

## Depth profiling of sodium and lithium doped samples using Rutherford backscattering spectrometry

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Various samples of Teflon chemically doped with lithium and sodium have been irradiated with hydrogen ions in order to study the depth profile using Rutherford backscattering (RBS) spectrometry which can detect even microgram of sample. Studies have also been done to see the effects of irradiation on the samples after and before doping them with sodium or lithium. Co-60 gamma-rays (1.17 and 1.33 MeV) and 1 MeV electrons have been used for irradiation.

**Keywords:** Rutherford backscattering, Depth profile, Diffusion, Teflon, Irradiation effect

### 1 Introduction

Nowadays, considerable amount of work is being carried out in the field of polymers and many research workers are trying to obtain good quality conducting layer on a polymer. Lithium and sodium are two such elements which when doped in a polymer changes the surface resistivity. Normally, chemical methods are used to dope lithium in a polymer. It is interesting to know the depth to which lithium can penetrate and also its concentration. RBS (Rutherford backscattering) is a method which is quantitative without using any reference standards and also is non destructive in nature<sup>1,2</sup>. An ideal technique of the depth profiling should be sensitive to detect even small amounts of the sample, provides precise depth information (having good depth resolution), should be rapid and simple to analyse. RBS using energetic ions is able to meet these requirements, since they give information about the composition and depth by directly scattering from the atomic nucleus, free from the matrix effect and also has a depth resolution of nanometre to micrometer depending on the energy loss of the backscattered ions in the sample matrix. It is very sensitive (ppm) for heavy elements.

### 2 Materials and Methods

Various samples were analysed with Rutherford backscattering spectroscopy, using 1 MeV proton beam. For this work, the ion accelerator at Institute of

Physics (IOP), Bhubaneswar was used<sup>3,4</sup>. The ion beam was allowed to fall on the samples stuck on a target holder placed in an evacuated scattering chamber. The scattered protons were allowed to fall on a surface barrier detector and the spectrum of the scattered ions were obtained on a multi channel analyzer coupled to the detector. The samples used for the RBS analysis were prepared utilising the following procedures as discussed below.

(i) Lithium on Teflon: In order to diffuse lithium in Teflon, pure metallic lithium was dissolved in dry tetrahydrofuran in presence of naphthalene. A large number of Teflon pieces  $1 \times 1 \text{ cm}^2$  area were dipped in this solution either before or after irradiation with Co-60 gamma rays and 1 MeV electrons. The irradiated samples and the non-irradiated samples were kept in the solution for five days. However, few samples were taken out from the solution after two days and then consecutively for 3 days. In this way, samples doped for two, three, four and five days were obtained.

(ii) Sodium on Teflon: The experimental procedure as carried out for lithium was also repeated with sodium. Metallic sodium was dissolved in solution of tetrahydrofuran in presence of naphthalene. Teflon samples of  $1 \times 1 \text{ cm}^2$  was cut from a sheet of thickness 0.5 mm. These samples were kept for different time periods ranging from 2 to 5 days.

### 3 Theory

When the hydrogen ions fall on the sample, they get scattered from different depths. The outcoming

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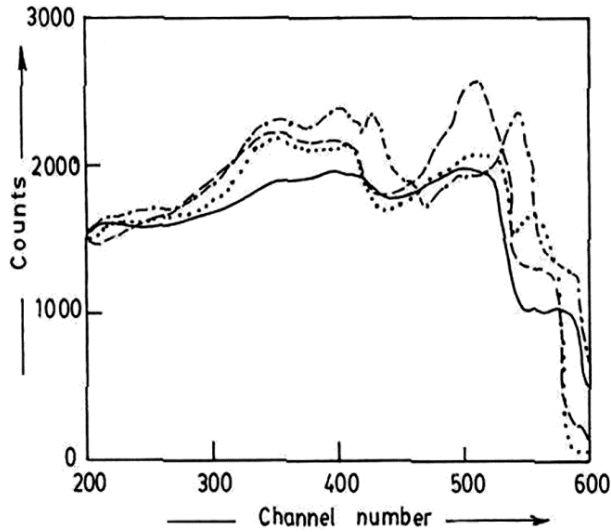


Fig. 1 — Spectrum of 1 MeV protons scattered from following materials (a) pure Teflon (—), (b) Teflon in lithium for two days (.....), (c) Teflon in lithium for three days (-----) and (d) Teflon in lithium for four days (-.-.-).

