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IRRADIATION TESTS ON DIAGNOSTICS COMPONENTS FOR ITER IN 1995

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One of the most important issues to develop the diagnostics for the experimental thermonu clear reactor such as ITER is the irradiation effects on the diagnostics components. As an ITER Engineering Design Activities (DE), we carried out the irradiation tests on the basic materals of the transmission components such as ceramics, windows, fiber optics and mirrors, and in-vessel diagnostics sensors such as bolometers in 1995. We investigated radiation induced conductivity (RIC) of a ceramics for 14 MeV neutrons in FNS. 14 MeV neutron induce luminescence of window material were evaluated absolutely in FNS. Radiation induce transmission loss of window materials and fiber optics have been measured in JMTR. Off line irradition tests were carried out for Molybdenum corner cube reflector (CCR) and gold coated mirrors in JMTR. The performance of the JT-60 type bolometer has been confirmed under the Co^{60} gamma-rays. Cold test of a magnetic probe was carried out before irradiation.

Keywords: Irradiation Effect, ITER, Diagnostics, Ceramics, Windows, Fiber Optics, Reflector, Bolometer, JMTR, FNS

This work is conducted as an ITER Engineering Design Activities and this report corresponds to 1995 ITER Technical R&D Task Agreement on "Irradiation Tests on Diagnostics Components"(T246).

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１９９５年におけるＩＴＥＲ用計測機器要素の照射試験

日本原子力研究所那珂研究所炉心プラズマ研究部
西谷　健夫[§]・飯田　敏行[*]・池田裕二郎[+1]・石塚　悦男[+2]・角田　恒己[+3]
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（１９９６年９月２日受理）

ＩＴＥＲをはじめとする核融合実験炉用計測装置の開発において最も重要な課題の一つは計測機器要素の放射線照射効果である。ＩＴＥＲの工学設計活動の一環として、ボロメーター等の真空容器内計測センサー及びセラミックス、窓材、光ファイバー、鏡等の光／信号伝送用基本要素の照射試験を1995年に実施した。FNSにおいて14 MeV中性子に対するセラミックスの照射誘起伝導の測定及び窓材の照射誘起発光の絶対測定を行った。またJMTRを使用し、照射下における窓材及び光ファイバーの透過損失を実時間で測定した。さらにモリブデン反射鏡（CCR）及び金蒸着鏡のオフライン照射をJMTRで行った。$\mathrm{Co}^{60}\gamma$線照射下においてJT-60用のボロメーターが正常に動作することを確認した。また磁気プローブについては照射前の特性測定を行った。

本研究はＩＴＥＲ工学設計活動の一環として実施したもので、本報告は工学R&Dタスク協定（T246）に基づくものである。

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1. Introduction

One of the most important issues to develop the diagnostics for the experimental thermonuclear reactor such as ITER is the irradiation effects on the diagnostics components. Typical neutron flux and fluence on the first wall are 1 MW/m^2 and $1MWa/m^2$, respectively for ITER. In such radiation condition, most of the present diagnostics could not survive so that those will be planed to be installed far from the vacuum vessel. However, some diagnostics sensors such as bolometers and magnetic probes still have to be install inside vessel. And many transmission components for lights, wave and electric signals are inevitable even inside vessel. As an ITER Engineering Design Activities (EDA), an extensive R & D program has been set up in order to identify radiation hardened materials that can be used for diagnostic systems. As the first phase of the R&D program in 1995, we carried out the irradiation tests on the basic materials of the transmission components such as ceramics, windows, fiber optics and mirrors, and in-vessel diagnostics sensors such as magnetic probes and bolometers.

Ceramics will be used as general insulating materials. They will be required in feedthroughs, connectors, mechanical supports and general standoffs, mineral insulated (MI) cables and their seals, substrates (bolometers), and other sensor devices such as pressure gauges. It is now also considered essential that only ITER relevant insulating materials be employed in components to be tested. For ceramics radiation induced conductivity (RIC) and radiation induced electrical degradation (RIED) are important issues under ac/dc electrical fields. Here we investigated RIC effect of a ceramics for 14 MeV neutrons.

Optical elements are the most sensitive to radiation damages among the transmission components. In optical fibers and windows, radiation induced luminescence and transmission loss are severe problem for spectrometric diagnostics. Also the change of the reflection coefficient is important in mirrors or reflectors. Of course not only the irradiation effect but also neutral particle sputtering is severe problem for the first plasma facing mirror/reflector, but we did not treat later in this report.

Bolometers are also installed inside the vacuum vessel to measure the whole radiation losses in the range infra red to soft x-ray. Those radiation power is much less than nuclear radiation (neutrons and gammas) in ITER. First of all we have to demonstrate the bolometric measurement in the nuclear radiation condition. We investigated the performance of the JT-60 type bolometer under the Co^{60} gamma-rays.

2. Radiation induced conductivity of ceramics for 14 MeV neutrons

K. Noda, T. Nakazawa, Y. Oyama, D. Yamaki and Y. Ikeda

2.1 Experimental object

To obtain experimental data on RIC(Radiation Induced Conductivity) of various ceramic materials at various temperatures under 14MeV neutron irradiation.

2.2 Experimental conditions

(1) Material

Alumina (Al_2O_3), Diameter = 10 mm, Thickness = 0.3 mm

(2) Irradiation facility

FNS DT neutron source in JAERI Tokai

(3) Irradiation conditions

Neutron flux range 10^{12} to 10^{15} n/m^{2}s (neutron dose rate range 10^{-2} to 1 Gy/s), Temperature range 300 to 570 K

(4)Experimental devices (incl. Capsule)

Electrodes and guard ring to avoid influence of surface leak current on the resistivity measurements were formed on the specimens by paining platinum paste and heating at about 1270K for several hours. In order to measure the resistivity of the specimen during the irradiation appropriately, the large ratio of electrical resistance between the specimens and insulators can be realized during irradiation by separating the insulators between the electrodes from the specimen position in the neutron irradiation field with the large neutron flux gradient. In the irradiation chamber, high vacuum can be attained using a turbomolecular pump system to avoid influence due to the ionization of surrounding gas.(fig. 2.1) Temperature of the specimens can be varied in the range 300 to 870 K by a heater attached.

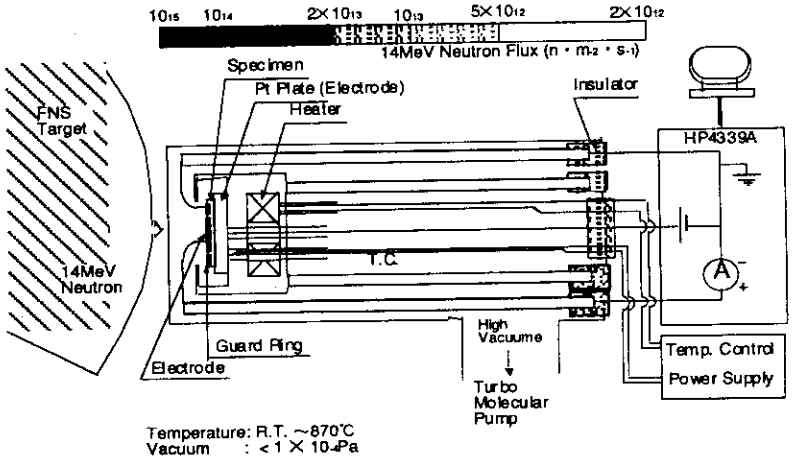


Fig. 2.1 A schematic illustration of irradiation chamber.

