

Progress Plan for Maintaining Academy Center Certification World Premier International Research Center Initiative (WPI)

Host Institution	Tohoku University
Research Center	Advanced Institute for Materials Research (AIMR)
Host Institution Head	Hideo Ohno
Center Director	Shin-ichi Orimo
Administrative Director	Nobuyuki Nishiyama

Please prepare this Progress plan based on your application for WPI Academy. Summarize the Center's future plans with regard to the following 8 items **within five A-4 pages**. (Also fill out the appendices at the end of this form.)

1. Overall Image of Your Center

* Describe the Center's overall image including its identity.

The goal of AIMR stipulated in the proposal for its foundation in FY2007 was to create new materials with innovative functions through a novel method of atomic and molecular control departing from traditional approaches, construct devices based on new fundamental paradigms, and contribute to society by building a foundation for safe and rich life. In order to achieve this goal, when the Interim Evaluation was carried out in FY2011, AIMR stipulated its identity as "discovering common elements and universal principles among different materials and creating new materials science which can develop new materials based on predictions," and proposed an innovative research strategy to promote "**mathematics-materials science collaboration**" at an institutional level. Based on the scientific principles achieved through the mathematics-materials science collaboration, AIMR strengthened international cooperation network with world-leading institutions, and now AIMR is recognized as a hub of international collaborations and global brain circulation. In FY2017, the following fiscal year after the termination of the WPI funding period, AIMR was admitted to "**WPI Academy**," and has made maximum efforts to keep "**World Premier Status**" given by WPI Program Committee for AIMR as an evaluation result. AIMR will maintain the basic policy and direction described above. Under the leadership of **Center Director Prof. Shin-ichi Orimo**, AIMR will develop new materials and devices and contribute to society through the implementation of "**Advanced Target Projects**" which raise the mathematics-materials science collaboration to the next stage where new real materials could be created.

2. Mid- to Long-term Research Objectives and Strategies

* Describe new challenges in the Center's research objectives and plans after FY 2020.

* Describe your future research strategy and plans and research organization including your line-up of Principal Investigators, and your outlook for fostering and securing the next generation of researchers.

AIMR's final goal is to contribute to society by creating new functional materials and developing new devices. If we apply the knowledge obtained through mathematics-materials science collaboration so far to the creation of new materials, we need to convert the information based on mathematics into the words

of materials science. To realize this, a materials scientist who has substantial experience in developing new materials and devices should become the leader and a new system which can develop novel materials through incorporating new mathematical tools appropriate for materials design should be introduced with the support of mathematicians. Prof. Shin-ichi Orimo (joined AIMR as a Principal Investigator on January 1st, 2013, became Deputy Center Director on November 1st, 2018, and became Center Director on October 1st, 2019) was appointed as the new leader to push AIMR into this new direction. Under the supervision by the new Center Director Prof. Orimo, AIMR researchers discussed the results obtained by the previous Target Projects (TP1-4) and subtracted bottlenecks which seemed to prevent the development of new materials, and set the following three **Advanced Target Projects (ATPs)**:

[ATP1] Local Structure Control in Topological Functional Materials

[ATP2] Integrated Control of Bond Variation and its Time Evolution

[ATP3] Improvement of Self-Organization Technology and Control of Biological Response

Through the newly launched ATPs, AIMR will deepen and mature the **mathematics-materials science collaboration** that has been developed over the past decade, and make it a standard direction of materials science in the 21st century. Specifically, in **ATP1**, by the analysis for topological phases in aperiodic system and complementary use of network information and geometric one, we will specify the relationship between local structure and global properties, and search for new quantum-element materials, leading to novel electronic and magnetic devices in the future. In **ATP2**, through time series analysis using persistent homology and multi-modality data assimilation, we will realize precise control of light element ionics, leading to novel energy devices. In **ATP3**, through the prediction and control by phase-field model, and subtraction of the relationship between geometry and dynamical behavior in complicated networks, we will control living/non-living interface and network response in living systems, leading to novel bio- and medical devices. With respect to "Spin-centered materials science" and "Design of hierarchical structure based on theoretical prediction" which has been recognized as priority areas are included in these ATPs constructively. AIMR assigns young Professors and Associate Professors to be the leaders of ATPs and also makes an effort to foster new leaders. Specific line-up of Principal Investigators (PIs) and outlook for fostering and securing the next generation of researchers will be described in the next section.

