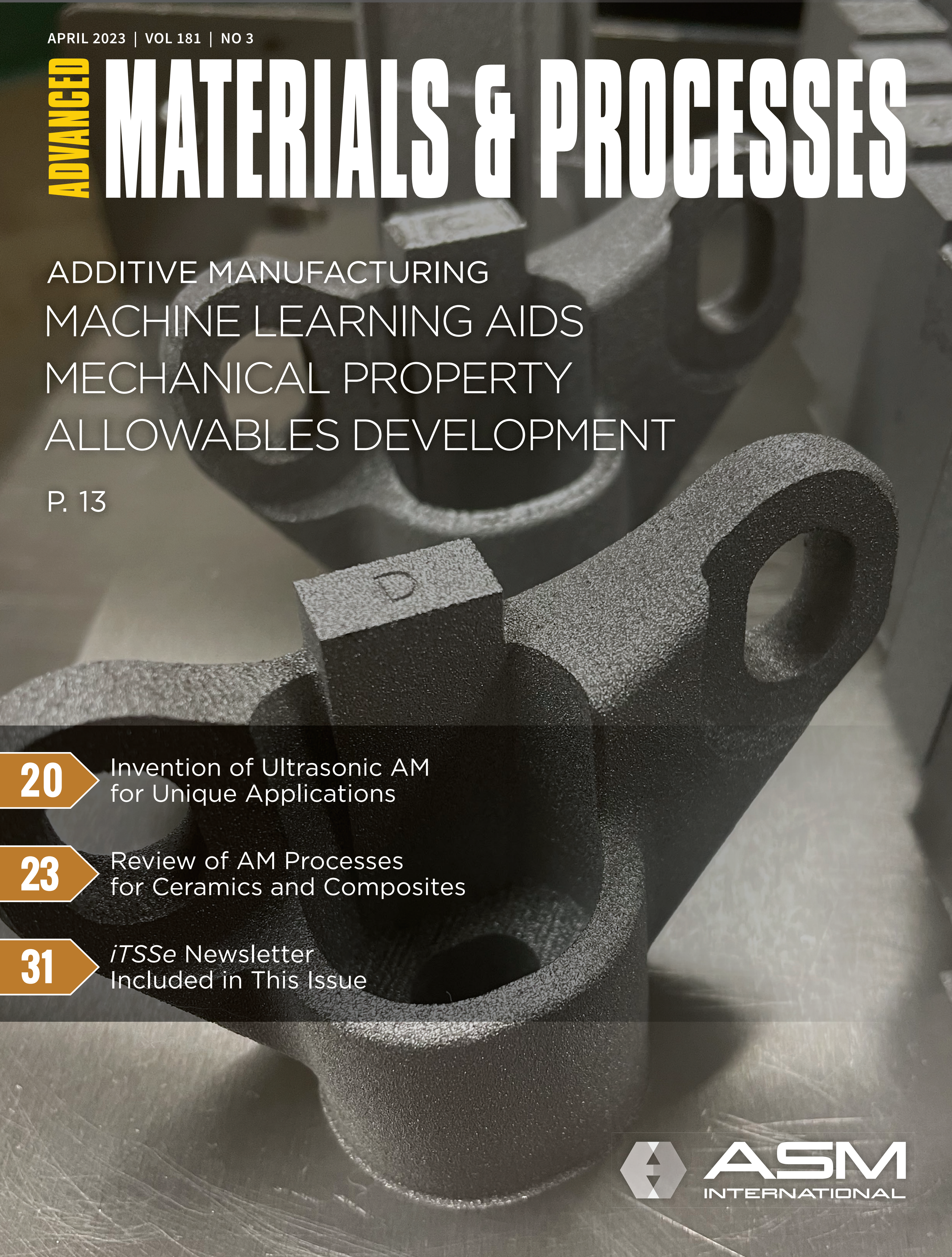
APRIL 2023 | VOL 181 | NO 3

ADVANCED MATERIALS & PROCESSES



ADDITIVE MANUFACTURING
MACHINE LEARNING AIDS MECHANICAL PROPERTY ALLOWABLES DEVELOPMENT

P. 13

ASM INTERNATIONAL

PROFILES IN MATERIALS SCIENCE

OSAKA UNIVERSITY'S ANISOTROPIC DESIGN & ADDITIVE MANUFACTURING RESEARCH CENTER

Learn about a unique research hub in this fascinating interview with center director Nakano Takayoshi and Hideyuki Kanematsu, FASM.*

