(Form4-2)

JOINT RESEARCH PROJECT

FINAL REPORT
For Japan-Korea Joint Research Project

AREA	1. Mathematics & Physics ②. Chemistry & Material Science 3. Biology 4. Informatics & Mechatronics 5. Geo-Science & Space Science 6. Medical Science 7. Humanities & Social Sciences

1. **Research Title:**
Piezoelectric thin films through a hydrothermal method and their applications for micro energy harvesting device

2. **Term of Research:** From 1st July 2009 To 31st June 2011

3. **Total Budget**

a. Financial Support by JSPS: Total amount: 2,400 thousand yen

1st Year 900 thousand yen 2nd Year 1,200 thousand yen

3rd Year 300 thousand yen

b. Other Financial Support : Total amount: 0 thousand yen

4. **Project Organization**

a. Japanese Principal Researcher	
Name	Takeshi MORITA
Institution / Department Position	The University of Tokyo, Graduate School of Frontier Sciences Associate Professor
b. Korean Principal Researcher	
Name	DaeYong JEONG
Institution / Department Position	University of Myongji, Dept. of Material Sci. & Eng. Assistant Professor

c. List of Japanese-side Participants (Except for Principal Researcher)

Name	Institution/Department	Position
Hiroshi HOSAKA,	The University of Tokyo, School of Frontier Sciences	Professor
Yoichi KADOTA	The University of Tokyo, School of Frontier Sciences	Ph. D candidate
Ryo AGEBA	The University of Tokyo, School of Frontier Sciences	Master Student
Gaku ISOBA	The University of Tokyo, School of Frontier Sciences	Master Student
Takafumi Maeda	The University of Tokyo, School of Frontier Sciences	Master Student

d. List of Korean-side Participants (Except for Principal Researcher)

Name	Institution/Department	Position
Sungwha LEE	Myongji Univ. Dept. of Material Sci. & Eng.	Master Student
Changwoo Baek	Myongji Univ. Dept. of Material Sci. & Eng.	Master Student

5. Number of Exchanges during the Final Fiscal Year*

a. from Japan to Korea *Japanese fiscal year begins April 1.

Name	Home Institution	Duration	Host Institution
For Final Fiscal Year(FY2011) Total: 0 persons		For Final Fiscal Year(FY2011) Total: 0 man-days	
Numbers of Exchanges during the past fiscal years			
FY2009: Total 2 persons FY2010: Total 1 persons			

b. from Korea to Japan

Name	Home Institution	Duration	Host Institution
For Final Fiscal Year(FY2011) Total: 0 persons		For Final Fiscal Year(FY2011) Total: 0 man-days	
Numbers of Exchanges during the past fiscal years			
FY2009: Total 0 persons FY2010: Total 1 persons			

6. Objective of Research

There has been a growing interest in the field of low power miniature sensors and wireless sensor networks. One specific topic receiving much attention is how to make a self-powered microsystem. Piezoelectric materials can convert the vibration energy to electrical energy with high efficiency. A PZT (lead zirconate titanate) material has large electro-mechanical coupling coefficients; however, a PZT is too stiff and brittle because it is ceramics basically. There are so many researches on the piezoelectric power generators. The drawback of these researches is the limitation of the input vibration energy because large input vibration amplitude results in breakage of the devices. By developing a flexible PZT films, it can be a breakthrough that enables large input vibration as a power generator. For a PZT thin film, it should be deposited on flexible substrates such as metal or polymer at the low temperature.

Tokyo Univ. developed a promising technology about the hydrothermal deposition processes. This group succeeded in depositing high quality lead titanate thin films and measuring this ferroelectric property. The lead titanate had been thought to be impossible to measure this property, however with the high quality thin film due to a hydrothermal method; it became possible for the first time. This success verifies the advantage of the hydrothermal method.

