APPLICATION OF RADIATION-INDUCED DOPING OF POLYANILINE FILM TO MEASURE INTEGRATED GAMMA-RAY DOSE

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INTRODUCTION

For safety operation of high energy accelerators, radiation dose measurement for accelerator components is very important since severe damages of electric parts, such as a breakdown of insulation and change of electric properties, take place if they receive high radiation doses. A dosimeter, which can measure integrated radiation doses up to at least 1 M Gy, is needed for this purpose. There are a couple of simple devices applicable to the measurement for a wide range of integrated doses; the dosimeters using conducting polymers are promising candidates for the measurements in high radiation fields.

Conducting polymers, represented by polyacetylene (1, 2) and polyaniline (3), are known to exhibit drastic increases in their electrical conductivities from insulator to conductor by doping. The device consisting of a conducting polymer and a source material of a dopant can be used as a dosimeter (4, 5). A dopant gas is produced through the radiation decomposition of the source material, and the polymer is doped with the released gas. In this dosimeter, radiation doses can be easily measured as an increase in conductivity of the polymers with a simple resistance meter. We applied this method to polyaniline systems, and the basic characteristics of the dosimeter using polyvinylchrolide powder (PVC) as the source material were reported in the previous paper (6).

In this study, the new system of a polyaniline and SF_6 gas was adopted as a dosimeter, and the conductivity change by radiation-induced doping was examined extensively. The relation between the integrated radiation dose and the conductivity change is described.

EXPERIMENTAL

1) Samples The polyaniline used in this work was of the emeraldine base form which was chemically synthesized from a 1 M perchloric acid solution of aniline. The polyaniline film was prepared by gently drying the solution of polyaniline on a glass plate placed horizontally. *N*-methyl-2-pyrrolidone was used as the solvent, and was evaporated completely at 80 °C under vacuum for 1 day.

The polyaniline system consisted of a polyaniline strip (0.5 × 4 cm, *ca.* 40 μm thick) and SF_6 gas (purity: 99.99%), which were sealed in a Pyrex glass tube (volume: *ca.* 2.5 cm^3). The pressure of SF_6 gas was 0.1 or 1 atom.

2) Irradiation The samples were irradiated with ^{60}Co γ-rays at room temperature. This irradiation was carried out at the ^{60}Co irradiation facilities of Japan Atomic Energy Research Institute. During the irradiation, the radiation-induced doping proceeds in the glass tube.

3) Measurement of Electrical Conductivity The resistance of the polyaniline film was measured with an ultra-high resistance meter (Advantest Co., Model R8340A) in a pure nitrogen atmosphere at room temperature. After γ-ray irradiation, the glass ampoule of the sample was open, and the resistance of the irradiated strip was measured.

4) Determination of Fluorine in the Polyaniline In order to examine the relationship between the conductivity change and the fluorine content of the strip, the content was determined by neutron activation analysis. A piece of the strip after the radiation-induced doping was irradiated by neutrons in the PN-3 pneumatic tube of the JRR3 reactor in Japan Atomic Energy Research Institute. The repeated irradiation technique was applied to the samples with low content of fluorine to obtain high precision of determination. The intensity of the 1633-keV γ-ray of ^{20}F (half life: 11 sec) formed by the (n, γ) reaction of ^{19}F was measured with a Ge semiconductor detector system. The fluorine content was determined from its γ-ray intensity, compared with reference samples.

RESULTS AND DISCUSSION

The volume conductivity of the undoped polyaniline film prepared was 1×10^{-13} S/cm and the surface conductivity was 1×10^{-13} S. The film prepared (the emeraldine base form) is very stable to radiation. The conductivity of the film decreased by only one half of its original conductivity even for ^{60}Co γ-ray irradiation up to 3.6 M Gy under vacuum. This change is negligibly small compared to an increase in conductivity by doping mentioned below.

Figure 1 shows the conductivity change of irradiated polyaniline strips with different pressure of SF_6 gas (0.1 atm and 1 atom). The abscissa represents the absorbed dose for the polyaniline film, and the ordinate shows the conductivity ratio of irradiated to non-irradiated polyaniline. The conductivity increasesd almost linearly on a log–log plot along with an increase in the dose over a wide region of about 10^3 to 1 M Gy; the maximun conductivity reached 10^8 times its original value above 1 M Gy. As shown in Fig. 1, the threshold dose can be controlled by changing the pressure of SF_6 gas.

The surface of the polyaniline film was doped more homogeneously in this polyaniline–SF_6 system than in the polyaniline–PVC system (6) where a heavy dopant gas (HCl) is produced by radiolysis in the solid source material. This indicates that gases are much suitable for the source material of the dopant.

Figure 2 shows a relationship between the content of fluorine (μg/cm^2) introduced on the surface of the polyaniline film through the radiation-induced doping and its relative conductivity. The content was obtained by subtracting the fluorine content originally contained in the undoped polyaniline film from the total content in the doped polyaniline obtained by the neutron activation analysis. The original content was determined to be 1.4 μg per 1 cm^2 of the film with the same method as the doped polyaniline films.

The conductivity change through doping is very influenced by species of the dopants and their amounts on the surface of conducting polymers. The concentration of the dopant gas depends on the G-value of the dopant gas liberated from the source material, the amount of the source material and the integrated radiation dose.

The linear increase range in this SF_6 system (Fig. 1) was narrower than that of the polyaniline–PVC system (6); however, the increase in the SF_6 system continued to *ca.* 1 M Gy, while that reached saturation at 0.1 M Gy in the PVC system. This SF_6 system is, therfore, considered to be more suitable for a dosimeter which is used in high radiation fields. A prototype dosimeter

with electrodes will be discussed.

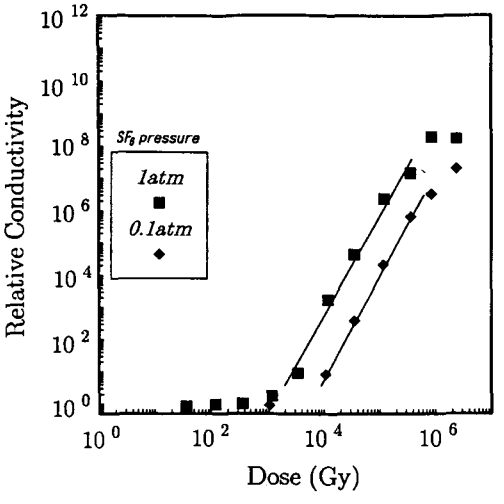

Fig.1 Relationship between the dose and conductivity change of the polyaniline film

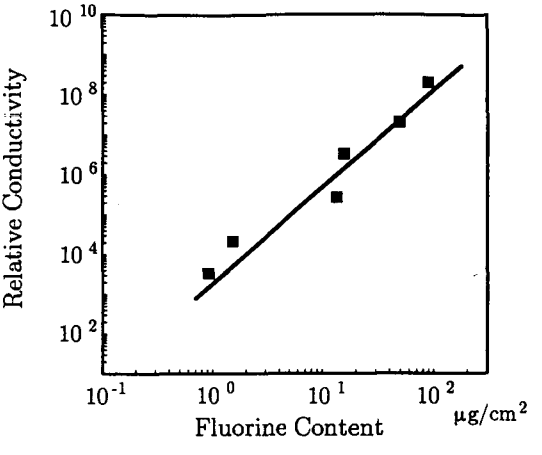

Fig.2 Relationship between the fluorine content of the polyaniline film and the conductivity

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