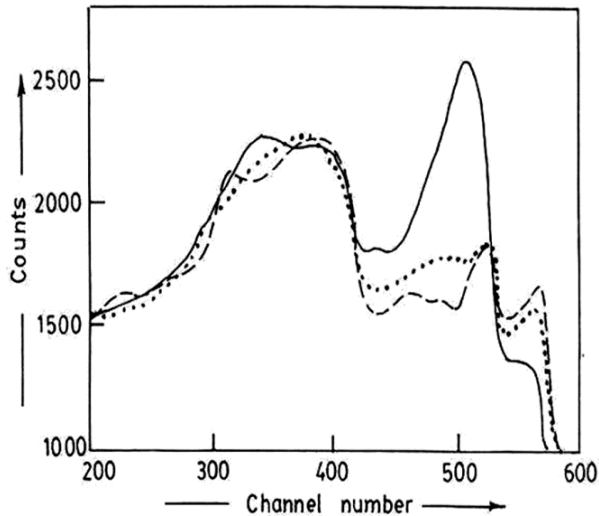


Fig. 2 — Spectrum of 1 MeV protons scattered from following materials (a) unirradiated Teflon in lithium for three days (—), (b) Teflon pre-irradiated with 1 MeV electrons and diffused in lithium for three days (-----) and (c) Teflon pre-irradiated with Co-60  $\gamma$  rays and diffused in Lithium for three days (.....).

ions have different energies which give information related to the depth and as such the energy of the backscattered ions can be used to calculate the depth using the information about the specific energy loss  $dE/dx$  which is almost constant in an energy range considering an almost homogeneous matter as the amount of impurity is quite low. The depth can be calculated as:

$$D = (E - E') / (dE/dx)$$

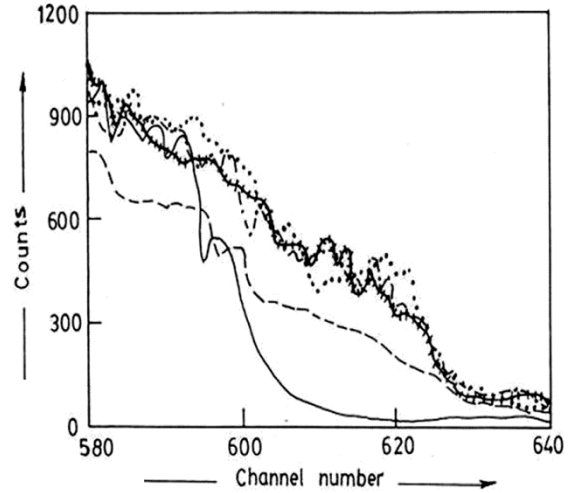


Fig. 3 — Spectrum of 1 MeV protons scattered from following materials (a) pure Teflon (—) and (b) Teflon in sodium for two days (.....), and (c) Teflon in sodium for three days (-----), (d) Teflon in sodium for four days (-.-.-) and (e) Teflon in sodium for five days (++++).

where  $D$  is the depth from surface,  $dE/dx$  is specific energy loss,  $E$  is the energy of the incident ion and  $E'$  is the energy of the out coming backscattered ions.

The more is the energy, less is the depth and the ions coming from the surface have no energy loss. The number of ions at a particular energy will give information related to the intensity of the impurity material. The information on depth and intensity can help to get the profile of the impurity in the sample. In Rutherford backscattering spectroscopy one is concerned with projectiles that move through a target, losing energy along their path, and are scattered by collision with a target atom<sup>5-8</sup>. The interaction between the projectile and target atom can be described as an elastic collision between two isolated particles and expressed in terms of a scattering cross-section. The energy of the projectile after the collision can be related to its energy before the collision by means of a kinematic factor. The kinematic factor leads to the ability for mass analysis.

#### 4 Results and Discussion

The results recorded in terms of backscattered proton versus channel number are shown in Figs 1 and 2, respectively, for lithium diffused in Teflon samples and in Fig. 3 for sodium diffused in Teflon samples. The experimentally obtained diffused spectrums were deconvoluted using a computer program for ion scattering analysis<sup>9-12</sup>. Figure 1

showed the lithium edge starting from channel number 430 and going till channel number 300.

Taking the energy loss equal to 2.36 keV per channel, the total energy loss comes out to be 306.8 keV. Taking 44.8 keV as the  $dE/dx$ , the depth to which the lithium has diffused comes out to be 4.9  $\mu\text{m}$ . The results for the unirradiated and irradiated (with Co-60 gamma-rays (1 Mrad) and 6 MeV electron ( $10^{14}$  e/cm<sup>2</sup>)) samples doped with the lithium solution for three days are shown in Fig. 2.

Figure 3 indicated that the sodium profile which starts from channel number 625 and extends up to channel number 580, has diffused to a depth even in a maximum permitted period of five days to 1.47  $\mu\text{m}$  which is smaller than the lithium depth, as expected.

## 5 Conclusions

Results showed that the concentration of lithium in Teflon increased with increase in the diffusion period. It was clearly seen from this figure that the maximum concentration of lithium found in the sample diffused for four days and minimum in sample diffused for two days. Lithium showed that concentration of diffused lithium increased after irradiation.

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