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POSITRON ANNIHILATION STUDY ON SURFACE STRUCTURE OF BIOLOGICAL SAMPLES IMPLANTED BY IONS WITH LOW ENERGY*

Lu Ting (陆 挺)[a)b)c)], Yu Wei-zhong(郁伟中)[d)], Zhou Hong-yu(周宏余)[a)b)c)], Zhu Guang-hua(朱光华)[a)b)c)], Wang Xin-fu(汪新福)[a)b)c)], and Wang Chao(王 超)[a)b)c)]

[a)] *Key Laboratory of Beam Technology and Materials Modification of Education Ministry, Beijing Normal University, Beijing* 100875, *China*

[b)] *Institute of Low Energy Nuclear Physics, Beijing Normal University, Beijing* 100875, *China*

[c)] *Beijing Radiation Center, Beijing* 100875, *China*

(Tel: 010-62208324, Fax: 010-62231765, E-mail: luting@bnu.edu.cn)

[d)] *Department of Physics, Tsinghua University, Beijing* 100084, *China*

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The organic materials of biological samples, such as lima bean and peanut, were implanted respectively by nitrogen ions with an energy of 100 keV and vanadium ions with an energy of 200 keV. The positron annihilation lifetime spectra of implanted and non-implanted samples were compared with each other especially in τ_3 and I_3. The experimental results showed that before implantation there were many small holes with diameters of 0.48 and 0.7 nm in lima bean and peanut, respectively. After ion implantation, the size of holes would be changed because of organism cross-linking and scission. The effective penetration range of implantation of ions with low energy into biological samples is about 200 μm.

Keywords: ion implantation, biological effect, positron annihilation
PACC: 6180M, 6180J, 8750G

I. INTRODUCTION

The biological effects, including physiological and genetic variations, have been clearly observed in plants whose seeds were implanted by nitrogen or carbon ions with energy ranging from 30 to 200 keV.[1−5] In order to study the mechanism of biological effect induced by implantation of low-energy ions, the surface structure of the organism, effective penetration range and distribution of low-energy ions in the organism must be understood. The distribution of low-energy ions in the organism has been studied by X-ray analyses induced by protons and photons.[6−12]

In this work, we attempt to use the positron annihilation technique (PAT) to measure the surface structure of biological samples and to assess the effect of ion implantation on them. PAT is usually used for detecting the microstructure and defects in metals and alloys. This is the first time PAT has been used in the biological field, to our knowledge. The experimental results demonstrate that it is a very successful measurement. Positronium (Ps) which must be formed in biological samples because of porous structure of plant seeds can serve as a nuclear probe and provide some information about the chemical and physical state of the environment.[13]

In addition, the depth of slowing-down of positrons emitted from ^{22}Na in the organism is about 200 μm. The comparison of positron annihilation lifetime (PAL) spectra between implanted and non-implanted biological samples would be helpful to understand the effective penetration range of ion implantation with low-energy ions in the organism.

II. EXPERIMENTS AND METHODS

The ion implantation of lima bean and peanut was performed on a 400 kV implanter located at the Institute of Low Energy Nuclear Physics in Beijing Normal University. The size of the lima bean sample was 5mm×15mm×20mm, and that of peanut sample 4mm×8mm×12mm. The samples of lima bean were implanted by nitrogen ions with an energy of 100 keV and a dose of 2×10^{16} ion/cm^2, while the samples of

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peanut were implanted by vanadium ions with an energy of 200 keV and a dose of 9×10^{16} ion/cm^2. During ion implantation the ion flux was kept at 0.4μA/cm^2. The measurement of PAL spectra of lima beans, including that of implanted and non-implanted samples, was performed on a positron lifetime spectrometer with FWHM 400 ps, located at the Institute of High Energy Physics, Chinese Academy of Sciences. The measurement of PAL spectra of peanut, including implanted and non-implanted samples, was performed on a positron lifetime spectrometer with FWHM 280 ps, located at the Department of Physics, Tsinghua University, Beijing, China.