3. Management System of the Research Organization

* Describe the system of organizational management via which the Center will execute the above-described research strategy and plans.

* In Appendix 1-3, list the Principal Investigators, enter the number of Center personnel (researchers, research-support staff, and administrative staff), and provide a diagram of the Center's organizational management system.

Center Director Prof. Shin-ichi Orimo, Deputy Center Director Prof. Hiroshi Suito, a mathematician, and PIs listed in **Appendix 1** will be united, pursuing pioneering research (two Junior PIs are not shown in the list of Appendix 1). In April 2019, two new PIs, Prof. Takafumi Sato (physics) and Prof. Hayato Chiba (mathematics) joined AIMR. Through the international recruitment started at the end of FY2018, AIMR received Dr. Tomoki Ozawa, a young researcher who has attracted a lot of attention by the achievements in the theoretical study of topological materials, as a Junior PI (Associate Professor) in February 2020. AIMR also invited Prof. Gerrit Ernst-Wilhelm Bauer who has been one of the world authorities on spintronics theory and Prof. Hirotomo Nishihara who has attracted much attention by the achievements in carbon

nanomaterials research as new PIs in April 2020. AIMR is gradually changing the priority research areas depending on the recent global trend. The Total number of researchers and staff members is shown in **Appendix 2**. AIMR will make its utmost effort to keep young researchers, for example, by employing them with external funds or utilizing the cross-appointment system. As shown in **Appendix 3**, the center's organization consists of research groups, research support division, and organization for collaborative research such as overseas Joint Research Centers. Center of Mathematical Sciences for Open Innovation (Head of the center is Prof. Hiroshi Suito, Deputy Director of AIMR) was established in FY2019 to promote collaboration with outside AIMR including industry, and we hope that this center will also play a role in the increase of funds from industry. The top-down management by the Center Director is maintained, so that the center can be managed with flexibility and quick decision-making. Using the cross-appointment system, for example, with National Institute of Advanced Industrial Science and Technology (specifically, AIST-TohokuU Mathematics for Advanced Materials Open Innovation Laboratory, MathAM-OIL), RIKEN (specifically, iTHEMS, SUURI-COOL Sendai), National Institute for Materials Science, and Kyushu University, we will promote personnel exchange and strengthen our activities. Furthermore, AIMR will make an effort to establish a career path for young researchers, for example, a tenure-track system by using the tenured positions provided by the host institution.

4. Plan for Promoting the International Circulation of World's Best Brains

* Describe your policy and concrete plan for promoting the international circulation of the world's best brains, which is an important function of the WPI Academy.

AIMR has conducted joint research with 13 overseas partner institutions. In particular, AIMR has established **Joint Research Centers** (joint laboratories) at the three institutions, the University of Cambridge, the University of Chicago, and Tsinghua University so far, and we will continue to employ and place postdoctoral researchers there to accelerate international joint research. We also ask the postdoctoral researchers to come to Sendai for their experiences of collaboration with AIMR researchers, and this effort will lead to global brain circulation. We are planning to set another Joint Research Center in Europe in the future, and we will examine this plan. We will also perform personnel exchange through **Fraunhofer Project Center** established in AIMR and this is one of the advantages of AIMR for promoting global brain circulation. **International Affairs Center (IAC)** continues to support AIMR so that AIMR can continue to act as a hub of global brain circulation. Specifically, IAC will support exchange agreements with overseas institutions and promote researcher exchange between AIMR and overseas institutions through AIMR's original exchange programs such as GI³ (Global Intellectual Incubation and Integration) Laboratory Program and AIMR Overseas Dispatch Program for Young Researchers. Although participation in international meetings as WPI Center(s) also contributes to international brain circulation, it will be described in the 6th section "Plan for Sustaining the WPI Brand."

5. Plan for Disseminating the WPI Program Achievements

* Describe your policy and concrete plan for disseminating WPI center achievements both within the host institution and to other universities, especially their experience and know-how accumulated on establishing top world research institute and advancing system reforms.

