

# International Joint Research Promotion Strategy of Sensor Industry for Leading the 4th Industrial Revolution

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## Abstract

*As the interaction between humans and objects increases, the hyperlinked society where all things are connected and communicated is accelerated. As the convergence between industries is intensifying, new products and services such as smart factories and autonomous vehicles are being created.*

*Although the sensor industry is an important core industry, leading the fourth industrial revolution, domestic technology level and localization are very low.*

*Therefore, in order to effectively utilize overseas technology resources in order to accelerate global technology competition, it is necessary to have an international joint research strategy to effectively utilize overseas technology resources in order to acquire core technologies and enhance industrial competitiveness through open innovation.*

*In this paper, Roly-Poly model for international collaborative research is introduced, and the prioritization of overseas research institutes in the sensor industry field is derived and a strategy for promoting international collaborative research is presented.*

*Through this research, we will preemptively search core and source technologies from the R & D stage of the sensor industry for leading the 4th industrial revolution and secure early related patents to strengthen the R & D capacity of Korea's sensor industry and activate industrial applications Will be contributed.*

**Keywords:** 4th Industrial Revolution, Roly-Poly model, Sensor industry, Sensor, ICT.

## 1. Introduction

With the advent of the Fourth Industrial Revolution, the economic system and social structure are fundamentally reorganized based on the development of new technologies.

As the interaction between humans and objects increases, superconducting society in which all things are connected and communicated is accelerating, and miniaturization, complexity and intelligence of ICT technology are actively researched. In order to respond to the rapidly changing future environment and to lead new technologies and markets in the global industrial environment, we must secure core technologies and original technologies. Although the sensor industry is an important base technology of the future-oriented industries such as Autonomous Vehicles and Internet of Things, which are the main technologies of the fourth industrial revolution, domestic technology level and localization are very low.

Therefore, in order to effectively utilize overseas technology resources in accordance with the acceleration of global technology competition, strategies for securing core technologies and enhancing industrial competitiveness are needed through Open Innovation. For open innovation, strategies should be pursued such as international joint research with strategic countries, strategic partnerships and global R & D networks, and the use of talented human resources from technology-leading countries.

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Through this, it is urgent to pursue international joint research based on open innovation to enhance connectivity to the end products and services.

## **2. Theoretical background**

### **2.1. Analysis of the 4th industry-based sensor industry**

Sensor technology is the base technology to enhance the core competitiveness of convergence products such as automobiles, robots, and advanced medical devices. It is a high-value-added technology that enhances existing industries and creates new industries through intelligent, ultra-small, to be.

In particular, sensor reliability, high performance, and increased demand for low-cost sensors are drawing attention to the development of new technologies such as micro and nanotechnology, which offer advantages of miniaturization, low power consumption and mass production. The sensor market is expected to accelerate to double its CAGR of 18.1% in 2022 compared to 2016. Looking at the market size by type of sensor, the growth of pressure and temperature, humidity sensor is expected to be large, and the market size of each component is expected to be large for ADCs, microcontrollers and DACs. In the sensor system, wireless network connectivity is preferred, and the market size by technology is MEMS> CMOS> other sensor technology.

The user demand market is expected to grow significantly in the consumer electronics, automotive, biomedical and healthcare sectors. The regional market size is in the order of the Americas> Asia Pacific> Europe> Rest of the World. In the Asia Pacific region, The market is expected to grow at a CAGR of 19.6%. The scope of the sensor industry includes the material industry for sensor manufacturing, the device industry that implements the inherent functions of the sensor using materials, the module assembled by using several devices, and the system industry for applying it to the real industry. If we compare and analyze the patents trends and technology levels of each country by dividing them into materials, devices, modules, and systems, the R & D level of material technology and system technology in Korea is insufficient. However, Technology has a significant level of skill and influence. This is expected to help technology transfer of devices and modules that developing countries do not have or to suggest strategies for overseas cooperation in sensor development.

In the 4th industrial revolution, sensor technology is attracting attention as a key infrastructure technology of IT convergence and super-connection era. It is the most advanced device that will open the future intelligent industry, it can be applied to various application industries such as space, aviation, and military service. In addition, the sensor industry is evolving into ultra-small, high-performance, and intelligent sensors with technologies such as nano / MEMS, SoC technology, noncontact/wirelessization, functionalization, automation, miniaturization and cost reduction and material diversification.

In this paper, for the international joint research of sensor industry, sensor range is divided into material, device, module and system.