(5) Measurement

The resistivity measurement was carried out with three terminal DC method with the guard ring using a HP4339A high resistance meter. Neutron flux was measured by a 232T fission counter, calibrated by measuring alpha particles generated from DT fusion reactions with a SSD (solid State Detector) at the low neutron flux.

2.2 Experimental results

The resistivity decreased at once just after the start of the neutron irradiation and a constant value of the resistivity was immediately attained. The constant resistivity was kept with a constant neutron flux. When the neutron irradiation was stopped, the resistivity was immediately increased.(Fig.2. 2)

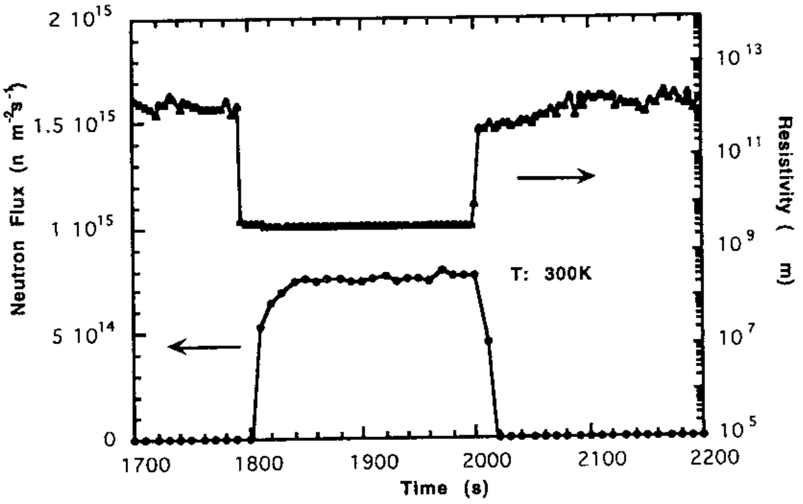


Fig. 2.2 Electrical resistivity behavior of Al_2O_3 at 300 K during in-situ measurement.

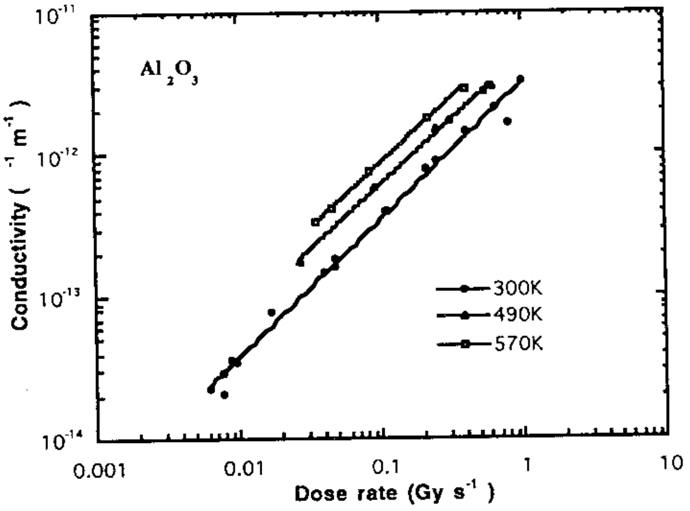


Fig. 2.3 Electrical conductivity of Al_2O_3 under irradiation at 300, 490 and 570 K versus 14 MeV neutron dose rate.

Similar resistivity behavior was observed at 490 and 570K. The electrical conductivity of the Al_2O_3 single crystal under irradiation at 300, 490 and 570K showed the linearity versus 14MeV neutron dose rate in a log-log plot. (Fig. 2.3)

2.4 Comments

The irradiation chamber for in-situ electrical resistivity measurements at various temperatures was developed. The measurements in the range 300 to 570 K can be carried out appropriately. Improvement of electrodes are needed for appropriate measurements at much higher temperatures.

2.5 Future plan

In-situ measurement of electrical resistivity of sintered Al_2O_3, Cr-doped Al_2O_3, etc. in the temperature range 300 to 570 K and improvement of the system for appropriate measurements at much higher temperatures.

Reference

[2.1] K. Noda, T.Nakazawa, Y. Oyama and H. Maekawa, Fusion Engineering and Design, 29 (1995) 448.

[2.2] K. Noda, T.Nakazawa, Y. Oyama, D. Yamaki and Y. Ikeda, J. Nucl. Mater., in press.

3. Light emission from window materials for 14 MeV neutrons

Y. Oyama, T. Iida, F. Sato and F. Maekawa

3.1 Experimental object

We will measure the light emission efficiency and spectrum for commercial materials

3.2 Experimental conditions

(1) Material

SiO_2(20^{ϕ}x$3mm^{t}$), Alumina (10^{ϕ}x$2mm^{t}$), Sapphire (20^{ϕ}x$3mm^{t}$)

(2) Irradiation facility

FNS DT neutron source in JAERI Tokai

(3) Irradiation conditions

Neutron flux $= 7 \times 10^{10}$ n/cm^2/s, Photon flux $= 6.3 \times 10^9$ photon/cm^2/s

Estimated Dose Rate =

0.655 Gy/s by neutrons, 0.0337 Gy/s by photons for quartz(SiO_2),

0.532 Gy/s by neutrons, 0.03 Gy/s by photons for sapphire(Al_2O_3)

(4) Experimental devices (incl. Capsule)

Sample disk was set at the end of 24.5ϕ x 140 mm long aluminum chamber and emitted photons were collected by two focusing lens to a single core optical fiber. The fiber length of 20 m in length transmitted photons from irradiation room to measuring room. The fiber was connected to photon counting grade photomultiplier cooled by electrical heat pump and also connected to photon spectrum analyzer with image intensifier. (Fig.3.1)

(5) Measurement

First the system was calibrated and the absolute detection efficiency was determined. The efficiency includes effective measured volume, transmission and collecting efficiencies. The irradiation was made for both 14 MeV neutron field and Co-60 gamma-ray field, because light emission by 14 MeV neutron induced gamma-rays was mixed by irradiation experiment. Finally the results was obtained by subtracting the latter response from the former response with normalization by energy absorption.

