Fluorine ion transmission through thin biological samples*

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Abstract F^{2+} beam with 3 MeV is used to irradiate thin biological samples (onion inner surface membrane and kidney bean coat) in the transmission measurement, its current density is 400~800 nA/cm^2. Results show that the onion samples can be broken up quickly under ion irradiating; as to kidney bean samples, about 60% of the implanted ions penetrate the samples, most of them lose part of their energy, fewer ions are found to be able to transmit through the sample without energy loss. SEM experiments are carried out to study sample's damage induced by the ions irradiation.

Keywords Ion implantation, Biological sample, Transmission measurement

1 Introduction

In the late of 1980s, ion beam technique began to be used in biology studies[1~3], such as agricultural breeding. More and more attention is being paid to this research field in recent years due to its prospective application. But up to now, the mechanism of ion biological effects is still not clear, especially those related with the essential physical process of ions in biological sample.

Most of all, ion range and depth profile in biological sample are still a problem, more experiments are needed to clarify why the range of low energy ions in biological samples is much larger than theoretical calculating results.[4,5] Our study[6] had shown that when ion dose is very low ($< 10^6$ ions/cm^2) and its damage to biological samples could be neglected, ion range (in mass thickness) in onion samples is about in the same range with the theoretical calculating value, only because biological samples usually is not uniform and its mass thickness in different area maybe have significant discrepancy, this makes ion space range and depth profile become much larger than the theoretical ones.

As high intensity ion beam is used in most of the current studies, sample damage induced by the high dose ions can not be neglected and implanted ions depth profile could be changed. In this study, the space depth profile of high dose ions in biological samples had been measured and sample's damage had been observed by using SEM.

2 Experimental details

Two kinds of thin biological samples had been used in the transmission measurement. One is the membrane of onion inner surface with average mass thickness of about 0.9 mg/cm^2, usually it is composed of only one or several layers of cells; The other is kidney bean coat with average mass thickness of about 10.5 mg/cm^2.

Transmission measurement was carried out at the 2×1.7 MV tandem accelerator of Peking University, the experimental arrangement is illustrated in Fig.1. Transmitted ion's back scattering spectra from a gold film (10 nm on silicon wafer) were recorded in the experiment instead of recording the transmitted ions directly, since it is possible that transmitted ion count rate could exceed the detector's ability and even damage the equipment. The angle between the incidence ions and the measured back scattering ions was 165°. 3 MeV F^{2+} of 400 to 800 nA/cm^2 was used.

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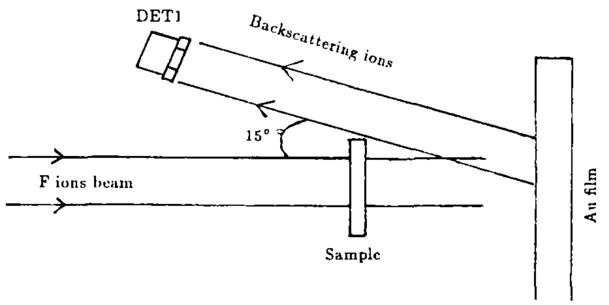

Fig.1 Schematic diagram of the transmission measurement experiment

Transmission spectra were recorded as a function of irradiating time (dose) in order to study the relationship between ion transmission ratio and dose. SEM measurement was used to study the topography of irradiated biological samples.

3 Results and discussion

3.1 Transmission measurement on onion samples

Onion sample had been broken up within few seconds under ion bombardment, it was impossible to get an interesting transmission spectrum before sample disappearing. However, this indicates the structure and composition of biological sample can be greatly damaged and changed due to high intensity ion irradiation.

3.2 Transmission measurement on kidney bean samples

Transmission spectra for five samples had been measured in the experiment, four of them are almost the same, one of them is shown in Fig.2(a), the left one is a little different as shown in Fig.2(b). It can be seen that F ions had certainly penetrated these samples with a ratio (transmitted ions to the incidence ions) of about 60%, most of these ions had lost part of their energy, but very fewer of them was found without any energy loss at a ratio of about 0.3%.

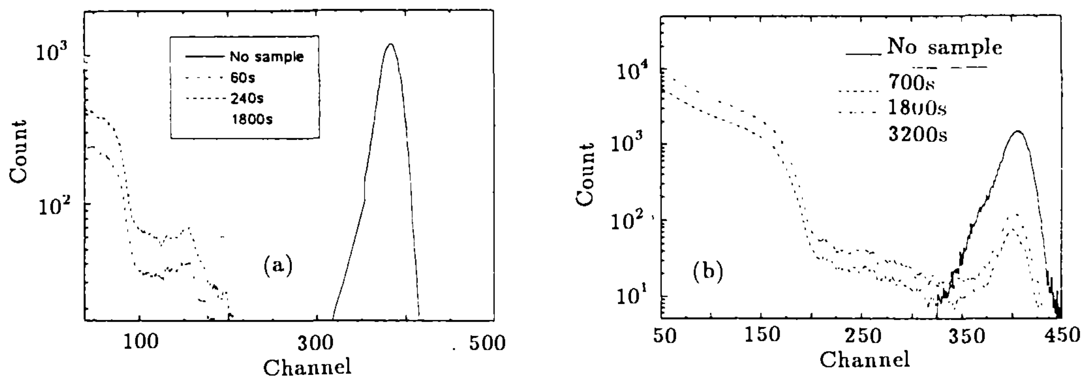

Fig.2 F ion transmission spectra of kidney bean samples with different irradiation time (dose)

