Development of a Real-time In-Beam Monitor with Plastic Scintillation Fibers for Particle Therapy

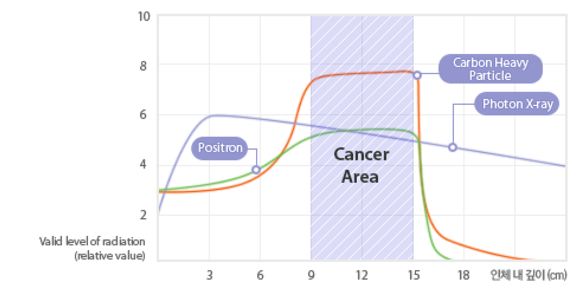
○Shunsuke Kurosawa[1,2,3,4], Kanta Takahashi[5], Akihiro Yamaji[1], Kouji Morimoto [6], Takeo Iwai[7], Hiraku Sato[7], Fuyuki Tokanai[5]

[1]Tohoku Univ. NICHe, [2]Osaka Univ. ILE, [3]Tohoku Univ. IMR, [4]Tohoku Univ. RCNS, [5]Yamagata Univ. Sci., [6] RIKEN RNC, [7] Yamagata Univ. Med.

E-mail: kurosawa@imr.tohoku.ac.jp, shunsuke.kurosawa.a6@imr.tohoku.ac.jp

1, Introduction

➢ Particle therapy



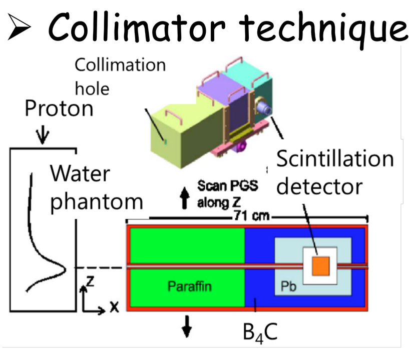
[1] https://www.kirams.re.kr/eng/khima/therapy01.do

Particle Therapy is a method of discharging heavy particle to cancer cells located deeply under the skin.

Heavy Particle Therapy device has shown successful full recovery rate of 90% for liver cancer, 100% for prostate cancer, 80% for lung cancer,, and 42% full recovery rate for recurrent cancer. The Heavy Particle Therapy Device has the advantages of zero pain or side effects on top of high killing power of cancer cells with the Bragg Peak effect [1].

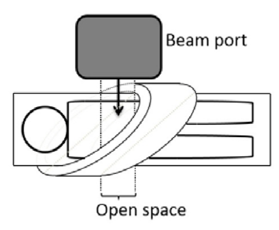
Dose verification in beam is highly required in particle therapy

➢ Collimator technique



Min et al. Appl. Phys. Lett. 89 183517 (2006)

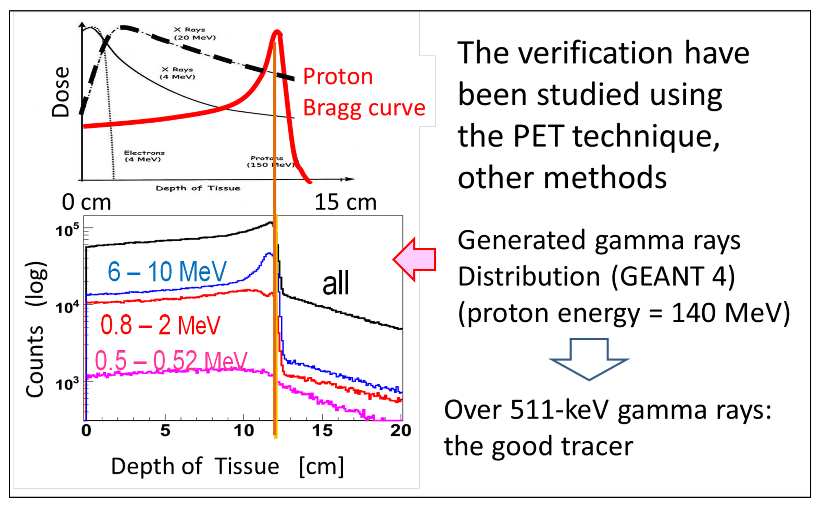
➢ Open PET



Yamaya, J. of Phys.: Conf. Series 777 012023(2016) QST

Although technique of positron emission tomography (PET) has been studied, the real-time imaging has been not realized due to large amount of noises such as scattered gamma-ray or other secondary particle in beam.