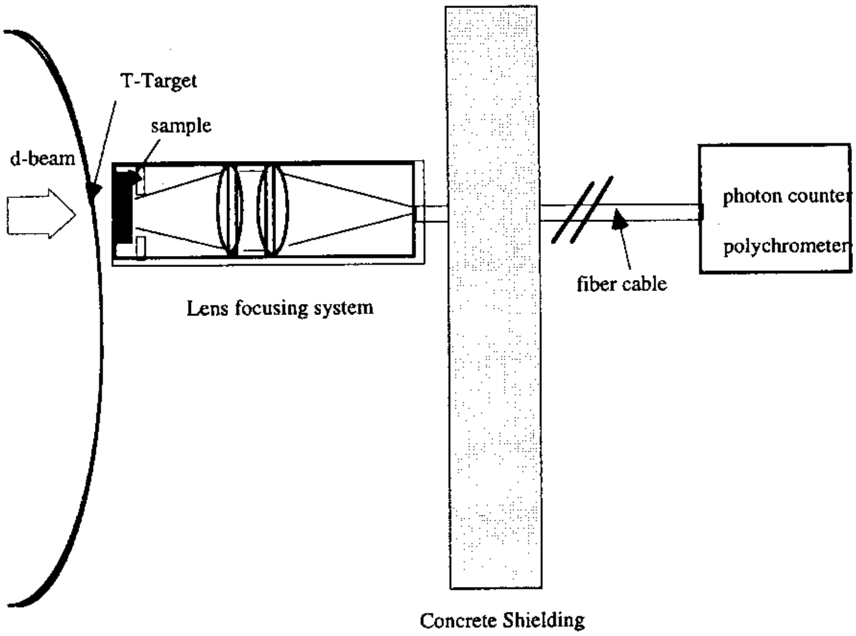


Fig.3.1 Experimental setup on FNS.

3.3 Experimental results

Light emission coefficients of 14 MeV neutrons for various materials are listed in Table 3.1. The typical light emission spectrum for pure silica glass is shown in Fig.3.2. The results shows neutron induced emission coefficient in 350-750 nm range was as ten times small as that of gamma rays. The coefficient in photon number of energy absorption in unit volume is less than 10 for the pure silica glass, 1500 for Alumina crystal, 150-240 for commercial sapphire (ORIEL).

Table 3.1 Light emission coefficient of 14 MeV neutrons for various materials.

Material	Light Emission Coefficient (photon/MeV)
High pure silica glass	<10
Sapphire (Alumina crystal)	1500
Sapphire (ORIEL)	150-240
NE102A	2800

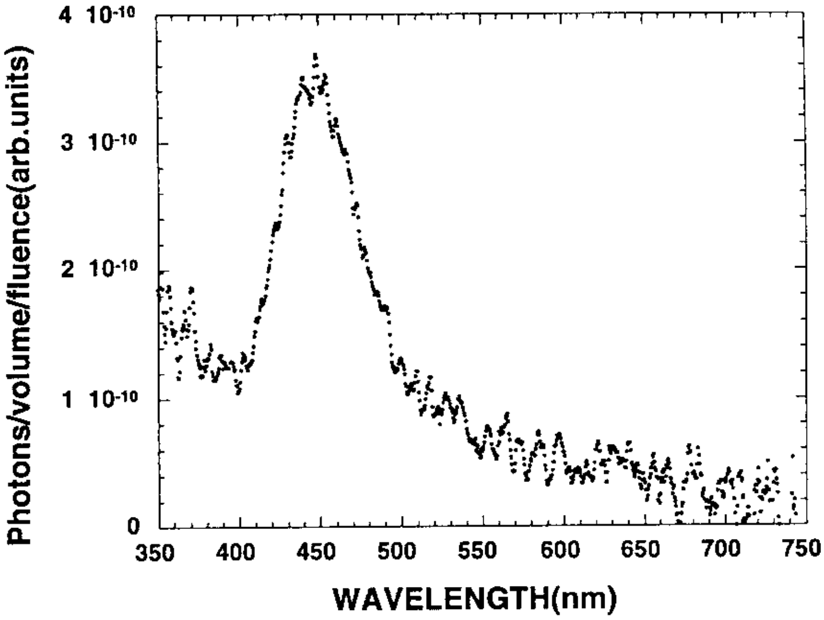


Fig.3.2 Light emission spectrum from SiO_2 during 14 MeV irradiation.

3.4 Conclusion and Comments

The absolute 14 MeV neutron induced light emission coefficients were obtained. Alumina and commercial sapphire showed different spectra. This is because of the different impurities, therefore the reference sapphire should be specified.

3.5 Future plan

The round robin quartz supplied from Russia and the sapphire of the other supplier are tested together with absorption characteristics measurement.

Reference:

[3.1] F. Sato, Y. Oyama, T. Iida, et al., "Experiment of 14 MeV Neutron Induced Luminescence on Window Materials ", submitted to SOFT'96

4. Irradiation tests of windows in JMTR

E. Ishitsuka and T. Sugie

4.1 Experimental object

To investigate the change of transmission spectrum by the effects of neutron irradiation and irradiation temperature.

4.2 Experimental conditions

(1) Material

Sapphire, $\phi 13 \times {}^{t}1$ mm

(2) Irradiation facility

JMTR in JAERI Oarai

(3) Irradiation conditions

Temperature 300 °C , Neutron fluence 2×10^{20} n/cm^2
Temperature 400 °C , Neutron fluence 3×10^{20} n/cm^2
Temperature 500 °C , Neutron fluence 4×10^{20} n/cm^2

(4) Experimental devices (incl. Capsule)

Five set samples are installed in the inner capsule for neutron irradiation, and each inner capsule are controlled at 300, 400 and 500 °C by the heater.

(5) Measurement

Transmission spectrum measurement by UV-3100 (Shimadzu Co.)

4.4 Experimental results

Transmission spectrum of neutron irradiated sapphire for wide range and narrow range are shown in Fig. 4.1 and 4. 2. And for un-irradiated and low fluence (old task : JB-IVA-2: 250 °C , 5×10^{19} n/cm^2) sapphire also shown in same figures. Transmission spectrum of neutron irradiated sapphire are similar as shown in Fig. 4.1. Narrow range spectrum is shown in Fig. 4.2. Spectrum of 250-400°C shows decreasing by neutron fluence. Spectrum of 500°C shows recover even in high neutron fluence.

Transmission rate of neutron irradiated sapphire in the wavelength of 200-800 nm decreased by defects of neutron irradiation. Decreasing of transmission rate depended on neutron fluence, however, slightly recover by high temperature irradiation.