TRIM95 calculating indicates that the range of 3 MeV F ion in biological sample (supposed composition: $C_3O_3H_4$) is less than 0.5 mg/cm^2, it is impossible for 3 MeV F ions to penetrate kidney bean coat samples with a mass thickness of 10.5 mg/cm^2; though there exists the possibility that some area of sample may be thin enough for ions to transmit through due to the biological sample inhomogeneous mass distribution. Other experiment had confirmed that the transmission ratio for 4 MeV F ions in the same kind of samples is less than 10^{-6} when ion dose is very low ($< 10^6$ ions/cm^2).[6] Therefore, there must be some other reasons for such a high ratio of those transmission ion.

Fig.3 is sample's topography after being irradiated for 30 min. It can be clearly seen that biological sample has been seriously damaged, the irradiated area becomes much porosity and the dimension of microholes there increases significantly. These changes indicate that the mass thickness of irradiated area had decreased significantly, also its mass distribution becomes inhomogeneous further. This is the main reason for the high transmission ratio measured in the experiment; meanwhile, there exists the possibility that some microholes can penetrate whole the sample along the ion incidence direction, ions go through these microholes would lose no energy. This is also the reason why high dose ions can penetrate these thick biological samples while low dose ion can not.

The transmission ratio for every channel at different irradiating time (dose) had been derived from Fig.2(b) as shown in Fig.4, it can be seen that the ratio keeps same no matter how many the ion dose is. This means biological sample's damage had occurred in a short time, but not have a linear relationship with ions dose. However the mechanism of sample's damage is not clearly yet, further experiment is needed.

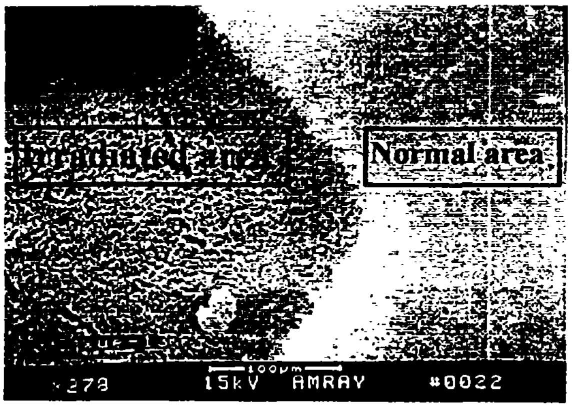

Fig.3 Topography of the irradiated kidney bean sample

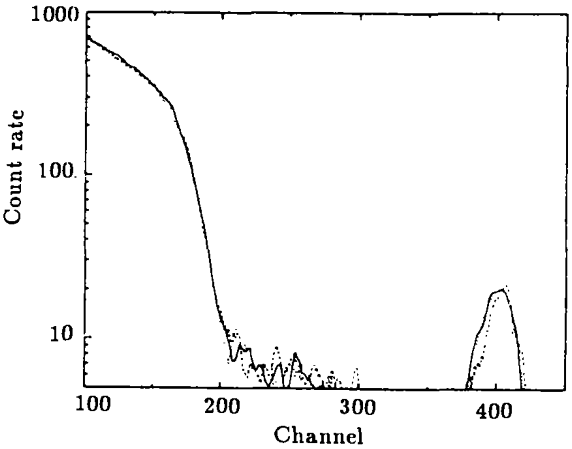

Fig.4 Count rate of transmitted ion as a function of irradiating time (dose)

4 Summary

Transmission measurement on onion samples and kidney bean coat sample had been carried out with 3 MeV F ions. 3 MeV F ions with current density of about $400 nA/cm^2$ can penetrate kidney bean coat at a ratio of about 60% after losing part of their energy for all samples besides about 0.3% of the incidence ions can penetrate one of the samples without energy loss.

Biological sample's damage induced by high intensity ion beam is very serious. Onion samples had been broken up within few seconds and the kidney bean coat samples become more porosity and inhomogeneous. This is the reason why high dose ions can penetrate those biological samples which are far thicker than their ranges while low dose ion can not. However, further experiment is needed to clarify the mechanism of biological sample damaging process induced by high dose heavy ions.

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