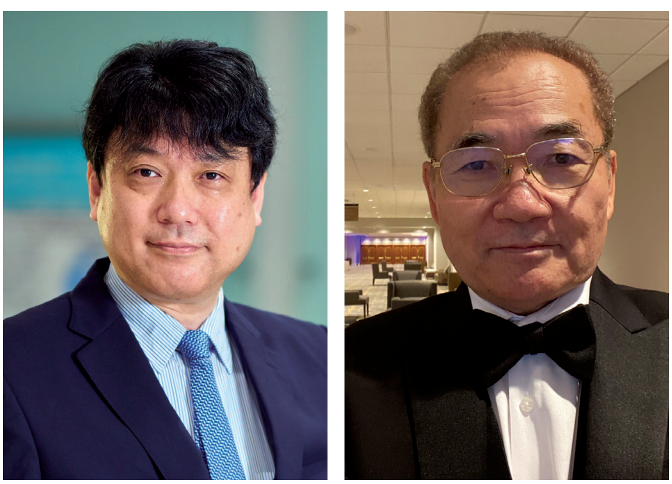


Fig. 1 — From left, Prof. Takayoshi Nakano, Osaka University, and Prof. Hideyuki Kanematsu, National Institute of Technology, Suzuka College.

Fig. 2 — Anisotropic Design & Additive Manufacturing Research Center at Osaka University.

Modern industrial systems that seamlessly integrate virtual and real environments are becoming more widespread around the globe. Many of these systems stem from the digital transformation of automation in the manufacturing industry, first introduced as Industry 4.0 in Germany and later Society 5.0 in Japan, which was proposed in the country's 5th Science and Technology Basic Plan. In parallel development, additive manufacturing (AM) has advanced significantly since its early days and is now becoming one of the core pillars of industrial technology.

In late 2014, Osaka University in Japan established the Center for Dissimilar Custom Design and AM Research & Development (commonly known as the Osaka University Metal AM Center) to connect research-based AM with industrial implementation. It recently established another specialized AM research group at its new Anisotropic Design & Additive Manufacturing Research Center, which will further develop AM technology via an industry-academia collaboration. In the following interview, Hideyuki Kanematsu, FASM, talks with Takayoshi Nakano, director of Osaka University's newest research hub, about the center's goals as well as the latest prospects for AM technology in Japan's academic and industrial circles (Figs. 1 and 2).

Hideyuki Kanematsu (HK): I was thoroughly impressed by the tour of the center, including the prominent display of participating companies. This is very different from the image of a traditional research center at a leading Japanese academic institution like Osaka University. It is a research center with a difference.

Takayoshi Nakano (TN): The city of Osaka has always been known as a merchant town. Osaka University represents the land and has cultivated a tradition of emphasizing practical learning. In that sense, other centers within the university place the same emphasis on industry-academia collaboration, but even so, our center in

*Member of ASM International

particular emphasizes implementation in society. You are correct in that we consciously designed the center in this way. There is sometimes a criticism of too much "seed research" at universities, which is one of the reasons we believe in increasing the amount of practical research taking place.

HK: Considering the current spread of digital science throughout society and its impact on materials science, it's interesting to note you were among the first to establish a research center for additive manufacturing at Osaka University in 2014. What were your aims?

TN: I did not anticipate the current situation when I started my research. As a graduate student, I studied titanium-aluminum intermetallic compounds and received my degree in this field. However, I gradually became involved in research on biomaterials, especially artificial bones. For example, I was pursuing the relationship between the orientation structure of crystals (crystal aggregate structure) and bone strength, which is necessary to manufacture optimal artificial bones (Fig. 3). As a consequence of this materials science perspective, I arrived at the need for technology to control the anisotropy of material crystals and to design and manufacture the 3D structures very precisely. The research center was established under these circumstances. It is gratifying to see that AM, which initially spread as a method to quickly form prototypes, has developed into a technology for finishing products close to the final state without conventional processing. I am deeply impressed by the increasing importance of this technology.

HK: Can you tell me about the different facilities in your center?

TN: Within our laboratories, we have equipment that enables various kinds of additive manufacturing. For example, we have an inkjet laminate molding machine, a thermal AM machine, and a machine that can analyze the formed material. We also have two large electron beam systems and two laser AM systems (Fig. 4). We use these to support our two core technologies. The first is what we call a cyber-physical system. This system analyzes a high quality database accumulated in physical space (through the AM process) in cyberspace (via simulation) and feeds it back to the process. By integrating cyberspace and physical space, we aim to optimize the AM process and create materials with enhanced functionality.