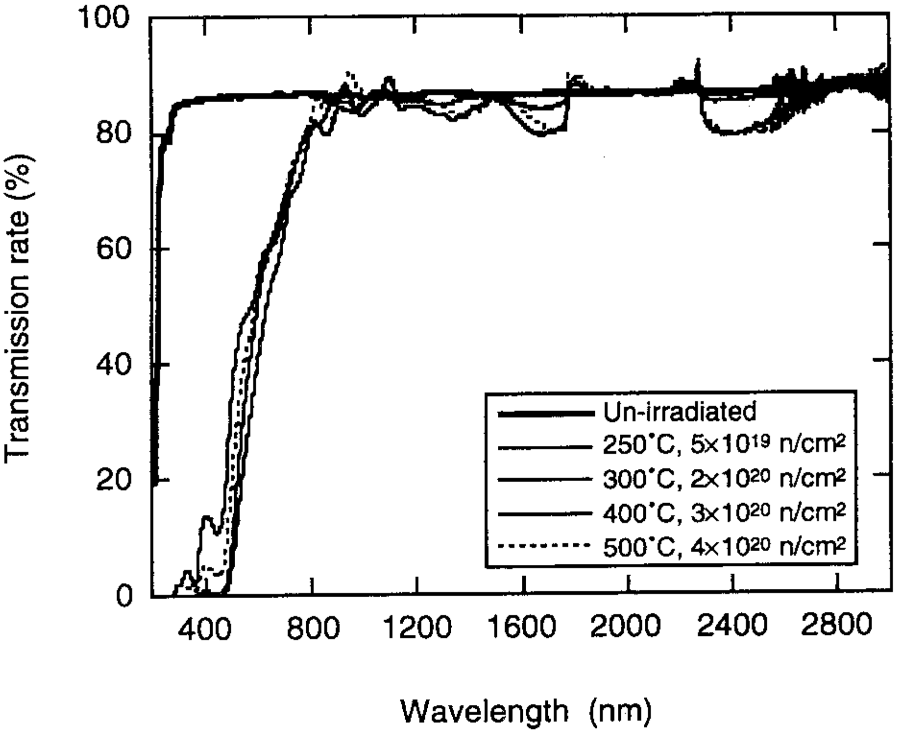


Fig. 4.1 Transmission spectrum of neutron irradiated sapphire for wide range.

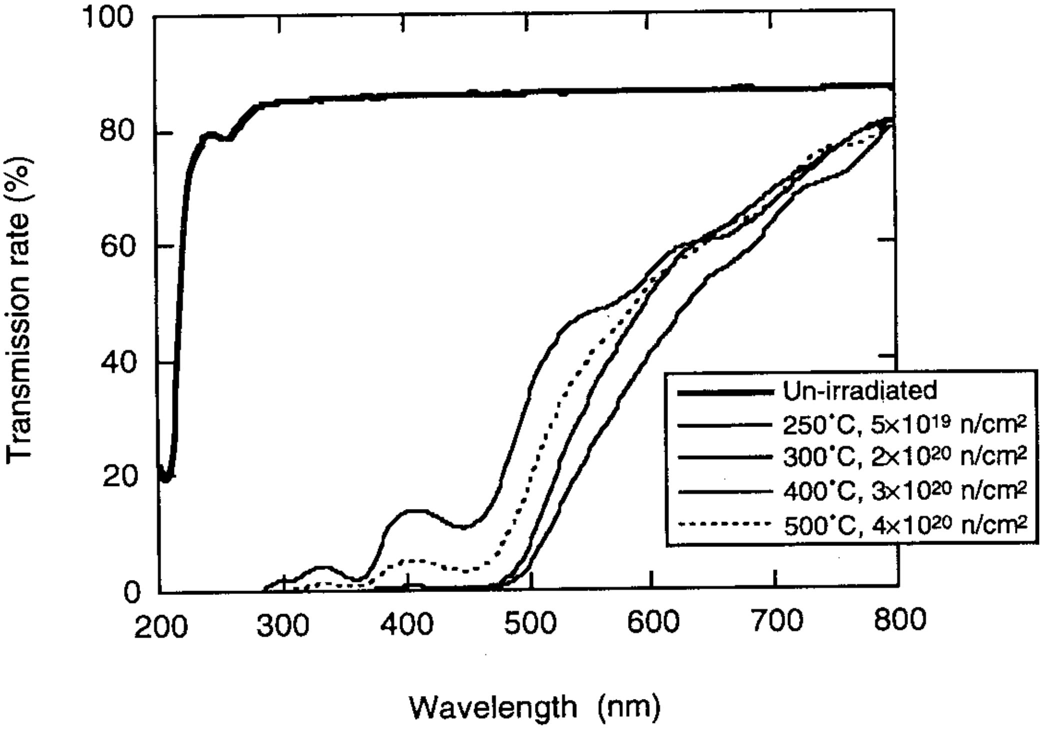


Fig. 4.2 Transmission spectrum of neutron irradiated sapphire for narrow range.

4.4 Conclusion

Recover of transmission rate at 500°C was a little, and may not be satisfied to use of windows materials for the fusion reactor. Umeda [4.1] reported that transmission rate of neutron irradiated sapphire (1.2×10^{17} n/cm^2) recovered by heating of 650°C and 5 min, however , the effects of neutron fluence and irradiation temperature are complicate, therefore, in-situ measurement is necessary in this study.

4.5 Future plan

We have a plan of an in-situ measurement of transmission spectrum for windows under the JMTR neutron irradiation with different temperature. Test material is Sapphire (Kyocera) and KU-1 quartz made in Russia. Outline of in-situ transmission spectrum measurement capsule is shown in Fig. 4.3. Capsule consist of 2 axis driving system, sample stage, Mo-CCR and heater. There are a couple of light beam, one is for measurement and another is a spear for any accident. Two light axis adjust by 2 points driving system. Stepping motor for sample stage rotation role as a sample changer. Irradiation temperature is 200 °C and 300 °C. The neutron fluence is estimated to be 3×10^{20} n/cm^2.

Reference

[4.1] Umeda, Journal of the atomic energy society of Japan ,Vol.35, No.6 (1993) 543.