➢ Gamma-ray Imaging



Compton camera is candidates for the real time monitor

Electron-tracking Compton camera (ETCC) can image gamma-rays with high sensitivity.

➢ Previous our Study of Gamma-ray Imaging

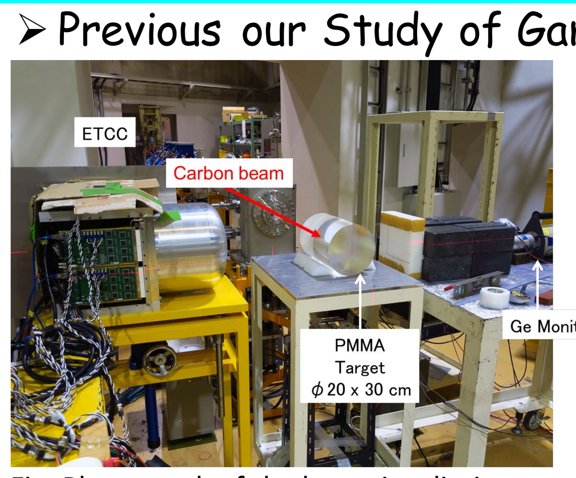


Fig. Photograph of the beam irradiation with the ETCC

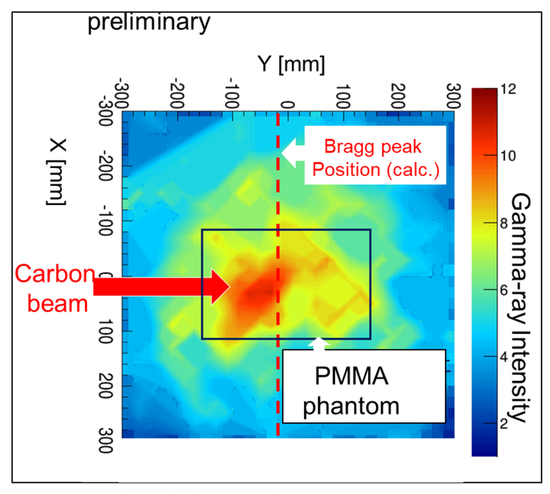


Fig. Result of the real-time image

We succeeded in gamma-ray imaging during the carbon beam with a flux of up to 10^7 cps and energy of 290 MeV/u in real-time

Still, the camera size is not suitable, and we found some problems while the operation. Also higher counting rate is hard to image.

We need a more compact detector!

2, Secondary Proton Imaging

➢ Alternative probes

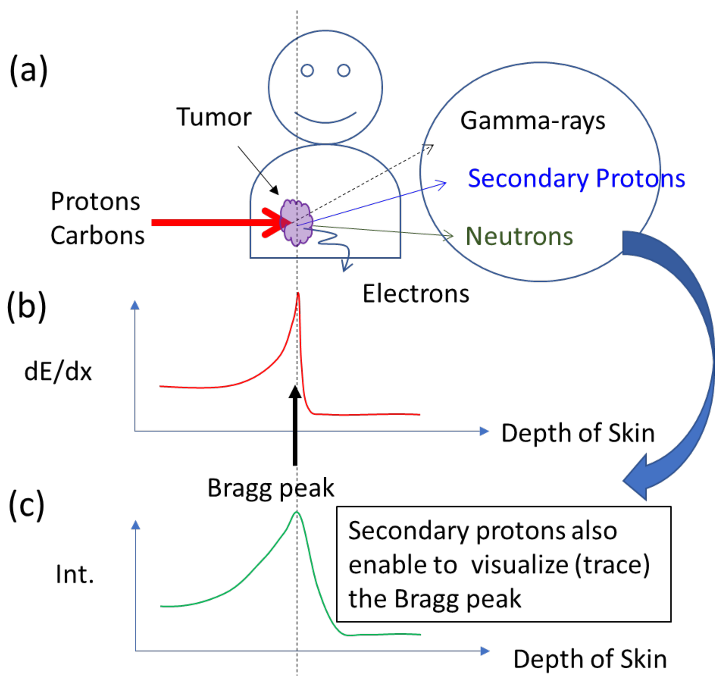


Fig. (a)Schematic view of treatment with Carbons (or protons), (b) Bragg peak image and (c) Concept of the tracer

