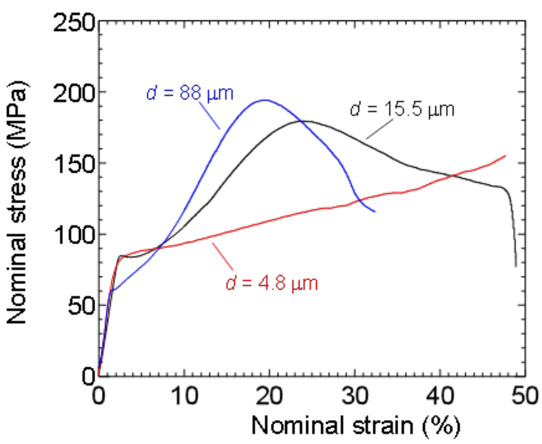

Figure 3. Effect of grain size on the stress-strain behavior of pure magnesium.

The nominal stress-strain curves of samples with 88 μm and 15.5 μm exhibit concave like profiles. Following initial yielding, a yield plateau region is observed (an increase in strain without an increase in stress), followed by a rapid increase in strain hardening and then fracture. The yield strength, yield plateau region, level of strain hardening, and fracture strain increase with the decrease in grain size from 88 μm to 15.5 μm. These behaviours were typically observed during compression of wrought magnesium and its alloys and were due to the ease with which extension twins formed [5,7]. In contrast, no plateau region was observed in the sample with grain size 4.8 μm after yielding, and no fracture of the sample was observed even after 50% compression.

The lesser concavity of the stress-strain curve profiles and increase in the fracture strain with a decrease in grain size, is likely caused by a reduction in the tendency for twining and a possible enhancement of dislocation slip and grain boundary sliding. In other words, there should be a change in the dominant deformation mechanism with decrease in the grain leading to improved compressibility. Changes in the microstructures with increasing applied strain (i.e., amount of compressive deformation) were observed to validate this. For this purpose, rectangular samples of size 3 x 6 mm were prepared and subjected to compression testing. The sample surfaces were polished to reveal the microstructure. Then several parallel-lines were drawn on the surface using focused Ga-ion beam (FIB) techniques. The deformed sample surfaces were then observed after compression to 10% and 20%.

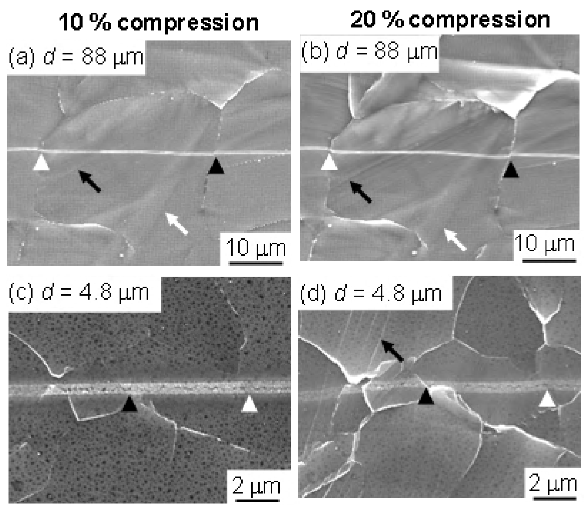

Figure 4. (a) and (b) deformed surfaces of the sample with the grain size of 88 μm. (c) and (d) deformed surfaces of the sample with the grain size of 4.8 μm. The white and black triangles correspond to locations without and with offset by grain boundary sliding, respectively. The white and black arrows denote deformation twins and slip traces respectively. The compression axis is vertical.

Figure 4 shows the effect of grain size on the deformed microstructures. The white, contrasted horizontal lines in these images were drawn using FIB before compression testing. After 10% compression, in the 88 μm sample (Fig. 4(a)), deformation twinning (white arrow), traces of slips (black arrows) are observed. Also, at some grain boundaries, the lines were not displaced (white triangle), while some were displaced (black triangle). The displacement of lines at grain boundaries indicates the occurrence of grain boundary sliding. These deformation-induced features become more noticeably clear with an increase in the compression to 20% (Fig. 4b).