In June 2017, Tohoku University was named as one of the **Designated National Universities**, and to strengthen the research capabilities of the university, four **world-leading research centers (Core Research Clusters)** for (1) Materials Science, (2) Spintronics, (3) Next-Generation Medical Care, and (4) Disaster Science were established. These Core Research Clusters are modeled after WPI research centers and placed under the umbrella of Organization for Advanced Studies (OAS) the same as AIMR, and AIMR is leading the Core Research Cluster for Materials Science. Since February 2018, a series of international joint symposia of the two Core Research Clusters for Materials Science and Spintronics has been annually held and know-how to organize international meetings cultivated by AIMR in the past ten years was fully utilized for organizing the symposia. Also, when Joint Research Center at Tsinghua University, Beijing, China was established as one of the activities of Core Research Clusters for Materials Science, the know-how accumulated by AIMR was used. The team playing a central role in the internationalization of Tohoku University is "**International Affairs Center (IAC)**." The IAC is the developed organization of the "International Unit" which was established inside the AIMR's Administrative Division in 2011 and played a key role in the internationalization of AIMR. The IAC was established to disseminate the know-how for internationalization accumulated by AIMR to the entire university. The IAC is currently dealing with wide range of international issues, for example, support for the establishment of joint laboratories between overseas institutions and the departments other than AIMR as well as support for the foreign researchers working at Tohoku University. It is obvious that experiences and skills accumulated by AIMR in the past decade have been disseminated to the whole Tohoku University, and AIMR will continue to play a central role in internationalization, strengthening of research capabilities, and system reform of Tohoku University.

6. Plan for Sustaining the WPI Brand

* Describe your plan for sustaining and enhancing the WPI brand.

We will timely renew the center's website, brochures, public relations magazines (AIMR Magazine), research highlights (AIMResearch), and the introduction of AIMR researchers (AIMR Research Profiles) to keep their freshness. On the other hand, we are also planning to combine some of the print media and promote insourcing to maximize the efficiency within the limited budget. Participation in international meetings such as E-MRS and NanoMat (Japan-France Workshop on Nanomaterials and WPI Workshop on Materials Science) as WPI Center(s) is one of the effective tools to sustain and enhance the "WPI-brand," and we will continue these activities. AIMR will host the NanoMat 2021 (The 14th Japan-France Workshop on Nanomaterials and the 5th WPI Workshop on Materials Science), and it will be a good opportunity to increase the degree of recognition of AIMR (under consideration concerning the details). "g-RIPS-Sendai" where students coming from the United States and Japan jointly tackle the problems which sponsor companies provide and find ways to solve them by using mathematics is also a beneficial event to attract interest of industry and the community of mathematics. AIMR will continue to promote this program through Center of Mathematical Sciences for Open Innovation which has been established inside AIMR.

7. Support by Host institution

* Describe measures that the host institution is and will take to support and sustain your Center.

The host institution, Tohoku University, is continuing to provide AIMR with the **position as a regular department**, authority, resources, and infrastructure even after the termination of the WPI funding period. Such policy of the university can be seen in the statements of Tohoku University's "Third Mid-term plan" that strengthening AIMR and constructing world-leading research environment and research support system are among the university's goals. Furthermore, the following two descriptions, "Promoting world's leading research activities in the fields of Materials Science and Spintronics" and "Strategical advancement of cross-sectoral, interdisciplinary research projects by placing Organization for Advanced Studies (OAS) on the top" are stipulated in "Tohoku University Vision 2030" established by President Dr. Hideo Ohno, and AIMR is recognized as the core department to lead these two activities. As mentioned previously, Tohoku University was named a Designated National University and the university has established world-leading research centers for four research fields (Core Research Clusters) including Core Research Cluster for Materials Science; AIMR is leading the cluster and the additional budget to play this role is provided for AIMR by the university. Tohoku University will continue to support AIMR to develop the university itself.

8. Resource Allocation Plan

* Describe your plans over a 5-year period for allocating resources acquired from the host institution (e.g., financial resources and positions) and from external research funding to use in carrying out the Center's functions and activities described above.

* In Appendix 4, enter concrete numbers in the Resource Allocation Plan.