➢ Simulation Study

PHITS (particle and heavy ion transport code system, version 3.02) suggested the secondary protons are expected to be a probe for the Bragg peak
(Iwai et al., JPS Conf. Proc. 24, 011030 (2019))

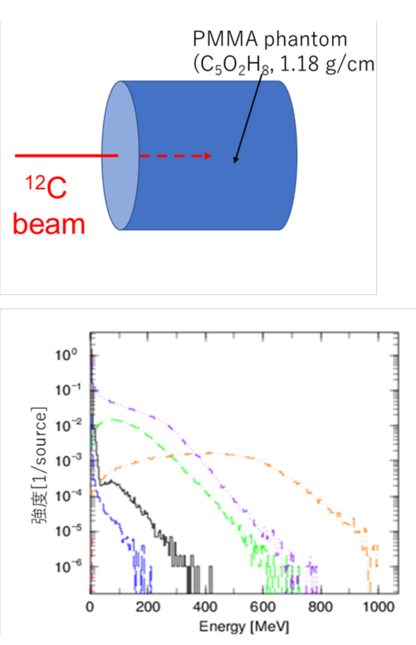


Fig. Schematic view of the Simulation Setup and energy spectra (sim. results)

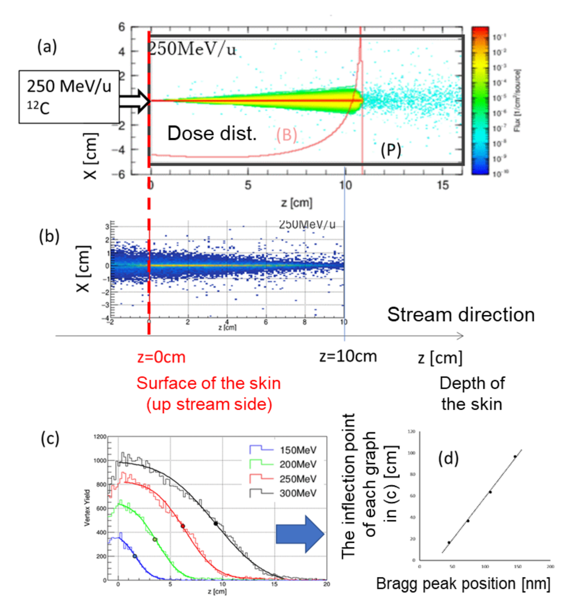


Fig. (a) dose distribution, (b)Secondary proton distribution , (c)its profile and (d) their inflection points vs. Bragg peak

➢ Schematic View of Its (Our) Imaging Device : Scintillating Fiber Imager (SFI)

Scintillation fibers (Kuraray SCSF-78/ BICRRON BCF-12) were assembled as follows.
(see the detail : K.Morimoto, et al., IEEE Trans. Nucl. Sci. **47**, 2034
Iwai et al., JPS Conf. Proc. 24, 011030 (2019))

