[illegible]

KFKI-1982-91

F. PÁSZTI
M. FRIED
A. MANUABA
G. MEZEY
E. KÓTAI
T. LOHNER

A SIMPLE METHOD TO PRODUCE QUASI-SIMULTANEOUS MULTIPLE ENERGY HELIUM IMPLANTATION

Hungarian Academy of Sciences

**CENTRAL
RESEARCH
INSTITUTE FOR
PHYSICS**

BUDAPEST

KFKI-1982-91

A SIMPLE METHOD TO PRODUCE QUASI-SIMULTANEOUS MULTIPLE ENERGY HELIUM IMPLANTATION

F. Pászti, M. Fried, A. Manuaba, G. Mezey, E. Kótai, T. Lohner

Central Research Institute for Physics
H-1525 Budapest 114, P.O.B.49, Hungary

To be published in J. Nucl. Mat.

HU ISSN 0368 5330
ISBN 963 371 982 8

ABSTRACT

If a monoenergetic ion beam is bombarding a target through an absorber foil tilted continously /i.e. its effective thickness changing continously/ then the depth distribution of the implanted ions in the sample depends on the way of the absorber moving. The present paper reports a way of absorber tilting for obtaining a uniform depth distribution and its experimental verification in the case of MeV energy helium ions implanted into aluminium target.

АННОТАЦИЯ

Если моноэнергетический ионный пучок перед тем, как попадать в мишень, проходит через абсорбер, который качается определенным образом, т.е. его эффективная толщина постоянно меняется, то распределение имплантируемых в мишень ионов по глубине зависит от способа качения. Данная работа предлагает способ движения абсорбера, обеспечивающий равномерное распределение по глубине, и описывает экспериментальную проверку в случае имплантации ионов гелия в алюминий с энергией несколько МэВ.

KIVONAT

Ha egy monoenergetikus ionnyaláb egy folyamatosan forgó /s ezáltal effektiv vastagságát állandóan változtató/ abszorberen áthaladva bombáz egy céltárgyat, akkor az abba implantált ionok mélység szerinti eloszlása a forgatás módjától függ. A jelen mü egy egyenletes mélységeloszlás létrehozására alkalmas forgatási módot, s annak MeV-es energiával aluminiumba implantált hélium ionok esetén való kisérleti ellenőrzését ismerteti.

Surface deformations due to high-dose helium implantation have received great interest. But most of the papers deal with model experiments using monoenergetic implantation either of low or high /up to 3.52 MeV/ energy ions [e.g. 1-3]. It is not adequate for the real situation in the future CTR machines working with D-T plasma where a broad energy spectrum of projectiles /consisting of energies practically from 0 to 3520 keV/ will reach the first wall simultaneously with different impinging directions.

Some attemps were done to produce ion bombardment of the surfaces with more than one energy [e.g. 4-7], but the common feature of these investigations is that they are restricted to sequential bombardment of different energy ions. The surface morphology of such a bombardment strongly depends on the mode of irradiation sequence, so in doing more realistic model experiments a simultaneous multiple energy bombardment is necessary. The first attemp on this way was performed by Okuda and Kuwahara [8] who used for the bombardment the backscattered helium beam /the incident energy was 40 keV/ from a scattering plate Nb. But there are still some problems i.e. the energy spectrum of backscattered ions at low energy region is not well-known and the backscattered yield is small especially at higher incident energies.

The present paper tries to demonstrate a simple and cheap method to produce a practically simultaneous multiple energy implantation where - in principle - no restrictions and limitations exist for obtaining different kind of energy spectrum from monoenergetic beam source. The basic idea is the following.

Let a monoenergetic beam of E_0 pass through an absorber foil which is tilted continously between two angles. Depending upon the current values of tilt angle φ , the effective thickness d of the foil is continously changing according to

$$d = d_0 \cdot \frac{1}{\cos\varphi} , \qquad /1/$$

where d_0 is the real thickness of the absorber foil. In this case for the same absorber and target material the implantation depth in the target is

$$R_p(E_1) = R_p(E_0) - d , \qquad /2/$$

where $R_p(E)$ is the projected range of ion energy E. The corresponding energies of ions, E_1 ,after leaving the tilting absorber and reaching the target surface can be regarded as simultaneous.multiple energy ion bombardment and their values can be evaluated from equation /2/.

The present experiment was performed for obtaining a constant helium concentration in a certain depth interval in Al target foil. The implantation was done using monoenergetic helium ions of energy 3 MeV through an Al absorber foil of thickness 3 $/$um onto Al target foil of thickness 10 $/$um. During bombardment the absorber was tilting periodically /T=60 sec./ between to angles /17° and 60°/ in such a way that its effective thickness i.e. the factor $\frac{1}{\cos\varphi}$ in eq. /1/ varies linearly with time.