On the other hand, in the 4.8 μm sample, except deformation twinning; all other deformation induced fracture are observed, especially after 20% deformation (Fig 4d(d)). In fact, the deformation twining is not frequently observed in the 4.8 μm sample, and the most dominantly observed features were traces of slips and grain boundary sliding in the investigated area.

These findings confirm that as grain size decreases, deformation twining decreases and dislocation slip and grain boundary sliding become the dominant deformations, resulting in increased compressibility of pure magnesium. This is because the formation of deformation twinning acts as a barrier to slip movement and promotes strain localization [4], leading to an earlier onset of failure. Thus, the refinement of grain size by extrusion at a lower temperature is an effective way to realize the higher compressibility and formability of pure magnesium.

References

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Event Report

13th ISAJ Annual Symposium-2022

Conveners: Dr. Elango Chandiran and Dr. Digvijay Singh,
National Institute for Materials Science, Japan

Indian Scientists Association in Japan (ISAJ) organized the 13th ISAJ Annual Symposium on "Frontiers of Materials, Life, & Earth Sciences and Beyond" at the Main Auditorium, Embassy of India, Tokyo, Japan. This year's symposium coincided with the 75th anniversary of India's independence and the 70th anniversary of the establishment of diplomatic relations between India and Japan.

Dr. Sunil Kaul, Chairman of ISAJ, gave an overview of the organization's activities outlining India-Japan collaboration in the field of science and technology in his welcome address. His Excellency Mr. Sibi George, the Ambassador of India to Japan, inaugurated the symposium with an inspiring speech. The Ambassador emphasized cooperation between India and Japan, such as the establishment of three India-Japan joint laboratories in areas of ICT, collaboration in digital technologies, start-up ecosystems, climate change and energy-related initiatives, and the efforts of ISAJ toward institutional engagements.

Professor Atsushi Suzuki (Yokohama National University) was presented with the ISAJ Lifetime Achievement Award for 2022, by His Excellency the Ambassador of India to Japan for his contribution on "Bridging between India and Japan researchers to strengthen research collaborations and co-operations in science and technology." The conveners gave a brief overview of the symposium. The inaugural session was then concluded with a vote of thanks from Dr. Alok Singh, Vice Chairman of ISAJ, thanked all the participants and guests for joining the symposium, the organizing committee members, the Embassy of India in Japan, donors, and sponsors for their support in making this symposium a great success.

Plenary and invited talks were given by established experts in various fields of science and technology from prestigious universities and research institutions. Response to the call for abstracts was overwhelming, with participants of various nationalities (India, Japan, Italy, France, Ukraine, Indonesia, and so on) associated with academic and research institutions across Japan and India. There were 12 plenary talks, 8 invited talks, and 47 poster presentations at the symposium. Five young researchers gave oral presentations in addition to the poster presentation. Three poster presenters were awarded with best presentation awards.

About 90 participants from various fields of science and technology took part in this year symposium. The participants included 14 eminent researchers, 7 professors, 6 young faculty members and 55 young researchers from academic and research institutes.

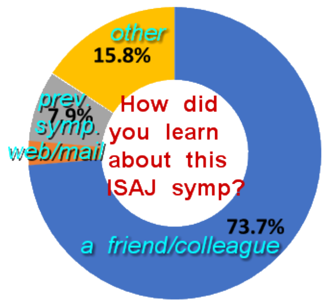
Research topics covered by plenary and invited speakers induced carbon dots, earth system modeling, tissue engineering, pandemic prediction, solar cells, organic chromophores, electron microscopy techniques, Aakash project, Ni-based superalloys, metallo-supramolecular polymers, smart hydrogels, engineered phage capsids, and more.