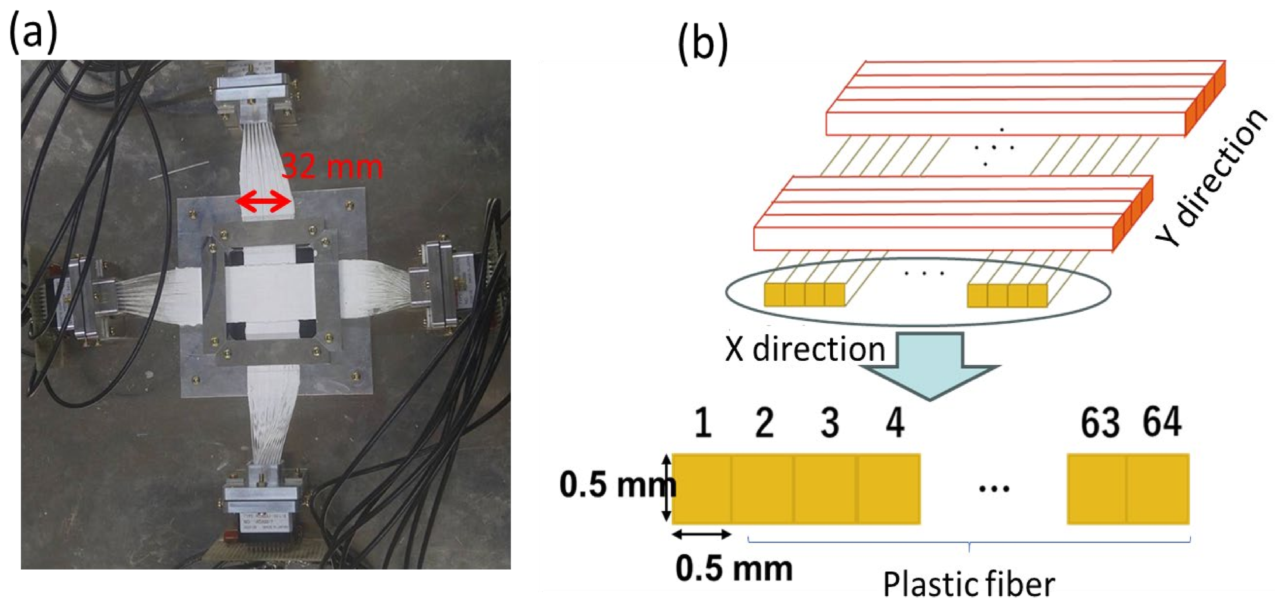


Fig. Photograph (a) and schematic view (b) of our detector (PSF)

3, First Imaging Test w/ Protons

➢ Reconstruction

SFI was irradiated with proton beams in Research Center for Accelerator and Radioisotope Science(RARIS),Tohoku University, and the image was reconstructed with position info. as shown in the right figure.

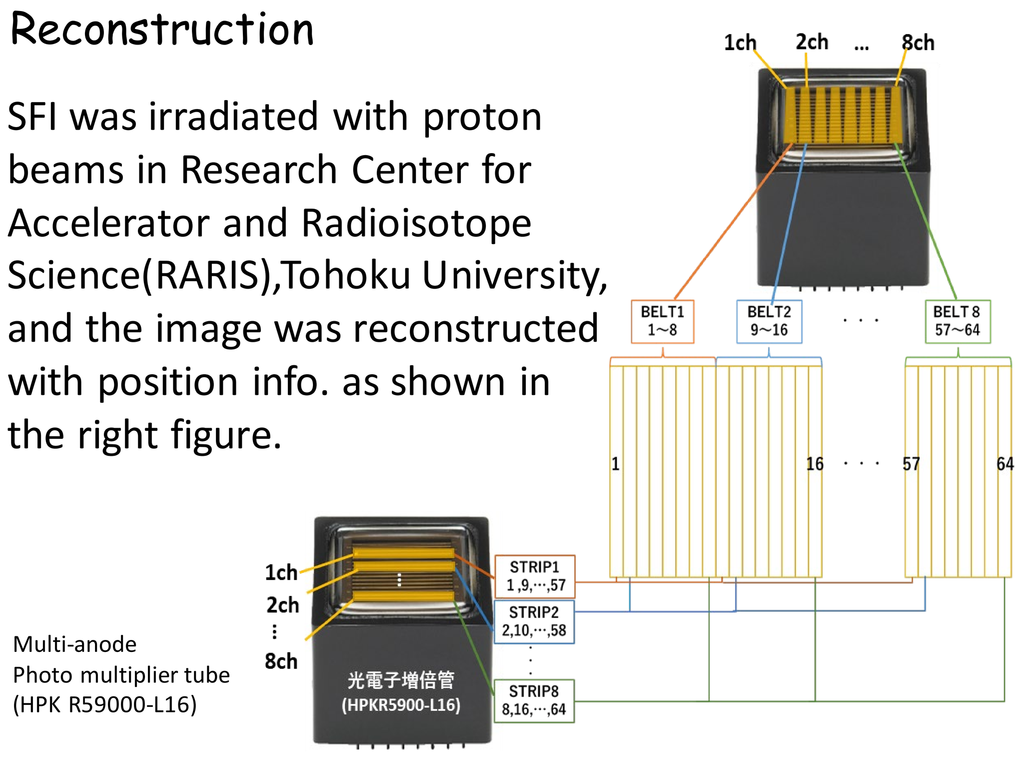


Fig. Reconstruction Scheme

➢ Imaging Results

We succeeded in imaging with "donut shape" using a donut-shaped plastic scintillator as a coincidence.