### **2.2. International joint research case study**

As the existing industry structure changes rapidly due to the 4th industrial revolution, new industries and markets are created through the convergence of the industries, so the open innovation ecosystem that can secure the demand technology is emerging as the core. As open researchers and information exchanges in the open innovation ecosystem environment are increasing and collaborative research with overseas institutions is being activated, management plans that can efficiently plan and perform international collaborative research and utilize and spread the achievements are emerging as major issues. A common management guideline that can be applied considering the characteristics of the legal system of the domestic and foreign countries is required to manage the entire period from the contracts of the international joint research to the implementation, sharing of research expenses, attribution and utilization, confidentiality. Since international law and system are different from country to country, there are differences among institutes. Therefore, it is necessary to analyze detailed regulations of foreign countries and to provide guidelines for detailed management for each country

and organization participating in international collaborative research. The contracts concluded between the participating countries and institutions in the conduct of international joint research can be smoothly concluded through the agreements between the parties, but they may be difficult due to the laws and regulations of each country, Are generally established and operating in favor of their own countries. If the detailed management guidelines are insufficient, the contract itself is not easy, and it is difficult to systematically manage the achievements. In view of the various institutional and cultural characteristics of the countries and institutions of international collaborative research, flexible management guidelines are needed.

It is very important to closely examine the amendments to the relevant laws and regulations prior to the joint research contracts as the laws of each country are changed. States such as the United States and France do not require the consent of other shareholders on the condition that the shared patent rights are granted to third parties on a non-exclusive basis, and the transfer of shares to the US, Germany, and France share patent rights is possible without the consent of other shareholders. It is necessary to secure the license including the precedent technology of the other party in the utilization of the achievements of the international joint research. In order to enhance post-management of international cooperation, a post evaluation system should be established so that evaluation of international cooperation results can be made, and discussions on improvement direction should be conducted through inspection meeting so that it can be linked to improvement of international cooperation project. In order to strengthen international cooperation capacity and raise awareness, it is necessary to find out new research topic for new growth motive for the expansion of international joint research and to lead development of leading technology and share research result

In order to establish an organization for international joint research, it should strive to eliminate barriers to international joint research by establishing an organization that will make a significant contribution to international joint research including establishing networks with overseas leading research institutes and raising funds.

### **3. Promotion strategy for international joint research**

#### **3.1. Roly-Poly Model Strategic for International Collaboration**

Conventional international collaborative research was focused on transferring advanced technology to simple technology, but differentiated strategy should be established in the situation where technology protectionism is deepening recently. Joint research should be pursued from the viewpoint of common patent rather than technology introduction and imitation of developed countries. In developing countries, expansion of market after joint application technology development should be considered rather than infrastructure-oriented ODA project.

The Roly-Poly model refers to a strategy to leap out of the technology developed through international collaborative research with technology-leading countries, to transfer our technology to developing countries and to promote joint technology development.

The type of international collaborative research on technology leading countries should be based on domestic technology level ① technology consulting for blank technology ② joint research on blank technology ③ joint research on core technology advancement.

- ① Technology consulting for blank technology is a technology that is not possessed domestically or has a lower technological power than that of technology-leading countries. Therefore, it is necessary to acquire skills through technology consulting with technology-leading countries.
- ② Joint research on blank technology is a case where long-term international collaborative research is required through the dispatch of research personnel to research institutes in technology-leading countries. It is easier to dispatch domestic researchers overseas than to attract overseas research institutes and secure researchers as a position to acquire skills and pursue. This can be achieved by participating in international collaborative research through the dispatch of domestic researchers overseas, and acquiring joint intellectual property rights.

- ③ Joint research on core technology advancement is to attract overseas researchers and research institutes by establishing open labs for collaborative researches in technical institutes or municipalities for collaborative research to enhance the core technologies possessed by domestic companies. International cooperation with source technology countries such as India, Russia, China and Eastern Europe is easier than cooperation with advanced countries, so it is possible to promote research and researcher attraction cooperation. In particular, in India, it is often the case that business partnerships are conducted through joint research with other countries in various fields. Since they have a strategic advantage in the field of materials, they can generate synergies through joint manpower management and mutual cooperation.

The types of international collaborative research on developing countries include ① technology transfer after domesticization of technology in technology-leading countries ② transfer of technology to meet technology transfer requirements ③ demonstration joint research.

- ① The technology transfer after domesticization of technology in technology-leading countries refers to the transfer of technology to the developing countries such as Thailand, Vietnam, Malaysia and Indonesia. In the case of technology acquired through technology consulting in technology-leading countries, there is a high possibility that there is no patent right in the country. Therefore, it is necessary to secure co-patents or prioritize long-term research and prioritize technology advancement and internalization. Transfer technology to developing countries after technology internalization.
- ② Transfer technology to meet technology transfer requirements can establish open lab / technology transfer center in domestic research institute or municipality through core technology and leading technology or establish technology transfer center in developing country to implement technology transfer. The establishment of technology transfer centers in developing countries can utilize international organizations such as World Bank, ADB, EDCF projects.
- ③ Demonstration joint research promotes the support of empirical research and development that can be applied directly to actual sites in developing countries.