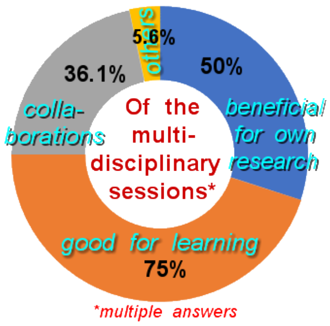
Participants institutions included National Institute for Materials Science (NIMS), The Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Yokohama National University, Japan Advanced Institute of Science and Technology (JAIST), Tohoku University, IIT Delhi, Research Institute for Humanity and Nature (RIHN), Tokyo Institute of Technology, University of Tokyo, University of Tsukuba, Jichi Medical University, Keio University, National Institute of Advanced Industrial Science and Technology (AIST), and others.

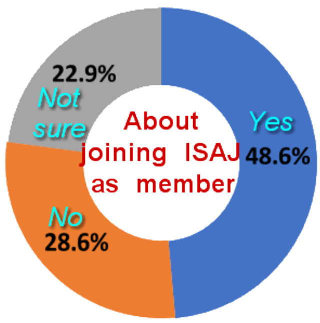
The symposium was concluded with the poster presentation awards to young researchers (all equal), recommended by a panel of experts from the diverse field of science and technology. The awards were presented by Mr. Mayank Joshi, Deputy Chief of the Mission of the Embassy of India in Japan, to Ms. Vanshita Sharma (Toyama Prefectural University), Dr. Barun Kumar Barman (National Institute for Materials Science) and Dr. Seema Choudhury (High Energy Accelerator Research Organization). Each poster award includes shopping vouchers worth 20,000 yen.

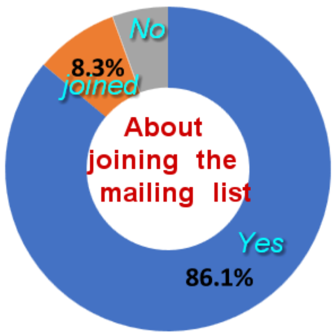
13th ISAJ Annual Symposium-2022

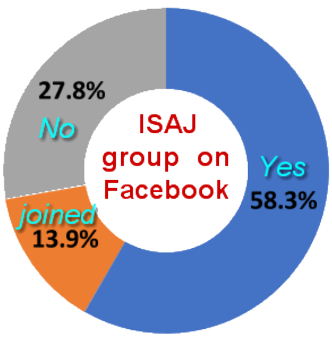
A survey was conducted by a questionnaire after the Annual Symposium of ISAJ in 2022. Participants have expressed enthusiasm about the symposium and have given opinion and made suggestions. Results of the survey are presented below.