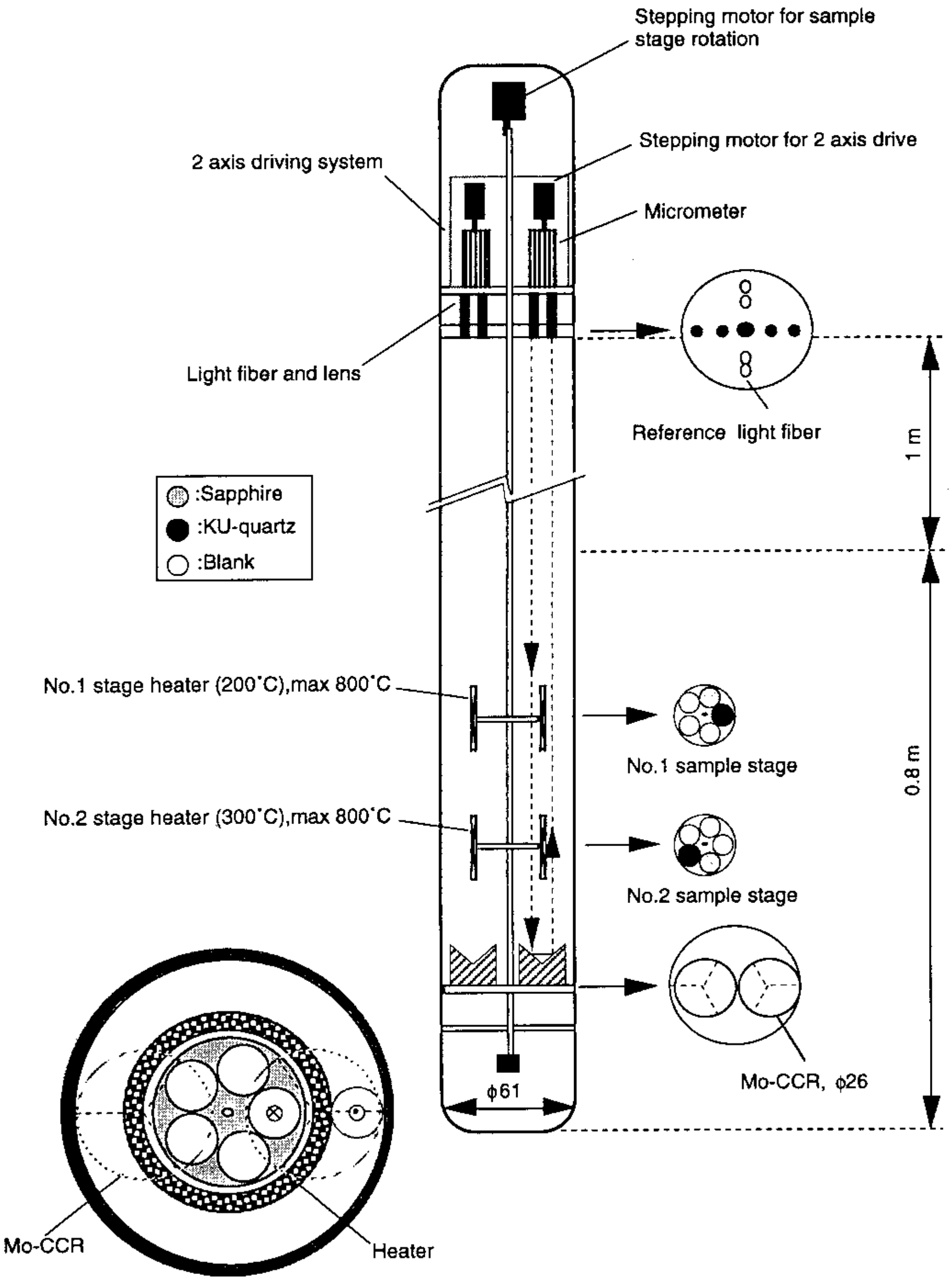


Fig. 4.3 Outline of in-situ transmission spectrum measurement capsule.

5. Irradiation tests of fiber optics

T. Kakuta and E. Ishizuka

5.1 Experimental objective

To investigate the radiation resistance of conventional type optical fiber, optical transparency and fluorescence have been measured.

5.2 Experimental conditions

(1) Material

Three kinds of SiO_2 based conventional optical fiber with polymer jacket were irradiated for JMTR irradiation.

i) Two types of Low-OH SiO_2 core, Fluorine doped SiO_2 clad, Step-index type optical fiber. (SI) : 200 μm of core, 250 μm of clad.
ii) Two types of SiO_2 based Single-mode fiber.(SM fiber): 10 μm of core, 125μm of clad.
iii) Two types of SiO_2 based Single polarization fiber. (PANDA fiber) : 10 μm of core, 125 μm of clad.

Total length of fibers was 60 m, and about 20 cm was inserted reactor core region. For CO^{60} irradiation tests, two kinds of Step-index type optical fiber are employed; Low-OH SiO_2 core and Fluorine doped SiO_2 clad with 200 μm of core, 250 μm of clad. Total length of fibers was 30 m, and 10m was exposed to CO^{60} gamma-rays.

(2) Irradiation facility

JMTR in JAERI Oarai and CO^{60} irradiation facility in JAERI Tokai.

(3) Irradiation condition

JMTR:

Fluxes $3.1 \times 10^{13}/cm^2s$ (E>1MeV), Fluence 1.3×10^{20} n/cm^2, Temperature 130°C, Irradiated fiber length about 20cm.

CO^{60}:

Dose rate 5.0 Gy/s, , Total dose 1.2×10^6 Gy, Room-temperature, Irradiated fiber length 10m.

(4) Experimental devices (incl. capsule)

Special capsule 94M-17J was used for this experiment. One end of fiber was connected to AQ-4303B Xenon-lamp of white light source and other end was connected to AQ-6315A optical spectrum analyzer. Fig. 5.1 shows the accommodation of optical fibers in 94m-17J capsule for JMTR. Same measurement system except the capsule was used for the CO^{60} irradiation tests.

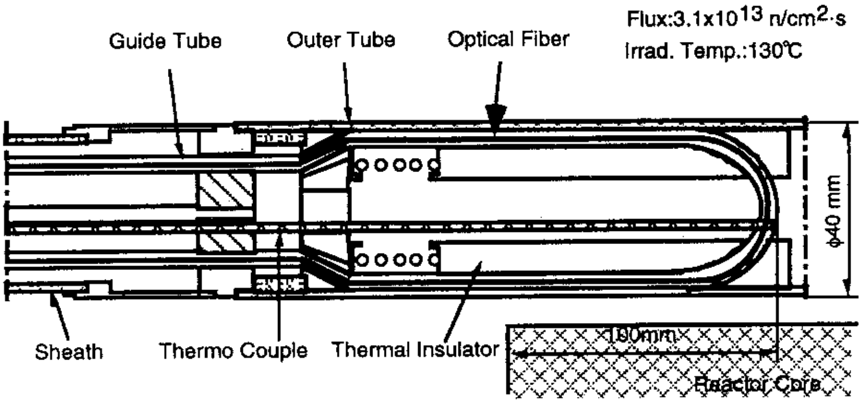


Fig. 5.1 Accommodation of optical fibers in 94M-17J capsule for JMTR.

(5) Measurement

In-situ measurement for optical transparency and fluorescence phenomena.

i) Step-index fiber (SI) : Wavelength region from 350 nm to 1750 nm.

ii) Single-mode fiber (SM) : Wavelength region from 800 nm to 1750 nm.

iii) Single polarization fiber (PANDA) : Wavelength region from 800 nm to 1750 nm.

5.3 Experimental results

(1) Figure 5.2 shows the induced loss spectrum in conventional type Step-index fiber during irradiation with JMTR. In this case, large absorption loss in the wavelength shorter than 700 nm by means of E' center and NBOHC, was observed. However, the conventional (not radiation hardened) SI fibers survived under irradiation up to about 1×10^{18} n/cm^2 in the wavelength region from 700 nm to 1700 nm. Some optical fluorescence radiation , sharp peak at 1270 nm and broad band in the wavelength region from 400 nm to 1700 nm, were measured.

(2) Figure 5.3 shows the induced loss spectrum in conventional type Single-mode fiber during irradiation with JMTR. Single-mode fibers were appeared good radiation resistance in the wavelength region from 800 nm to 1400 nm. One of SM fiber, the absorption loss was less than 5 dBm at the irradiation up about 1×10^{20} n/cm^2.

(3) Single polarization type fibers, which a kind of SM type fiber, were appeared good radiation resistance in the wavelength region from 800 nm to 1300 nm [5.1,5.2,5.3].

(4) Figure 5.4 shows the induced loss spectrum in Step-index type optical fiber measured with Co-60 gamma-ray source. Large absorption loss in the wavelength shorter than 900 nm by means of E' center and NBOHC, was observed.