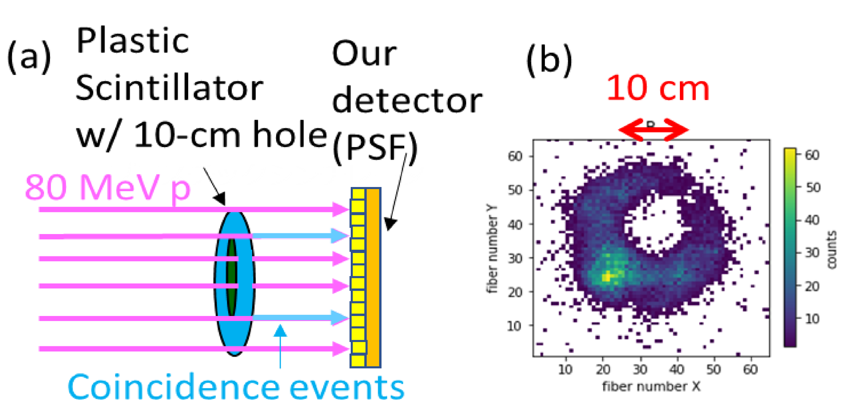


Fig. (a) Schematic view of the experimental setup and (b) the imaging result

4, Carbon Imaging Test

➢ Optimization for the Read System

Previous system was used with CAMAC system, and we renewal the system with FPGA to be compact (down size) for commercialization.

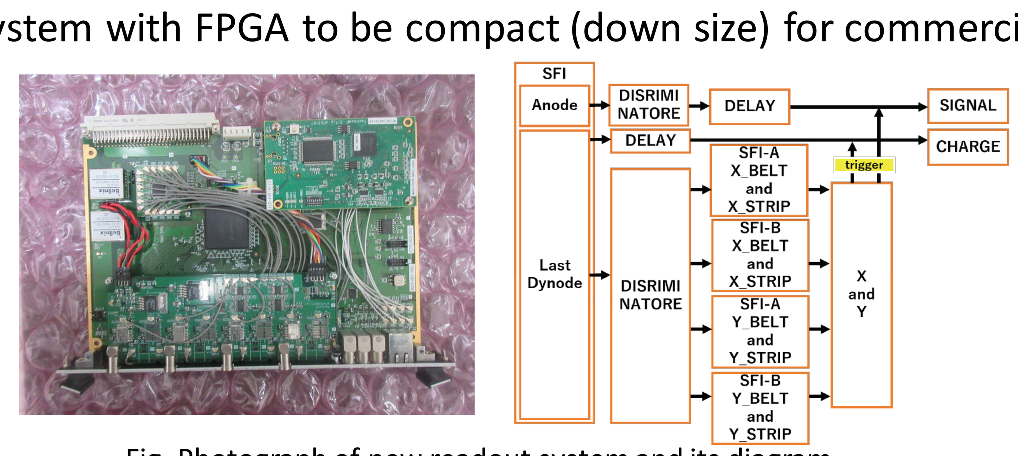


Fig. Photograph of new readout system and its diagram

➢ Set up in East Japan Heavy Ion Center, Yamagata Univ. Hospital https://www.id.yamagata-u.ac.jp/nhpb/en/index.html