The mechanics of such an absorber tilting is shown schematically on fig. 1. A synchronized electro-motor fastened together with a gear transmission box rotates a screw attached to the tilting axis at the point A. This screw while rotating is forced by a carriage at B to tilt between two angles mentioned above. As it is shown on the figure the carriage is forced to move along a straight line CB through a freely revolving screw-nut arround an axis fastened in the carriage. By this way the value $\frac{1}{\cos\varphi} = \frac{AB}{AC}$ /see fig. 1/ varies linearly with time since the distance AC is constant and AB is a linear function of time due to the constant rotation of the screw. The periodicity of tilting is guaranteed by two electronical microswitches placed on the line followed by the carriage and change the rotating direction of the motor when the carriage touch it. The absorber holder is fastened in such a way that it follows the tilting motion of the screw.

By this mechanism the effective absorber thickness and so the implantation depth in the target varies periodically and linearly with time according to a triangle function.

The effect on the lateral helium distribution in the target due to angular spreading of the beam after leaving the absorber is minimized by placing the absorber foil as close as possible to the target surface. In the present experiment the maximum distance between the beam spot on the absorber and on the target was 6 mm. L. Meyer's calculations [11] on the angular spreading of a beam passing an absorber of thickness τ =0-20 were extended for higher values of τ . Here τ is the mean number of collisions of incident particle in the absorber,

$$\tau = \pi a^2 Nt \qquad /3/$$

where a is the Thomas-Fermi screening radius and Nt is the absorber thickness. In the present calculations for higher values of τ the angular distribution of the beam is assumed to be Gaussian. If the stopping power of ions in the absorber is assumed as a linear function of depth then the total angular spreading can be considered as a Gaussian distribution with FWHM value in degrees

$$\nu_{\frac{1}{2}} \simeq \frac{Z_1 Z_2}{2.14a} \sqrt{\frac{\tau}{E_0 E_1}} \qquad \text{for } \tau \geqslant 20 , \qquad /4/$$

where Z_1 and Z_2 are the atomic number of incident ions and absorber material, respectively, the energies are given in keV and a in nm units. Based on this calculations in our case the spreading of the beam spot on the target was found not more than 1 mm. It means that at the central part of the beam spot of 3x3 mm^2 the effect of the angular spreading can be neglected.

During bombardment for each position of the absorber i.e. for every implantation depth in the target, the value of the depth straggling is the same and corresponds to the incident energy E_0, since the material of both sample and absorber is the same.

In order to study the depth profile distribution of the implanted helium ions a significant amount of helium /1.5x10^{18} ions/cm^2/ was implanted using a beam spot of 3x3 mm^2 with irradiation current /dose rate/ of not more than 2 μA/cm^2 for preventing a significant temperature raising of the target and absorber. After implantation we used 3 MeV proton beam to analyze "in situ" the central part of the implanted region by RBS method using a beam spot of 0.5x0.5 mm^2.

The energy spectrum of the backscattered protons for multiple energy helium implantation is shown on fig. 2a. Here clearly seen the wide profile of nearly constant helium concentration. For comparation on fig. 2b is shown the energy spectrum of the sample that has been implanted by mono-energetic helium ions of energy 980 and 2400 keV. The depth scales for the helium distribution were evaluated and it is also shown on the figures.

It is useful to notice that all the experiments were done on a vacuum chamber of 4-5x10^{-5}Pa. The background of the back-scattered spectra at the helium position was minimized by placing the target on a special geometrical arrangement of the sample holder.

As mentioned above one can apply this simple method to produce a constant helium distribution in a certain depth in the target. By changing, for example, the positions of the microswitch one can vary the implanted depth interval without changing the energy of the beam. On the other hand by covering the target surface by a certain thickness of foil one can get a constant helium concentration from a certain depth right to the target surface. These possibilities may be used to clarify some important questions that exist at the present time in investigating the surface deformations caused by light ion bombardment.

For example:

1. What is the main parameter that influences the critical dose for the surface deformations, is it the local atomic concentration or the total amount of implanted ions? [9,10]
2. What's happened when the implanted profile reaches the surface? [6,7]
3. What is the dependence of blister cover thickness on the shape of the depth profile? [9,10]

Besides, this method offers a certain tool in controlling a special depth profile of dopant concentration used in producing semiconductor devices with ion-implantation technology.

These investigations are in progress.

Acknowledgements

The authors wish to thank Mr. L. Cserge for manufacturing the apparatus excellently in a very short time.

References

1 R.G. St.-Jacques, J.G. Martel, B. Terreault, G. Veilleux, S.K. Das, M. Kaminsky and G. Fenske; J. Nucl. Mat. 63 /1976/ 273.

2 D.K. Sood, M. Sundararaman, S.K. Deb, R. Krishnan and M.K. Mehta; IEEE Trans. Nucl. Sci. NS-26 /1979/ 1308.

3 F. Pászti, L. Pogány, G. Mezey, E. Kótai, A. Manuaba, L. Pócs, J. Gyulai, T. Lohner; J. Nucl. Mat. 98 /1981/ 11.

4 M.I. Guseva, V. Gusev, U.L. Krasulin, Yu.V. Martynenko, S.K. Das, M. Kaminsky; J. Nucl. Mat. 63 /1976/ 245.

5 M.I. Guseva, V. Gusev, Yu.V. Martynenko, S.K. Das, M. Kaminsky; J. Nucl. Mat. 85-86 /1979/ 1111.

6 K.L. Wilson, L.G. Haggmark, R.A. Langley; Proc. of Int. Symp. on Plasma Wall Int., Jülich 18-22 Oct. 1976, Pergamon Press /1977/ p. 401.