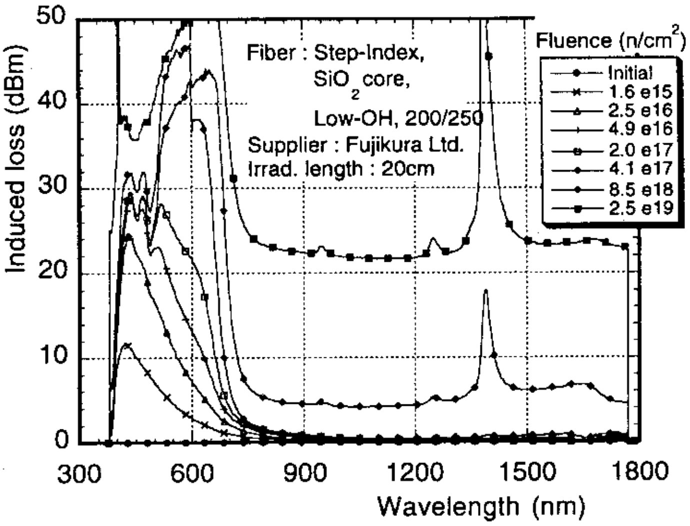


Fig.5. 2 Induced loss spectrum in conventional type Step-index fiber during irradiation with JMTR.

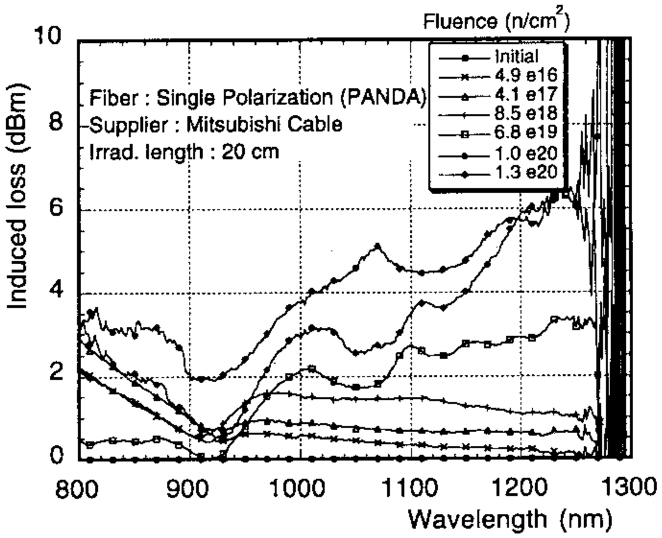


Fig. 5.3 Induced loss spectrum in conventional type Single-mode fiber during irradiation with JMTR

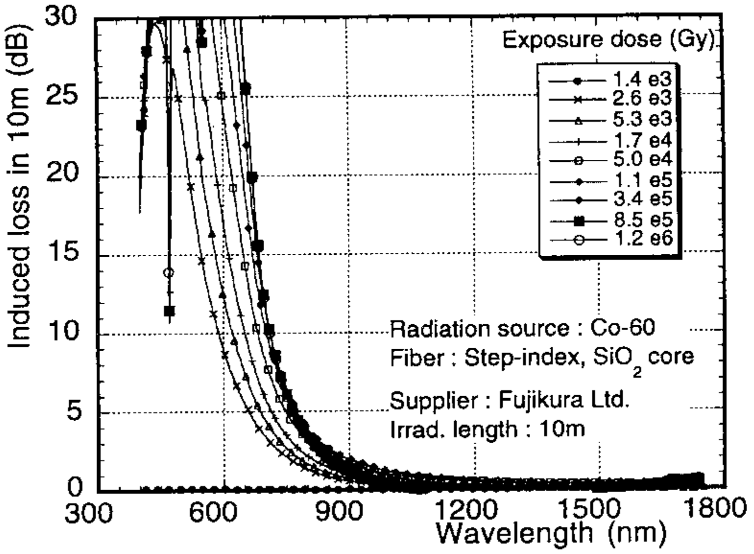


Fig. 5.4 Induced loss spectrum in Step-index type optical fiber measured with Co^{60} gamma-ray source.

5.4 Conclusion

Single-mode type (incl. PANDA fiber) appeared good radiation resistance in the wavelength region from 800nm to 1300nm. The conventional SM type fiber survived irradiation up to about 1×10^{20} n/cm^2.

5.5 Future plan

In 1996, we have a plan of similar irradiation test for aluminum jacket fibers radiation hardened Step-index fiber.

Reference :

[5.1] T. Shikama, M. Narui, T. Kakuta, et al., Nucl. Instrum. Methods B 91 (1994) 342.

[5.2] T. Shikama, T. Kakuta, et al., Journal of Nuclear Materials 225 (1995) 324.

[5.3] T. Kakuta T. Shikama, et al., “Development of In-Core Monitoring System using Radiation Resistant Optical Fibers”, 1994 IEEE Conference Record, NSS11-11, 371 (1994).

6. Irradiation tests of window/reflector

E. Ishitsuka, H.Sagawa and A. Nagashima

6.1 Experimental object

To investigate the change of mirror surface by neutron irradiation.

6.2 Experimental conditions

(1) Material

i) Molybdenum corner cube reflector (Mo-CCR) : $\phi 13\times{}^{h}15$ mm

ii) Au-coated mirror : $\phi 15\times{}^{t}1$ mm

(2) Irradiation facility

JMTR (Japan Materials Testing Reactor)

(3) Irradiation conditions

1.4×10^{20} n/cm^2, 200 °C

(4) Experimental devices (incl. Capsule)

Irradiation by capsule.

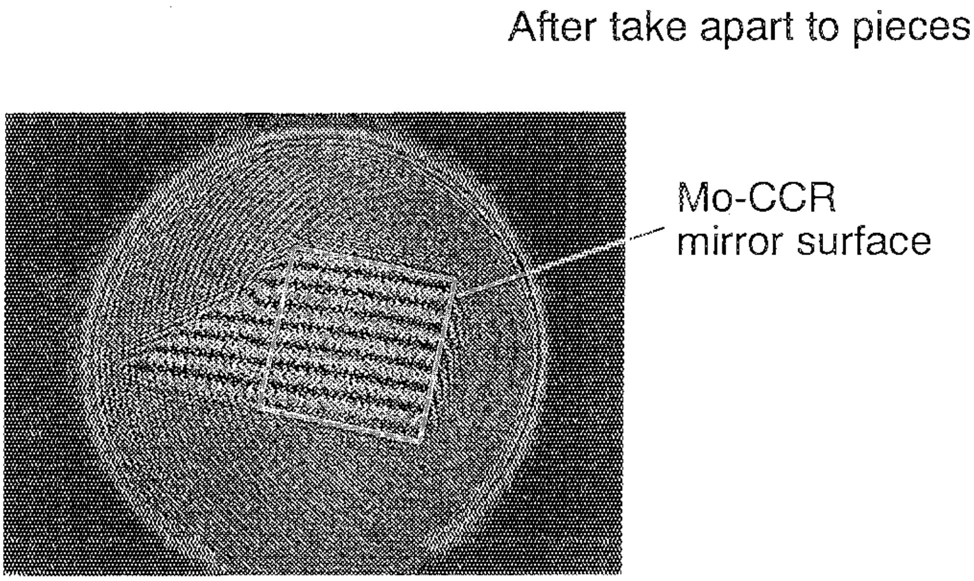
(5) Measurement

For Mo-CCR, interference measurement by interferometer of He-Ne laser and SEM observation were done. Appearance observation was carried out by post irradiation examination for Au-coated mirrors.