The second core technology we support involves atomic orientation, structure, and isotropic/anisotropic design (Fig. 5). In the AM process, in addition to controlling complex 3D shapes, the crystal orientation can be controlled at the atomic level to shift from isotropic, in which physical properties and functions are expressed uniformly in all directions, to anisotropic, in which specific functions are realized in a particular direction. This multiscale control of structure and material properties is a core technology of our center.

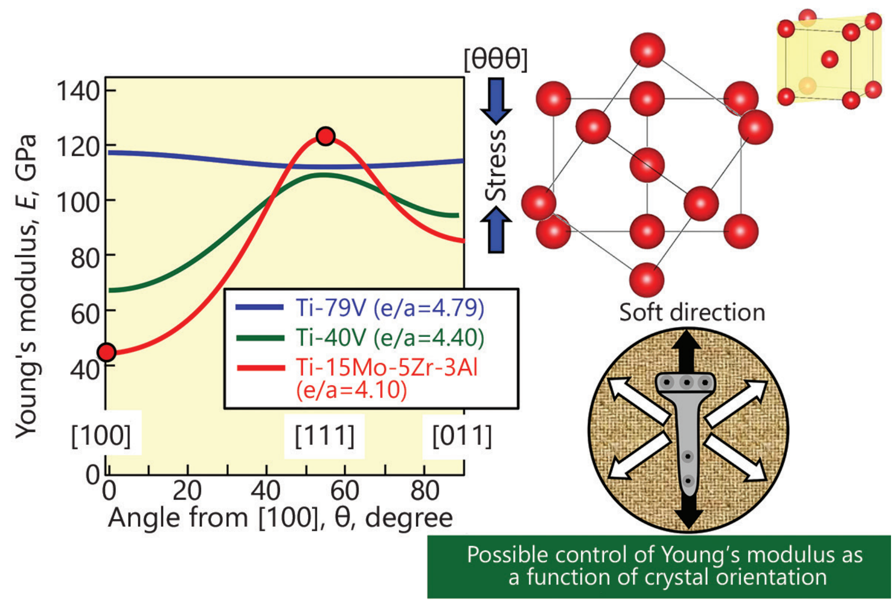
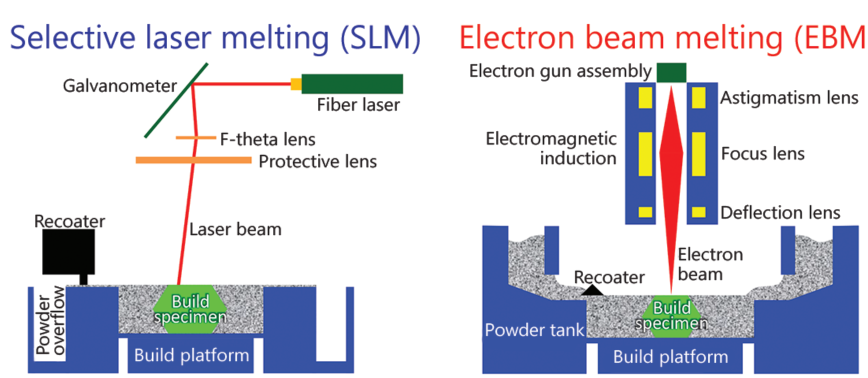


Fig. 3 — Relationship between crystal orientation structure and bone strength.



Equipment	EOSINT M 290 (EOS), left	EBM Q10 (Arcam AB), right
Heat source	Yb fiber laser	Electron beam (CeB_6)
Maximum power, W	400	3500
Minimum beam spot size, μm	~60	~100
Maximum scan speed, m/s	7	8000
Atmosphere	Ar or N_2	He: 2 x 10^{-1} Pa (vacuum)
Preheating temperature	RT-200°C	0.5-0.8 T_m (T_m: melting point)
Powder particle size, μm	10-50	45-105

Fig. 4 — Comparison of 3D printers based on laser and electron beam melting.