The host institution, Tohoku University, promises to keep permanent staff members (about ten tenure faculties and about ten administrative staff) already placed at AIMR, and maintain the additional ten tenure positions provided for AIMR in the WPI funding period. The six of the ten positions have been occupied by Professors Shigemi Mizukami (PI), Ayumi Hirano (PI), Hiroshi Suito (PI), Hayato Chiba (PI), Associate Professor Hiroshi Yabu (tenure-track Junior PI), and Associate Professor Tomoki Ozawa (tenure-track Junior PI). The other remaining positions will be gradually used when we have the opportunity. The financial resource from the host institution will be used mainly for employing researchers who belong to the laboratories of new PIs or Junior PIs joined AIMR using the tenure positions and for keeping young researchers (employing one researcher for each laboratory) and administrative/support staff members. Part of the resource will also be used for some projects to maintain international cooperation. We entrust individual laboratories with the acquisition of research funds for their own research. However, AIMR will provide research money to start and promote Advanced Target Projects (ATPs) and/or fusion research and strongly support interdisciplinary fusion research based on the AIMR's identity focusing on mathematics-materials science collaboration. Although the present budget from the host institution to AIMR is a bit exceeding the amount initially planned when AIMR applied for WPI Academy Center Certification because additional budget for operating Core Research Cluster for Materials Science described above is being provided for AIMR, the budget will decrease in the future due to the constant reduction of the allocation of operational subsidies to national university corporations from the government (see **Appendix 4**). The many of the administrative staff members of AIMR concurrently have positions in Organization for Advanced Studies (OAS) and participate in the management of OAS, so that AIMR can keep the number of administrative staff members in return. This is the scheme designed by the host institution to maintain the firm support for AIMR.

List of Principal Investigators

- If the number of principal investigators exceeds 10, add columns as appropriate.
- Give age as of 1 April 2020
- For investigators who will not participate in the Center project at the time of submission of this Progress Plan, indicate the time that their participation will start in the "Notes" column.

	Name	Affiliation (Position title, department, organization)	Academic degree, Specialty	(Notes) Enter "new" or "ongoing"
1	Center Director Shin-ichi Orimo	Professor, AIMR, Tohoku University	Ph.D. / Materials Engineering and Chemistry	ongoing
2	Deputy Center Director Hiroshi Suito	Professor, AIMR, Tohoku University	Dr. of Engineering / Mathematical Modeling and Numerical Simulation	ongoing
3	Tadafumi Adschiri	Professor, AIMR, Tohoku University	Dr. of Engineering / Hybrid Materials, Supercritical Fluid Technology	ongoing
4	Gerrit Ernst-Wilhelm Bauer	Professor, AIMR, Tohoku University	Dr. rer. nat. / Spintronics	new
5	Hayato Chiba	Professor, AIMR, Tohoku University	Ph. D. / Informatics	ongoing
6	Shunsuke Fukami	Professor, Research Institute of Electrical Communication (RIEC), Tohoku University	Dr. of Engineering / Spintronics	ongoing (promoted to PI from Junior PI in FY2019)
7	Tomoteru Fukumura	Professor, AIMR, Tohoku University	Dr. of Engineering / Solid State Chemistry	ongoing
8	Ayumi Hirano	Professor, AIMR, Tohoku University	Dr. of Science / Bio-devices	ongoing
9	Motoko Kotani	Professor, AIMR, Tohoku University (Executive Vice President for Research of Tohoku University)	Dr. of Science / Mathematics (Geometry)	ongoing
10	Dmitri Valentinovich Louzguine	Professor, AIMR, Tohoku University cross-appointment: AIST-TohokuU Mathematics for Advanced Materials Open Innovation Laboratory (MathAM-OIL)	Dr. of Engineering / Materials Science	ongoing
11	Shigemi Mizukami	Professor, AIMR, Tohoku University	Dr. of Engineering / Applied Physics, Spintronics	ongoing
12	Hiroto Nishihara	Professor, AIMR, Tohoku University	Dr. of Engineering / Carbon-based Nanomaterials	new
13	Seiji Samukawa	Professor, Institute of Fluid Science, Tohoku University	Dr. of Engineering / Nano- Process Engineering	ongoing
14	Takafumi Sato	Professor, AIMR, Tohoku University	Ph.D. / Physics	ongoing
15	Yuichi Ikuhara	Professor, School of Engineering, Institute of Engineering Innovation, The University of Tokyo	Dr. of Engineering / Ceramics, Electron microscopy	ongoing