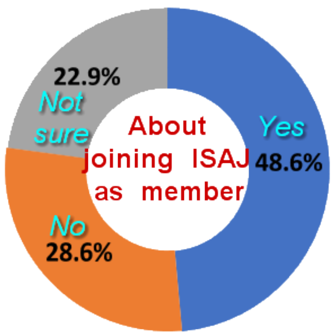


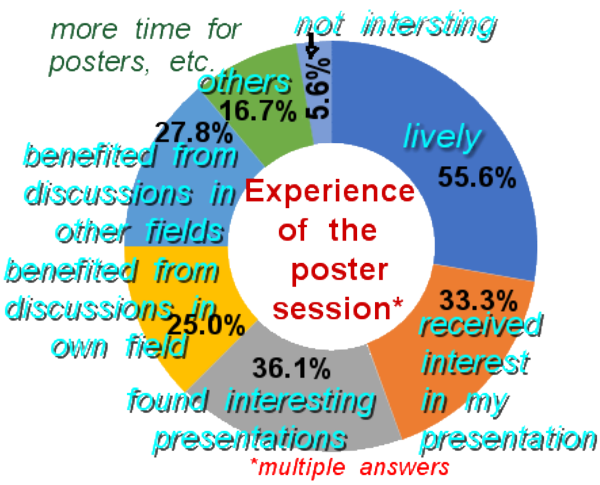












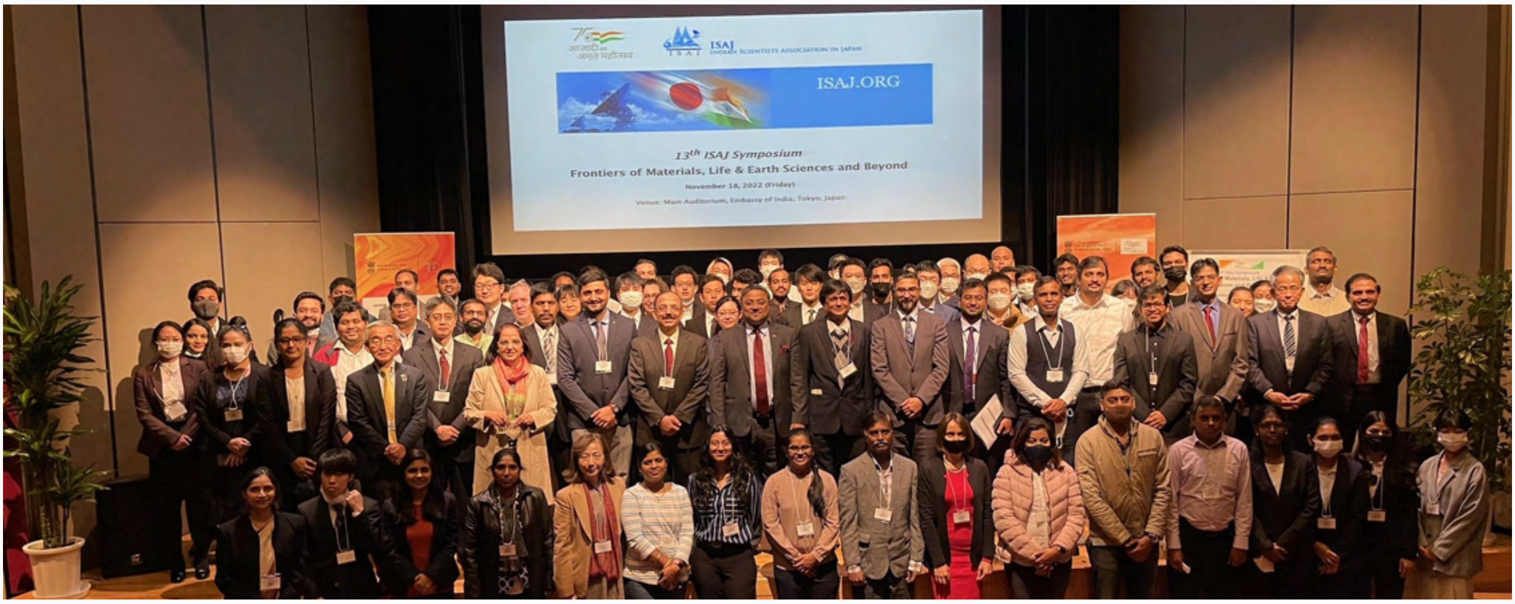
13th ISAJ Annual Symposium-2022


The Ambassador presents ISAJ Lifetime Achivement award to Prof. Atsushi Suzuki


A session and session chairs


The most lively part of the symposium - the Poster Session!

Poster presentation awards being given by Deputy Chief of Mission Mr. M. Joshi.



Group picture of all participants of the 13^{th} Annual Symposium.

Ambassador of India His Excellency Mr. Sibi George is in the center.

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About ISAJ

The Indian Scientists' Association in Japan (ISAJ) is a Non-Profit Organization (NPO) aimed at networking and promoting Science and Technology Cooperation between India and Japan.

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