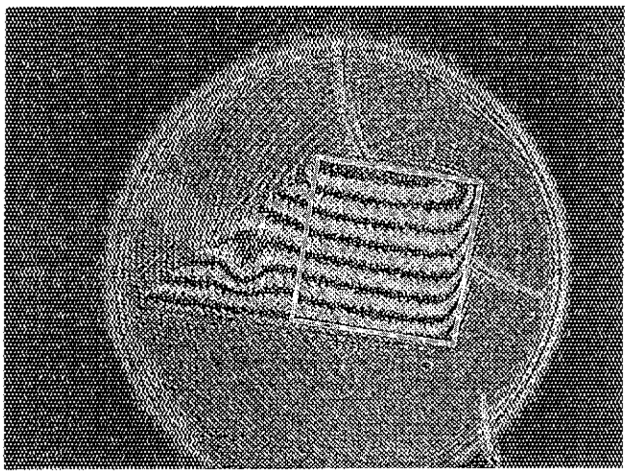
6.3 Experimental results

For Mo-CCR , surface condition was observed by interferometer and SEM. The results of interference measurement are shown in Fig. 6.1. The interference fringes of mirror surface are parallel, and the bad effects of neutron irradiation did not observed. The warp of interference fringes for left side of neutron irradiated Mo-CCR may occur by bolt for fix. The results of interference measurement shows surface roughness did not change by neutron irradiation. SEM observations were curried out on magnification of ×95-9500, the surface of Mo-CCR was smooth and the effects of neutron irradiation could not observed.

Surface of neutron irradiated Au-coated mirror became dark. One on the possible reason is that amalgam was generated in the gold coating due to Au(n,γ)Hg reactions for thermal neutrons.



(a) Un-irradiated Mo-CCR



(b) Neutron irradiated Mo-CCR

Fig. 6.1 The results of interference measurement.

6.4 Conclusion

The effects of neutron irradiation on Mo-CCR did not observed, and Mo-CCR may be possible to use on fusion reactor.

6.5 Future plan

The irradiation test on Mo-CCR was terminated. We have a plan of in-situ measurement of reflectivity for Aluminum mirror which is one of the most important candidate as a first plasma phasing mirror/reflector for visible spectroscopic diagnostics.

7. Gamma irradiation test on a bolometer

T. Nishitani, T. Sugie, A. Nagashima, Y. Morita and S. Kasai

7.1 Experimental object

To check the bolometer characteristics in radiation environment. To establish the radiation test technique for bolometers

7.2 Experimental conditions

(1) Material

JT-60 type gold resistor bolometer: Stainless-steel mounting frame, Gold absorber and Polyimide sheet (Fig.7.1). Sample dimension: 22 mm × 37 mm.

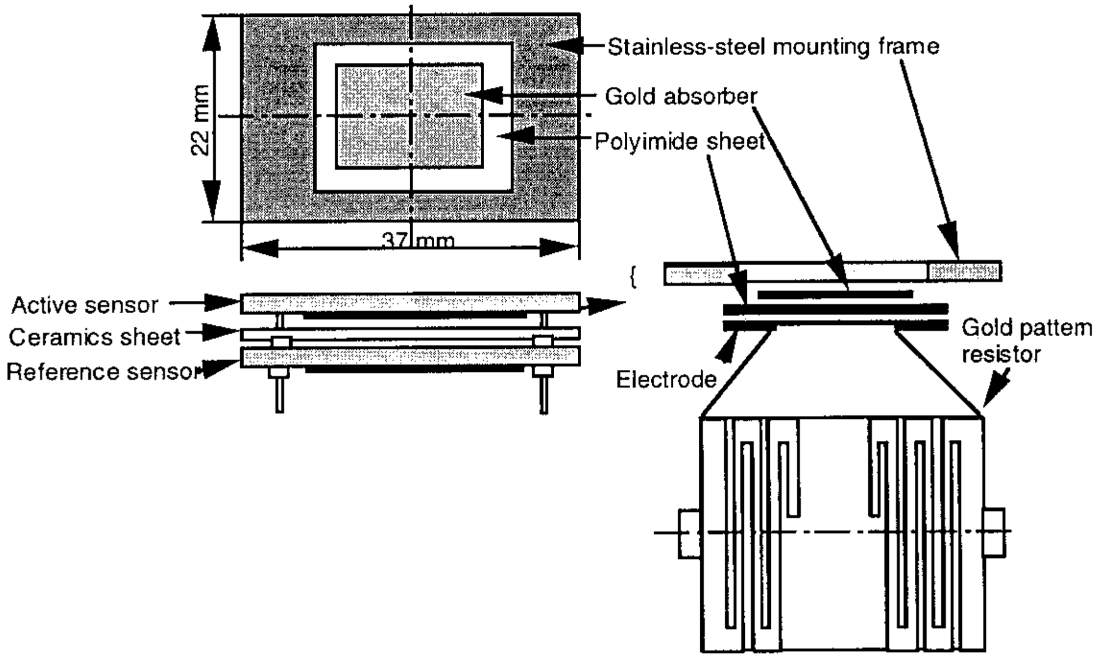


Fig. 7.1 Schematics of the JT-60 type gold resistor bolometer.

(2) Irradiation facility

Co^{60} irradiation facility in JAERI Takasaki

(3) Irradiation conditions

Gamma dose rate : 1.6×10^6 R/h, Temperature : ~40°C (room temperature + Gamma heating), Circumstance : vacuum (~10^{-5} torr)

(4) Experimental devices (incl. Capsule)

Experimental setup for the gamma irradiation test of the bolometer is shown in Fig.7.2. The test sample is set in a vacuum chamber. The transient response of the bolometer signal for pulsed laser light and the resistance are measured under the gamma irradiation. The loss of the laser light due to damages of window and fiber optics is evaluated by changing the bolometer to mirror.

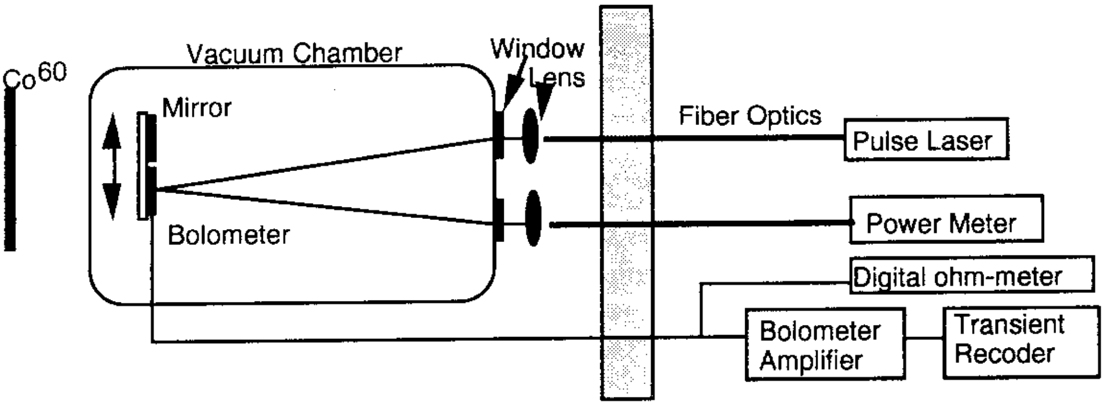


Fig. 7.2 Experimental setup for the gamma irradiation test of the bolometer.