### 3.2. Prioritization analysis of overseas research institutes in sensor industry

In order to select the priority of overseas research institutes for international joint research, we selected them based on the superiority of technology of overseas research institutes, international cooperation will, possibility of joint research and technology transfer, funding conditions for joint research, and cultural environment.

The excellence of the technology possessed by overseas research institutes is determined by analyzing the patent status such as the number of patents and the success rate of patent applications.

International cooperation will be an important factor for future international collaborative research. It will be analyzed through the status of international cooperation status of international research institutes, status of joint researches, status of MOUs, status of visiting researchers, overseas exchanges of researchers, and status of overseas research institutes. The establishment year of the research institute is also an important factor. As the start-up period is divided into 'within 10 years', '10 years or more', '30 years or more', There is a tendency for international cooperation and joint research to be favorable, so consultation for international cooperation can be easy. In the case of old research institutes over 50 years, there are advantages such as accumulation of know-how and know-how, patent holding, and global cooperation network. We will also grasp the willingness of the international cooperation through the policy and support status of the government and the public institutions.

The possibility of collaborative research and technology transfer is analyzed by analyzing the number of overseas joint researches, the number of overseas technology transfers, and the number of

overseas joint patent applications to identify the possibility of joint research and technology transfer by overseas research institutes.

The possibility of accessing core technology is required because it is very secure against core technology in defense, aerospace, and space research. Therefore, it is necessary to analyze technology openness and accessibility to core technology through international cooperation such as joint research. It is also necessary to analyze the possibility of attribution to joint research results and the system of joint patents and intellectual property rights.

The requirements for funding for joint research are also important items, and it is necessary to discuss the method of funding research and the burden rate when carrying out international joint research. Therefore, prioritization should be done through analysis of research funding status and procurement status. Collaborative research can carry out large-scale R & D that is difficult to promote alone because the participating research institutes share the cost or risk of purchasing expensive R & D equipment. It is possible to create collaborative research funds by utilizing the government's overseas researchers and start-up / enterprise support programs such as the Horizon 2020 funding program to support and nurture EU research and technology development, FrenchTech France, and the US Mass Challenge.

Cultural environment can be an important factor in exchanging researchers such as dispatching and attracting researchers for international collaborative research, and it is necessary to grasp the possibility of adapting cultural environment, settlement conditions, and cultural openness when exchanging researchers. It is necessary to grasp the condition and environment for the environment such as traffic, education, financial culture infrastructure and rich green environment as important factors for exchanges such as attracting and dispatching researchers. Cultural comparisons use Hopkins Ted 's cultural dimension theory to compare and analyze cultural differences by country. Hobbes Ted compares the occurrence of cultural differences in four dimensions: degree of individualism or collectivism, power gap, degree of avoidance of uncertainty, and masculinity.

**Table 1.** Prioritization analysis result of overseas research institutes in sensor industry.

Sensor industry promising field	Excellence in technology	International cooperation will	Possibility of collaborative research	Funding Requirements for Collaborative Research	Co-patentability of research results	Cultural environment	overseas research institutes
Intelligent sensors	●	●	●	◐	●	●	Grenoble (France) Fraunhofer EMFT (Germany) ICAMR (United States) Imec (Belgium) CENSIS (Scotland) NASA (US) ONR (US) CEA (France) CNRS (France) JST (Japan)
	●	◐	◐	○	◐	●	
	●	●	◐	◐	◐	●	
Intelligent semiconductor	●	●	●	◐	◐	●	
	●	●	◐	◐	◐	●	
	●	◐	◐	◐	◐	●	
	●	◐	◐	○	◐	●	
Internet of things	●	●	●	◐	◐	◐	
	●	●	●	◐	◐	●	
	●	◐	◐	○	◐	●	
	●	●	●	◐	◐	◐	
	◐	●	●	◐	◐	●	
New Sensor materials	●	●	◐	◐	◐	●	
	●	●	◐	◐	◐	●	
	●	◐	◐	◐	◐	●	

Smart sensor, smart semiconductor, new sensor material, IoT, etc., which are related to the application and utilization of the sensor industry considering the characteristics of the 4th industrial revolution that information is collected, processed, shared, spread, The following is an example.

Overseas laboratories for international collaborative research in the field of intelligent sensors were France Grenoble, Germany Fraunhofer EMFT, and ICAMR USA. International collaborative research in the field of intelligent semiconductors came from ICAMR in the US, Grenoble in France and IMec in Belgium.