III. RESULTS AND DISCUSSION

The lifetimes and intensities of positrons for lima bean and peanut are shown in Tables 1 and 2, respectively, where τ_1 is the lifetime of annihilation for free positrons in the bulk state of the medium, I_1 is the intensity of τ_1; τ_2 and I_2 are the lifetime and intensity for annihilation of bound positrons in the medium, respectively, and τ_3 is the lifetime of "pick off " annihilation of orthopositronium (o-Ps) in the medium; τ_3 represents the size of defects in the medium, and I_3 is the intensity of τ_3, which represents the part of the defect volume in the total volume of the medium in which positron annihilation takes place.

Table 1. The results of PAL spectra of implanted and non-implanted samples of lima bean.

	τ_1/ns	I_1/%	τ_2/ns	I_2/%	τ_3/ns	I_3/%
Implanted by N^+	0.177±0.002	37.7±0.8	0.477±0.005	47.1±0.6	1.643±0.009	15.2±0.2
Non-implanted	0.178±0.002	37.3±0.8	0.479±0.005	47.1±0.6	1.694±0.009	15.5±0.2

Table 2. The results of PAL spectra of implanted and non-implanted samples of peanut.

	τ_1/ns	I_1/%	τ_2/ns	I_2/%	τ_3/ns	I_3/%
Implanted by V^+	0.259±0.003	66.28±0.60	0.699±0.005	17.94±0.60	2.650±0.009	15.78±0.20
Non-implanted	0.259±0.003	65.24±0.60	0.671±0.005	18.49±0.60	2.598±0.009	16.27±0.20

It can be seen from Table 1 that there are many holes with a diameter of 0.48 nm in the lima bean sample and the volume of all these holes is about 15% of the total volume of the lima bean sample. From Table 2, it can also be seen that the diameter of holes is 0.7 nm and the volume of holes is about 16% of the total volume of the peanut sample.

The difference between the size of defects in implanted and non-implanted samples means that the effective penetration range of implantation of low-energy ions can reach about 200 μm in biological samples, deduced from the slowing-down of positrons in the organism. It must be mentioned that the ion implantation can cause both organism cross-linking and scission.[14] These two actions are competitive during the process of ion implantation. Which is dominant depends on the kind, energy and dose of ion implantation. The organism cross-linking makes the hole smaller, thus τ_3 would be smaller. The organism scission makes the hole bigger, hence τ_3 would be bigger. Therefore, the change of τ_3 will be influenced by the offset between the two actions.

IV. CONCLUSIONS

There are many small holes in the surface structure of plant seeds. The diameter of the holes is 0.48 nm for lima bean and 0.7 nm for peanut. The effective penetration range of the implantation of ions with low energy into the biological sample is about 200 μm. Hence, the embryos of the plant seeds would be affected by the implanted ions during implantation.

References

[1] Yu Z L 1991 *Nucl. Instrum. Methods* B **59/60** 705

[2] Yu Z L *et al.* 1993 *Nucl. Instrum. Methods* B **80/81** 1328

[3] Lu T, Wei J Z and Zhu F S 1991 *J. Beijing Normal University (Nature Science)* **27** (4) 421 (in Chinese)

[4] Lu T, Xie L Q, Zhu F S and Wei J Z 1994 *Nucl. Tech.* **17** (7) 443 (in Chinese)

[5] Lu T 1995 *Looking to the 21st Century, Proceeedings of the First International Conference on Frontiers of Physics* (Shantou, China) p 135

[6] Chen X B *et al.* 1999 *Acta Phys. Sin.* **48** 192 (in Chinese)

[7] Xiao L *et al.* 1999 *Acta Phys. Sin.* **48** 468 (in Chinese)

[8] Chen X B *et al.* 2000 *Acta Phys. Sin.* (*Overseas Edition*) **9** 379

[9] Tang Z L *et al.* 2000 *Acta Phys. Sin.* **49** 1076 (in Chinese)

[10] Li Y T *et al.* 2000 *Acta Phys. Sin.* **49** 1400 (in Chinese)

[11] Chen X B *et al.* 1993 *Acta Phys. Sin.* (*Overseas Edition*) **2** 695

[12] Wang R J *et al.* 1999 *Acta Phys. Sin.* **48** 1496 (in Chinese)

[13] Lu T 1995 *J. Beijing Normal University* (*Nature Science*) **31** (2) 204 (in Chinese)

[14] Venkatesan T 1985 *Nucl. Instrum. Methods* B **7/8** 461