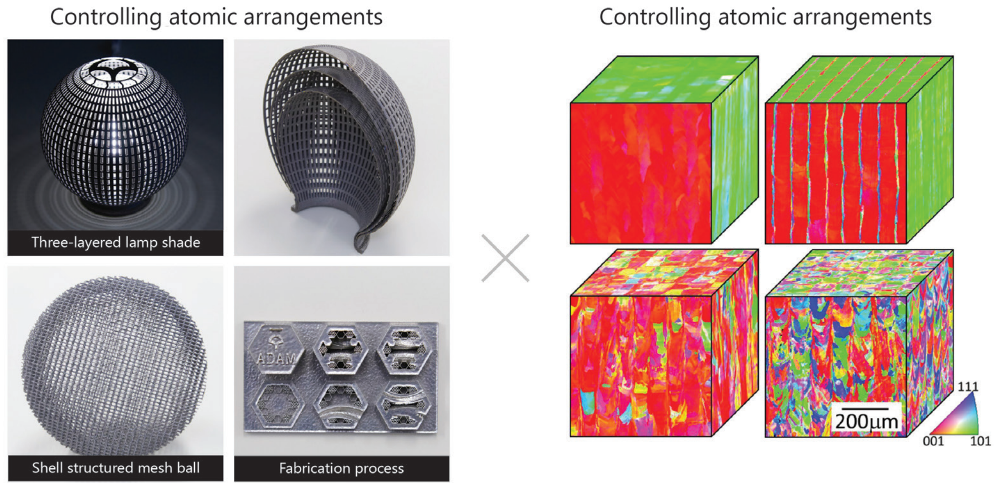


Fig. 5 — Atomic orientation, structure, and isotropic/anisotropic design.

HK: How are you shaping these core technologies based on the variety of AM processes you support?

TN: The center has several projects going on. One of them is the national science project called SIP. This program was established in 2014 to realize science and technology innovation through the Council for Science, Technology and Innovation's command post function and its leading role in management that transcends the boundaries of ministries and old disciplines. The first project won significant funding support at the center, followed by another large round of funding in the second phase of the SIP. Ten themes that are considered essential and critical to Japan's economic and industrial competitiveness were selected for the program. These research themes aim to create new materials by integrating materials engineering with information engineering and using digital space. These goals have become a major driving force for strengthening our industrial capabilities.

In addition, Japan has a large fund called JST-CREST. This fund was established to promote original and internationally advanced basic research under the management of a research director to achieve strategic goals set by the government. The research was aimed at creating innovative materials with artificially custom-controlled mechanical functions. This involved studying the strengthening mechanism at specific interfaces ranging from nano to macro that is expected to be formed by metal 3D printing, learning from bone tissue, and freely designing and introducing particular interfaces based on the coordination of analysis in physical space and cyberspace. The fact that our center has been awarded significant funding from the Japanese government for one project after another shows how much Japan considers AM technology to be the main focus of next-generation materials development. We are proud to be a leader in this field and we are all working with a sense of responsibility and pride.

HK: Thank you for explaining how important the AM center is to Japan's materials science initiatives. Can you talk about some of your latest plans?

TN: While strengthening industry-academia collaboration, we will deepen and further accelerate the deployment of AM technology in materials development. However, we are also looking to develop AM technology into a process that will be the core of future materials development as a more significant wave. One such movement is the AM research group. I launched this research group last year in discussion with my colleagues and the people from companies that have been cooperating with us. I am currently the president of the Japan Institute of Metals. This AM research group was launched on April 1, 2022, as one of the industry-academia cooperative research groups at the Japan Institute of Metals. The purpose of this study group is to contribute to strengthening Japan's manufacturing industry by building AM science and technology beyond the framework of industry-academia-government and even academic societies and by spreading AM technology widely in Japan through digital technology.

The organization intends to develop AM technology for all materials by encompassing metals, polymers, ceramics, glass, resins, cells, and composite materials. In the future, we will regularly hold AM-related events including trend surveys, research meetings, seminars, and symposiums. We will also make policy proposals to the government and summarize the activities of the Science Council of Japan to establish the Japanese Institute of Additive Manufacturing (JIA) in about four years. We are preparing to develop this new academic institution with three pillars: AM science, AM technology, and AM business. We have held several workshops with participation across a wide range of fields, from government and public offices to academia and industry, with more than 500 people attending each workshop. **~AM&P**

For more information: Hideyuki Kanematsu, professor of materials science and engineering, National Institute of Technology (KOSEN), Suzuka College, Japan, kanemats@mse.suzuka-ct.ac.jp.