Overseas laboratories for international collaborative research in the IoT field are CENSIS in the UK, Grenoble in France and Fraunhofer EMFT in Germany. International collaborative research on sensor new materials has been analyzed to have priority over IMEC in Belgium, Grenoble in France and ICAMR in the US.

We applied the MDMS (Material, Device, Module, System) process using the roly-poly model through the results of the prioritization of overseas research institutes for the sensor industry's international joint research.

The MDMS model is a collaborative model that promotes international collaborative research between technology leading countries in the material and system phases and developing countries in the device and module phases. Open Labs and Mirroring Centers for joint research with research institutes in developed countries will be promoted to develop joint patents.

Material will establish a cooperation system with research institutes in developed countries (including India) in order to shorten the period of sensor material development and increase the likelihood of success. INP of Grenoble Research Complex in France Collaborative research of sensor material is possible in cooperation with LMGP Research Institute in Grenoble University.

ICAMR, Florida, USA, is looking for ways to cooperate in the development of semiconductor sensor materials. In cooperation with Nano Lab in Delhi and IIT, it is possible to cooperate in the development of nanotechnology and biosensor related materials, and to cooperate with Indian Basic Science Institute (IIS) Bangalore to develop sensor material.

System part needs to find connectivity with research institutes (including India) or multinational companies in developed countries to secure system reliability of sensors. Joint development of sensor system is needed through specific business promotion with Germany's Fraunhofer EMFT. Through international cooperation with Glasgow CENSIS (Sensor Innovation Center) in Scotland, it is possible to develop and cooperate with marine sensors. Efforts should be made to jointly develop systems through cooperation with Blackmore in the US and Murata in Japan. In addition, collaborative research for sensor networks is possible through cooperation with India's world-class software enterprise research institute Infosys.

In the Device-Module phase, it is necessary to carry out technology transfer to developing countries through R & D of domestic leading research institutes and to secure future Asian markets. India can be considered as a partner in device research and development because of its potential as a major player in international collaborative research and future market potential Thailand has a master plan that shows a strong will for the 4th Industrial Revolution, deviating from the existing tourist industry and automobile industry. Therefore, it is necessary to attract research institutes and companies from Chulalong University in Thailand to jointly develop and expand the market in the future. Future market securing strategies are needed to actively support technology transfer to developing countries.

#### **4. Clustering strategy for international joint research**

In order to carry out international joint research with research institutes in developed countries, it is possible to utilize domestic open labs and mirroring centers or to link them with overseas research complexes.

In the self-building, domestic combustion leads the international joint research by establishing the open lab and the mirroring center. Local communities will participate in international collaborative research by participating in Open Lab, MIRREN Center, which was established for international

cooperation in local governments. The linkage of overseas research complexes can directly participate in overseas research complexes and promote international joint research.

As with international cooperation in developed countries, it is possible to use domestic open labs and mirroring centers to carry out technology transfer or international collaborative research with developing countries, or to establish technology transfer centers in developing countries or participate in research parks in existing developing countries.

**Table 2.** Establishment of Joint Research Clustering Using Roly-Poly Model.

Division		self-building	local governments	overseas research complexes
Leading country	Technical Consulting	◐	◐	●
	blank technology joint research	●	●	●
	CORE technology advancement joint research	●	●	●
Developing country	Technology transfer after blank technology internalization	◐	◐	●
	Strengths Technology Transfer	◐	◐	●
	Empirical Joint Research	○	○	●

## 5. Conclusion

The core of the Fourth Industrial Revolution is the emergence of new products and services through super intelligence through connections between various objects (objects, people, devices, etc.), fusion between heterogeneous technologies and industries, and online and offline convergence. Interaction between the various actors is a prerequisite for success, and therefore a global ecosystem-based approach that is not object-oriented is desperately needed.

The global ecosystem-centered approach can be flexibly developed in line with global trends by participating in various domestic and overseas technology development entities. It is accompanied by research and development of sensor technology that is the basis for building intelligence, convergence, personalization and global ecosystem of the 4th industrial revolution . By establishing a sustainable industrial ecosystem, which is a core element of the 4th industrial revolution, we will secure global industry leadership and establish a win-win cooperation system among the participants. Through the creation of new services, it is possible to secure the capacity to take over the new markets represented, and ultimately to advance and revitalize the manufacturing industry.

Technology development for leading the fourth industrial revolution is a key driver of the new growth engine, but it is necessary to actively nurture it. In order to develop sensor technology for core / infrastructure technology, it is necessary to concentrate on developing and developing a full-scale technology development strategy. Also, it is necessary to know the importance and urgency of demand, Information sharing is needed. In order to have a strong technology for new technologies, joint research through building strategic partnerships with strong technology holders is needed.

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