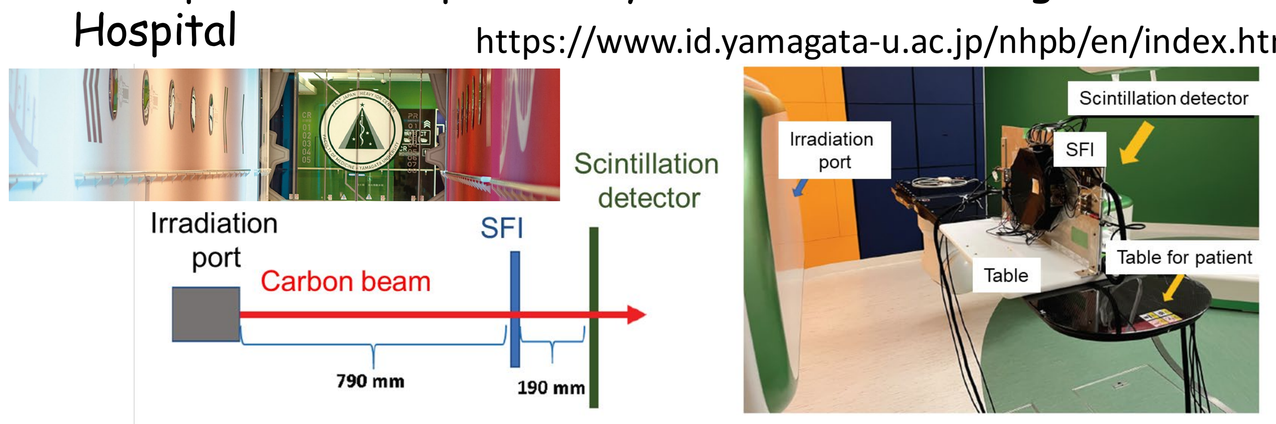


Fig. Schematic view of the setup and its photograph

➢ Results

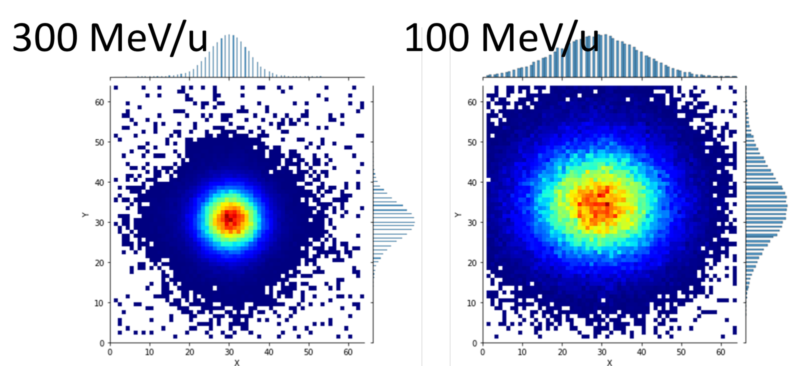


Fig. Results of the Carbon Imaging

The results showed spread image was observed as the carbon energy was smaller. These results were consistent with those with a gaseous detector measured by manager in the hospital.

➢ Energy Spectra

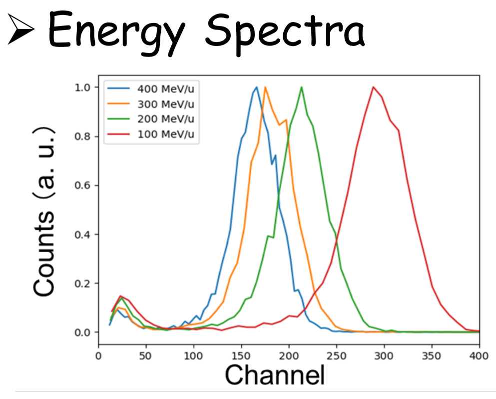


Fig. Energy spectra (Energy deposit in the scintillation material) for several incident Carbon Energies

➢ Energy Spectra

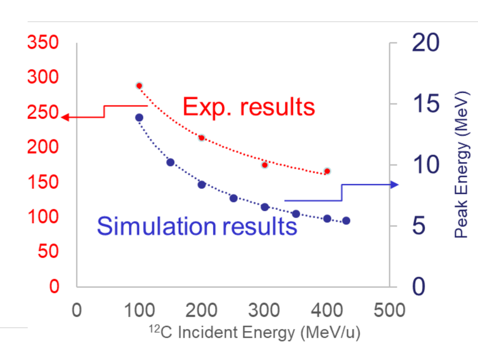


Fig. Incident Carbon Energy v. peak position of let graphs and their simulation.

5, Summary

We fabricated Scintillating Fiber Imager (SFI) to obtain secondary proton imaging to verify the Bragg peak and its dose to realize the real-time dose monitor of particle therapy. This results was expected to improve the Quality Assurance of its therapy.

➢ Acknowledgements

This work is partially supported by (i) Grant-in-Aid for Japan Society for the Promotion of Science Research Fellowships (Kakenhi Kiban A, S. Kurosawa) (ii) Development Program for Advanced Measurement and Analysis (SENTAN), the Japan Science and Technology Agency (JST), (iii) Adaptable & Seamless Technology Transfer Program through Target-driven R&D (A-STEP) (S. Kurosawa) , JST (iv) Project to Promote Innovation for Recovery from the Earthquake, the Ministry of Economy, Trade and Industry (METI), (v) support industry program, METI and (vi) the Association for the Progress of New Chemical Technology. In addition, we would like to thank following persons for their support: Mr. Yoshihiro Nakamura in Institute of Multidisciplinary Research for Advanced Materials (IMRAM), Tohoku University and Mr. Yoshihiro Murakami, Mr. Hiroshi Uemura, Ms. Keiko Toguchi and Ms. Megumi Sasaki in IMR.