Research Infrastructure Foundation for Core-technology Incubation of Radiation Detection System

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Abstract - The development of radiation detection systems mainly consist of two parts-radiation detector fabrication including material development, and its appropriate electronics development. For the core-technology incubation of a radiation detection system, radiation fabrication and an evaluation facility are scheduled to be founded at the RFT (Radiation Fusion Technology) Center at KAERI (Korea Atomic Energy Research Institute) by 2015. This facility is utilized for the development and incubation of bottleneck-technologies to accelerate the industrialization of a radiation detection system in the industrial, medical, and radiation security fields. This facility is also utilized for researchers to develop next-generation radiation detection instruments. In this paper, the establishment of core-technology development is introduced and its technological mission is addressed.

Key words : Radiation detection system, Crystal growth, Compound semiconductor, Fabrication process, Evaluation facility

INTRODUCTION

In past years, radiation detection systems were developed at many research institutes and academies in the Republic of Korea. In addition, most radiation detection systems including radiation detectors are imported. To concentrate and industrialize these scattered radiation detector technologies, the research infrastructure was expected to be established at a national level to increase the national competitive edge. The development of radiation detectors has also changed from a gas-filled detector into a solid-state detector based on compound semiconductors owing to their merits such as high atomic number, high density, room temperature operation, and direct coupling with electronics (Knoll 1999). In a planned infrastructure, crystal growth and a compound semiconductor fabrication process, which are bottleneck-technologies in the development of radiation detection systems, are scheduled to be developed and to support industrial circles. In this paper, the planned facility, equipment, and their utilization for radiation detector fabrication are introduced. The application fields of radiation detectors are also briefly addressed.

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ESTABLISHMENT OF RESEARCH INFRASTRUCTURE FOR RADIATION DETECTOR

The designated site of the research infrastructure for radiation detectors is at the RFT (Radiation Fusion Technology) center at KAERI (Korea Atomic Energy Research Institute). Completion of the construction is planned for 2015. The size of the radiation detector fabrication facility is 1,200 m^2 of the overall research facility (3,300 m^2). A bird's-eye view of the

Fig. 1. A bird's-eye view of research building for core-technology development of radiation detector and electron beam accelerator.

research building is shown in Fig. 1. The research building is shared with the facility for the development of core parts of an electron accelerator. The research infrastructure for the radiation detector mainly consists of a crystal growth facility, a compound semiconductor fabrication process facility, and a performance evaluation facility. The planned layout of the facilities is shown in Figs. 2 and 3. In this section, these facilities are introduced in detail.

Crystal growth facility

There has been a drift toward changing scintillators into semiconductor materials owing to their principal superiority. Single crystals, which have a repetitive atomic arrangement in a solid lattice, have excellent chemical and electrical properties. The major proposed candidates for radiation detectors materials are CdZnTe, CdTe, TlBr, HgI_2, etc. Among these, the CdZnTe semiconductor is the most promising. The major developing scintillators are cerium-doped lanthanum bromide ($LaBr_3$) and halide single crystals. Halide is composed of group seven elements in the periodic table such as chlorine (Cl), bromine (Br) and iodine (I). $LaBr_3$ is a new compound scintillator for X-ray and gamma-ray detection at room temperature. Recently, $LaBr_3$ has been used as a radiation detector for nuclear medicine imaging and container inspection systems. Scintillators based on oxide are also newly developed. Ceramic scinitllators such as cadmium tungstate ($CdWO_4$), bismuth germinate ($Bi_4Ge_3O_{12}$), are Lutetium oxyorthosilicate (Lu_2SiO_5) have merits as radiation detectors, such as their scintillation properties, chemical stability, and physical hardness. These newly developing materials designed for development in this facility.

The designated size of the crystal growth facility is 216 m^2. It was designed to maintain a constant temperature and humidity to prevent a fluctuation of the outer temperature for crystal growth. The installed equipment and their utilization are summarized in Table 1.