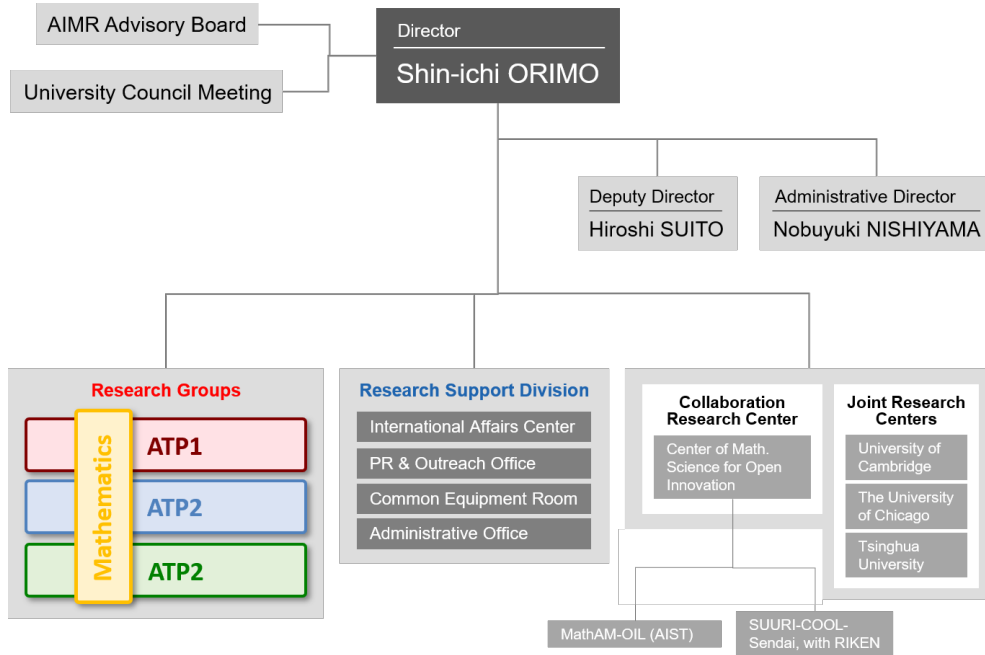
16	<u>Eiji Saitoh</u>	Professor, Department of Applied Physics, School of Engineering. The University of Tokyo	Dr. of Engineering / Quantum Nano Science	ongoing
17	<u>Mingwei Chen</u>	Professor, Johns Hopkins University, Whiting School of Engineering	Dr. of Engineering / Materials Science	ongoing
18	<u>Yong P. Chen</u>	Professor, Department of Physics and School of Electrical and Computer Engineering, Purdue University	Ph.D. / Condensed Matter Physics, Nanotechnology	ongoing
19	<u>Tomasz Dietl</u>	Professor, Head of Laboratory of Cryogenic and Spintronic Research, Institute of Physics, Polish Academy of Sciences	Ph.D./ Condensed Matter Physics (Theory)	ongoing
20	<u>Alan Lindsay Greer</u>	Professor, Department of Materials Science & Metallurgy, University of Cambridge	Ph.D. / Metallurgy & Materials Science	ongoing
21	<u>Chris Pickard</u>	Professor, Department of Materials Science & Metallurgy, University of Cambridge	Ph.D. / Materials Theory	ongoing
22	<u>Thomas P. Russell</u>	Professor, Department of Polymer Science and Technology, University of Massachusetts Amherst	Ph.D. / Nano-Science Technology	ongoing
23	<u>Alexander Shluger</u>	Professor, Department of Physics and Astronomy, University College London (UCL)	Ph.D. / Computational Materials Science, Condensed Matter Physics	ongoing
24	<u>Qi-kun Xue</u>	Professor, Department of Physics, Tsinghua University	Ph.D. / Surface Science	ongoing

*Percentage of time that the principal investigator will devote to his/her Academy center work vis-à-vis his/her total working hours.

Appendix 3 Diagram of Organizational Management System

- Diagram **separately** the Center’s organizational management system **and** its position within the host institution in an easily understood manner. If you are planning to change your organization management system and/or its position within the host institution in or after FY 2020 compared to their description in Appendix 3-1 of Activities report, show the changes in the diagram.

Management System within AIMR



Position of AIMR in the Host Institution