Before Dr. Jeong moved to the Myongji University, he has worked in KIST on piezoelectric materials, actuators, and piezoelectric energy harvesting. In KIST, Dr. Jeong has fabricated the PZT film using the Pulsed Laser Deposition method and characterizing the thin films for the energy generation. Now, Myongji Univ. is studying on 2-2 composites for energy harvesting and studying the effect of electrode design on energy harvestings.

This research aims to develop a micro piezoelectric power generation device fabricated by using the ultrasonic-assisted hydrothermal method. This deposition process was developed by Japanese side researchers. Different from conventional thin film technologies, this technology enables 150 degrees PZT deposition that is extremely low temperature for the piezoelectric thin film. This advantage is useful to deposit a piezoelectric film on a flexible substrate. Moreover, the piezoelectric substance with thick film thickness can be comparatively formed by irradiating during the hydrothermal process.

7. Methodology

A PZT thick film was deposited on a flexible substrate was tried. The titanium thin film was deposited on the Engineering plastics (PEEK) by the electron-beam deposition. And PZT thick film was deposited with the ultrasonic-assisted hydrothermal method on this titanium film. Such titanium film is indispensable for our deposition process because only titanium, which is one chemical component of PZT, can be a base substrate for the hydrothermal method. After various trials and errors, we found the appropriate titanium thickness and excellent PZT film on the flexible substrate. Such flexible bimorph transducer is only fabricated with our technology.

Other requirement to the piezoelectric film is its thickness. The hydrothermal method had the problem of slow deposition speed, and taking a lot of time. To overcome this disadvantage, we developed the ultrasonic-assisted hydrothermal method. The high-power ultrasonic transducer was attached to the hydrothermal reactor container as shown in Fig.1 and the ultrasonic wave was irradiated to the chemical solution during the hydrothermal process. The connecting part with the reactive container is designed to the node point of the excited vibration mode. The hydrothermal synthesis condition is shown in Table I.

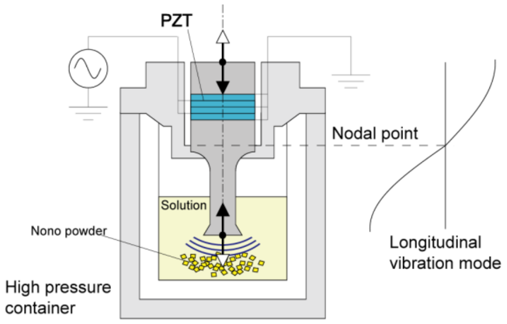

Fig. 1 Ultrasonic assisted hydrothermal method.

Table I. Reaction conditions.

Hydrothermal Method			
$Pb(NO_3)_2$			2.898 g
$ZrCl_2O \cdot H_2O$			0.846 g
TiO_2			0.140 g
KOH		8N	17.5 ml
H_2O			52.5 ml
Solution Volume			70 ml
Temperrature			140 °C
Reaction Time			12 hour

The evaluation of characteristics was carried as a bimorph type power generation device. The dimensions of the generator was 2mm in width, 10mm in length, 0.05mm in thickness, and the mass of 0.5g. This generator was attached to the vibration generator and the acceleration of 70 m/s^2 was given. This vibration energy was successfully converted to the electric power with the piezoelectric effect of the deposited PZT thin film.

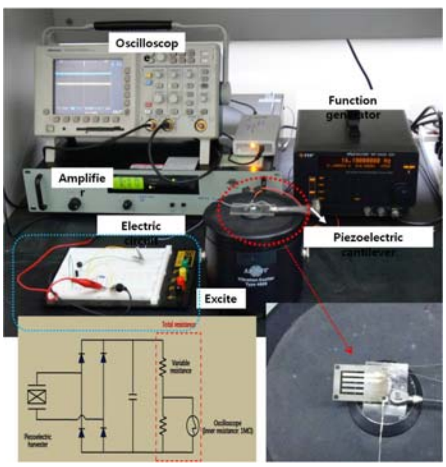

Fig. 2 Piezoelectric energy harvesting measurement system.