Compound semiconductor fabrication process facility

Cadmium zinc telluride (CdZnTe), Cadmium telluride (CdTe), mercury iodide (HgI_2), and thallium bromide (TlBr) wide band gap semiconductors have attracted increasing interest as X-ray and gamma-ray detectors owing to their superior physical properties to conventional semiconductors such as silicon and germanium. Radiation detector fabrication using these compound semiconductors cannot be applied in established facilities such as the Nano Fab. Center and ETRI (Electrical and Telecommunication Research Institute) owing to contamination during processing. These facilities were originated to develop electronic devices based on silicon wafers. These compound semiconductors, including conventional Si semiconductor detectors, are designed for pro-

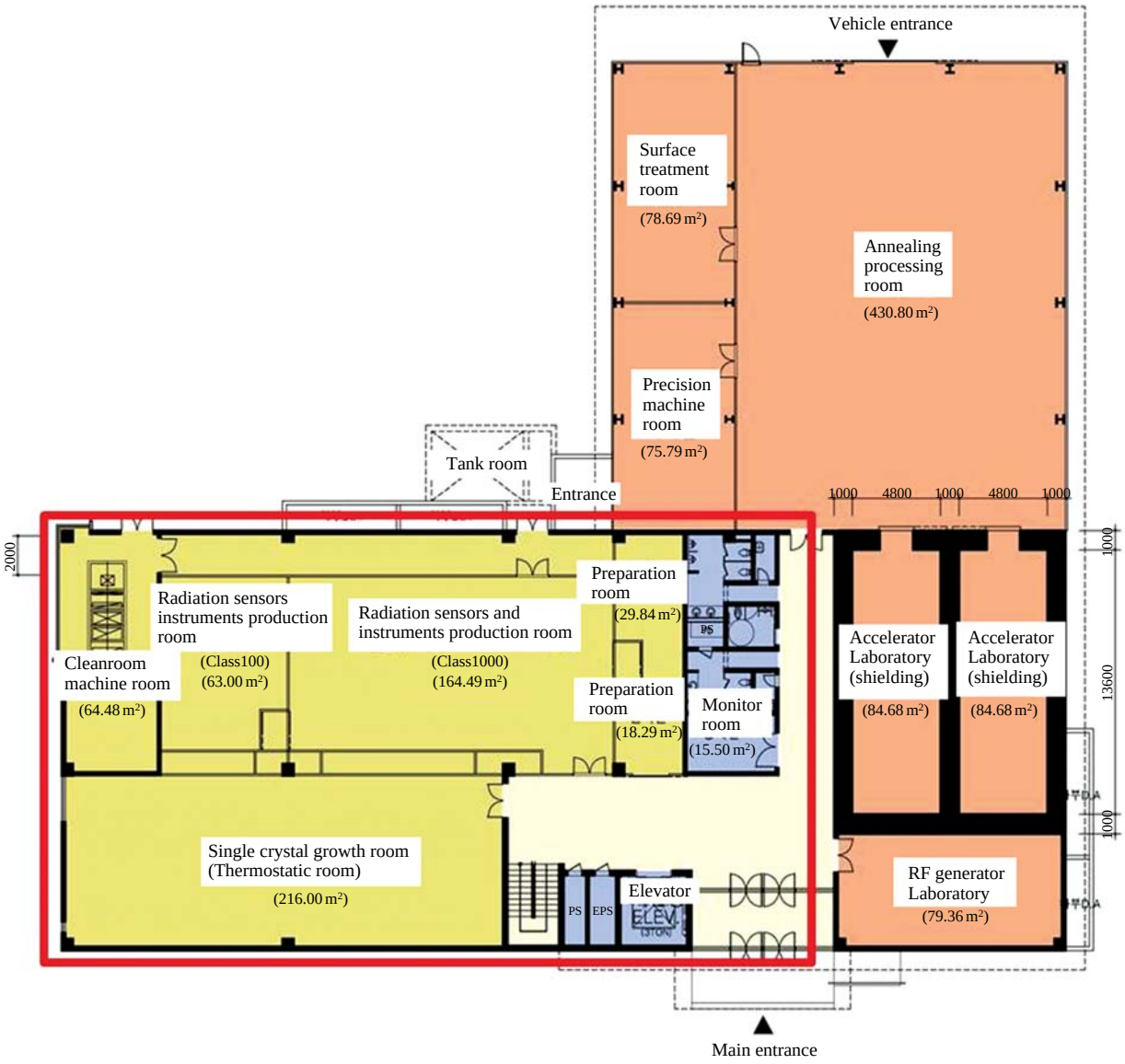

Fig. 2. A plan view of research building for core-technology development of radiation detector (red box).