(5) Measurement

The resistance of the bolometer was measured. The in-situ measurement of the bolometer sensitivity for the pulsed laser was carried out in the Gamma-ray radiation environment.

7.3 Experimental results

At the gamma dose of 9 × 10^7 Gy, the bolometer resistivity seems to be decreased slightly with the gamma dose. However the variation is only ±0.3% as shown in Fig. 7.3.

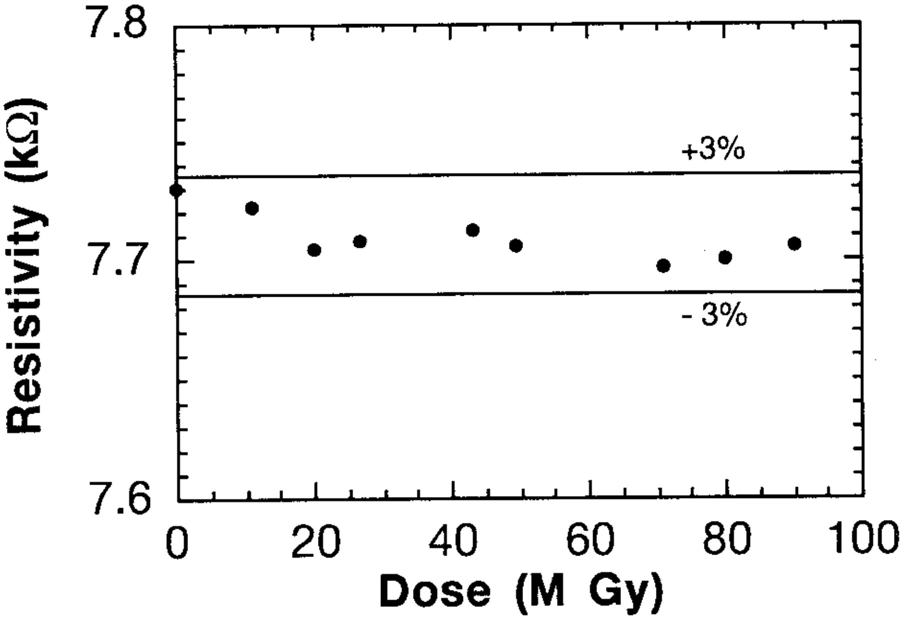


Fig. 7.3 Resistivity of the bolometer as a function of the gamma dose.

Figure 7.4 shows the bolometer sensitivity as a function of the gamma dose. There were no significant change in the bolometer sensitivity within the gamma dose of 9 × 10^7 Gy.

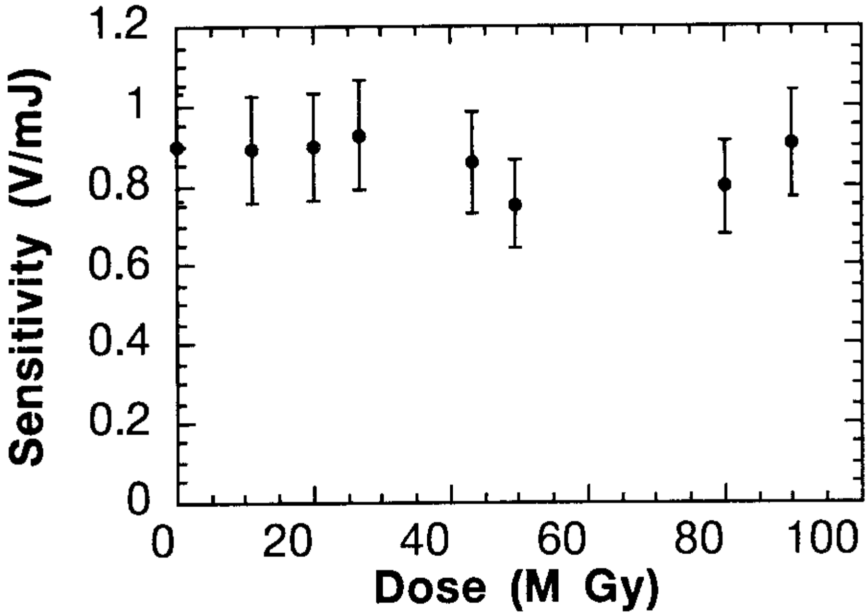


Fig. 7.4 Bolometer sensitivity as a function of the gamma dose.

7.4 Conclusion

The in-situ test technique for bolometers was established for gamma irradiation. The performance of the bolometer using polyimide sheet has been confirmed in the gamma irradiation condition.

7.5 Future plan

We will continue this irradiation test in middle of 1996. In the next step, we have a possibility to develop the ceramic bolometer which can be used in high temperature up to 300°C. When the new bolometer is completed, we will carry out similar irradiation test for it.

References

[7.1] T. Nishitani, K. Nagashima, et al., Rev. Sci. Instrum. 59 (1988) 1866.

8. Cold test on magnetic coil

H. Sagawa and H. Kawamura

8.1 Experimental object

To obtain experimental data on electrical characteristics of the magnetic coil under neutron irradiation. In this case, prior to the irradiation test, the experiment on electrical characteristics without neutron irradiation was performed to compare the irradiation experiment which will be carried out in the near future.

8.2 Experimental conditions

(1) Material

The magnetic coil was made of ϕ1.6mm MI-cable with a copper core and MgO insulation material. The coil had 280 turns around a ceramic bobbin which was ϕ9.0mm×50mm^L. The coil was installed in the outer tube which was made of SS316 and was ϕ 44mm × 100mm^L.

(2) Irradiation facility

To be irradiated in JMTR.

(3) Measurement

The magnetic probe was heated up to 650°C with the electrical furnace. The impedance, inductance and insulation resistance between the core wire and the sheath material were measured at the temperatures of R.T., 100°C, 200°C, 300°C, 400°C, 500°C, 600°C and 650°C. The high resistance meter was used to measure the insulation resistance and the provided voltage was 10V. The impedance analyzer was used for the impedance and the inductance and the measured frequencies were 100Hz, 1kHz, 10kHz and 100kHz.

8.3 Experimental results

The data is under analysis.

8.4 Future plan

The magnetic probe will be irradiated in JMTR at the end of 1996. The irradiation conditions such as neutron flux, neutron fluence and irradiation temperature are under consideration.

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