Table 1. Summary of crystal growth equipments and their utilization

Furnace	Utilization
Vertical Bridgman Furnace	Crystal growth for compound semiconductors (CdZnTe, CdTe, CdMnTe, ZnS, CdS, ZnSe, ZnTe, CdSe, $PbMoO_4$ etc.)
Traveling Heater Furnace	Crystal growth for compound semiconductors (CdZnTe, CdTe, CdMnTe, etc.)
Czochroski Furnace	Crystal growth for oxide scinitllators ($Bi_4Ge_3O_{12}$, $CdWO_4$, Lu_2SiO_5 etc.)
Zone Melting Furnace	Purification of compound semiconductors
Vacuum Distillation Furnace	Purification of compound semiconductors and scintillators
Sublimation Purification Furnace	Purification of compound semiconductors and scintillators
Horizontal 3-zone Furnace	Quartz tube preparation etc.

cessing in this facility.

The designated size of the compound semiconductor fabrication process facility is 288 m^2. This facility consist of class 100 and class 1,000 clean rooms for the lithography

Fig. 3. A plan view of research building for core-technology development of radiation detector (red box).

Table 2. Summary of semiconductor process equipments and their utilization

Fabrication process equipment	Utilization
Oxidation Furnace	Oxidation of semiconductor
Photoresister coater	Lithography
Photoresister track system	Lithography and inspection
Dry etcher	Etching process
Wet etcher	Etching process
Oxide etcher	Oxide etching process
Horizontal 3-zone Furnace	Quartz tube preparation etc.
Plasma-enhanced chemical vapor deposition	Thin film formation
Low pressure chemical vapor deposition	Thin film formation
Sputter	Metallization, Radiation converter deposition
Thermal evaporator	Metallization, Radiation converter deposition
Electron beam evaporator	Metallization, Radiation converter deposition
Dicing saw	Semiconductor cutting
Wire bonder	Signal wiring
Flip-chip bonder	Pixel-type semiconductor signal extraction
Microscope	Inspection

Table 3. Summary of preparation and evaluation equipments and their utilization

Crystal processing and performance evaluation equipment	Utilization
Grinding and polishing machine	Single crystal processing
Diamond wire Saw	Single crystal cutting
Optical Microscope	Inspection for single crystal and semiconductor
Optical transmittance measuring system	Scintillator, semiconductor transmittance inspection
Probe station	Semiconductor characterization
Hole measurement system	Semiconductor characterization
Alpha step	Thickness measurement for deposited material on semiconductor
Photoluminescence Measurement system	Photoluminescence Measurement for semiconductor
X-ray diffraction	Crystallization inspection
X-ray fluorescence spectrometer	Elemental analysis
Current source	Radiation detector and electronics evaluation (Electrical response)
Nuclear instrument modules	Radiation detector evaluation (Radiation response)
Oscilloscope	Radiation detector and electronics evaluation
Electrometer	Radiation detector evaluation

Fig. 4. A conventional radioisotope identifier and recently developed compact radioisotope identifier [Thermo Scientific Corporation, http://www.thermoscientific.com] (Images from Thermo Scientific Corporation Web pages).

process and other fabrication processes, respectively. The installed equipments and their utilization are summarized in Table 2.

Performance evaluation facility

The designated size of this facility is 288 m^2. This facility is designed for the processing and evaluation of single crystals and radiation detectors. The installed equipments and their utilization are summarized in Table 3.

In addition to these three main facilities, sample preparation facilities are also provided as demanded.

APPLICATION FIELDS OF RADIATION DETECTOR

Conventional radioisotope identifiers, which are equipped with a scintillator detector, are bulky, heavy, and high power consuming. A compact radioisotope identifier, which is equipped with a CdZnTe semiconductor, is a recently developed radiation detector. It has a superior performance such as better energy resolution than a conventional detector. Fig. 4 shows a compact radioisotope identifier. An XRF (X-ray Fluorescence Spectrometer) is an industrial radiation detector used to explore environmental contaminants, which are

Fig. 5. Portable XRF system and its application [Thermo Scientific Corporation, http://www.thermoscientific.com/Fluke corporation, http://www.Fluke.com] (Images from Thermo Scientific Corporation and Fluke corporation web pages).

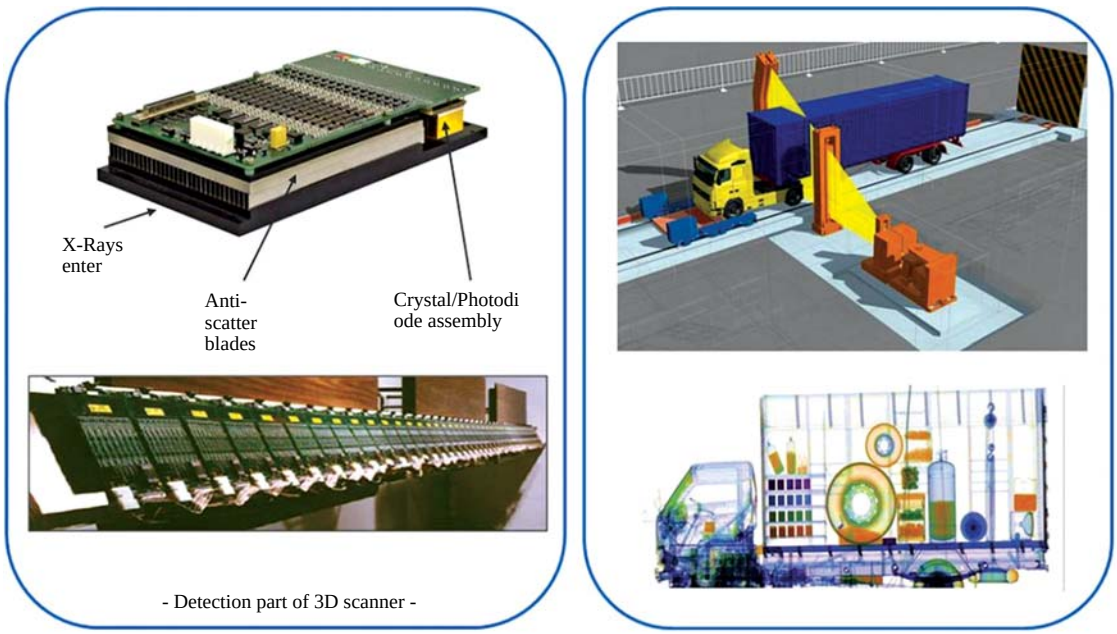

Fig. 6. A 3D scanner and its operation principle [SAIC corporation, http://www.saic.com] (Images form SAIC Corporation web pages).

mainly composed of heavy meals. In recent years, portable XRF instruments have been developed by virtue of compact X-ray generator and a radiation sensor. A portable XRF is utilized in heavy metal analyses on-site and in soil analyses in space probes. They are also utilized to ascertain the genuineness of art works. A portable XRF system is shown in Fig. 5. A 3D scanner can simultaneously detect and discriminate organic and inorganic substances. It can also draw these substances through image mapping. This 3D scanner can give 2D image information and simultaneously analyze the composition of substances. This 3D scanner technology has attracted the attention of counter-terrorism industries.

Table 4. Application fields and extended products of radiation detector

Application field	Developments and its extended products
Atomic energy industry	Radiation Monitoring System (RMS), personnel dosimeter, environmental radiation monitoring in the vicinity of nuclear power plant, radioactive waste storage facilities, and etc.
Material/heavy chemical industry	Development of superfine material, novel material, molecular thin-film processing instrument, polymer reform processing instrument, and etc.
Nano-technology industry	Semiconductor physical property device, nano-particle sizing device, nano-particle manufacture device, new material characterization device, neutron image system, and etc.
Medicine/biotechnology industry	Positron Emission Tomography (PET), Digital Radiography (DR), Computed Tomography (CT), Mammography, Cyber knife, Image Guided Radiation Therapy (IGRT), Intensity Modulated Radio Therapy (IMRT), Tomography, X-ray image system, sterilization of food and medical appliances, plant breeding, radioactive medicine, and etc.

This is shown in Fig. 6. Other application fields and their extended products using radiation detectors are summarized in Table 4.

CONCLUSION

A radiation fabrication and evaluation facility is scheduled to be founded for core-technology incubation of a radiation detection system. This facility is utilized for the development and incubation of bottleneck-technologies to accelerate the industrialization of radiation detection systems in industrial, medical, and radiation security fields. This facility will be based on and serve for the development of radiation sensor materials, radiation detectors, container inspection systems, radiation therapy systems and so on, which need to be obtained for a strategic nation approach. These types of R&D equipments will be selected in view of technical barriers and future market growth. This facility will be a development guide along with a research institute, university, and industry. This facility will be an R&D hub combining the human-resources of a university, an infrastructure of a research institute, and the market needs of industry. This facility will also contribute to the radiation equipment industry through the promotion of technology, and a policy related to provincial government participation and long-term construction planning for the industry complex.

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REFERENCES

Knoll GF. 1999. Radiation detection and measurement. 3th ed. John Wiley and Sons, New York.

Thermo Scientific Corporation, http://www.thermoscientific.com

Fluke corporation, http://www. Fluke.com

SAIC corporation, http://www.saic.com

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