7 W. Jäger and J. Roth; J. Nucl. Mat. 93-94 /1980/ 756

8 S. Okudą, H. Kuwahara; Appl. Phys. Lett. 38 /1981/ 23.

9 E.P. EerNisse and S.T. Picraux; J. Appl. Phys. 48 /1977/ 9.

10 M. Risch, J. Roth, B.M.U. Scherzer; See ref. 6. p. 391.

11 L. Meyer; Phys. Stat. Sol. /b/ 44 /1971/ 253.

Figure caption

Fig. 1. Schematic drawing of the absorber tilting apparatus /fastened to the vacuum chamber outside/

Fig. 2. Energy spectrum of the backscattered protons incident to Al target foil that has been implanted by a/ multiple energy, b/ different values of monoenergetic helium ions.

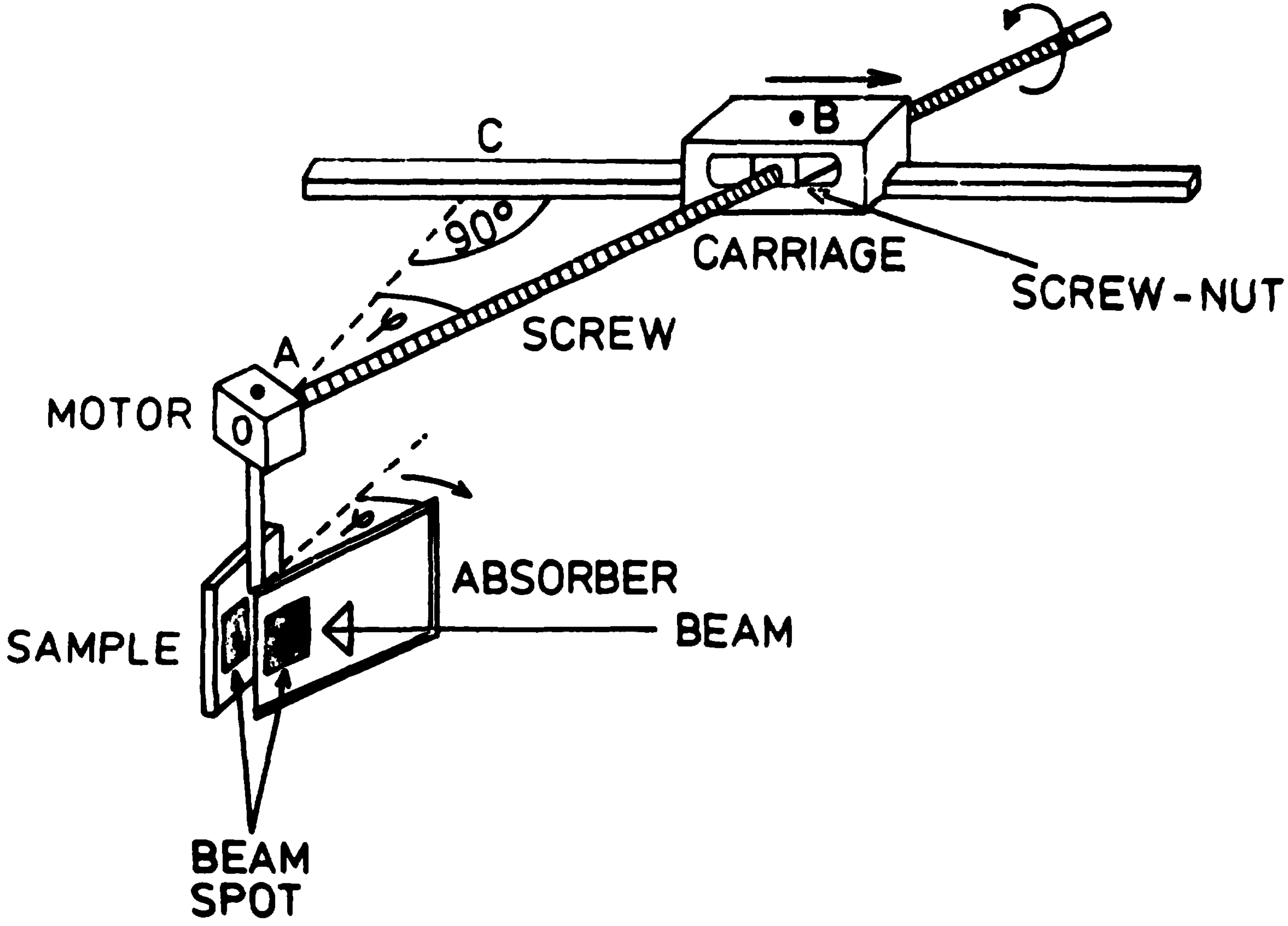
C
• B
90°
φ
A
SCREW
CARRIAGE
SCREW-NUT
MOTOR
0
φ
ABSORBER
BEAM
SAMPLE
BEAM
SPOT

Fig. 1

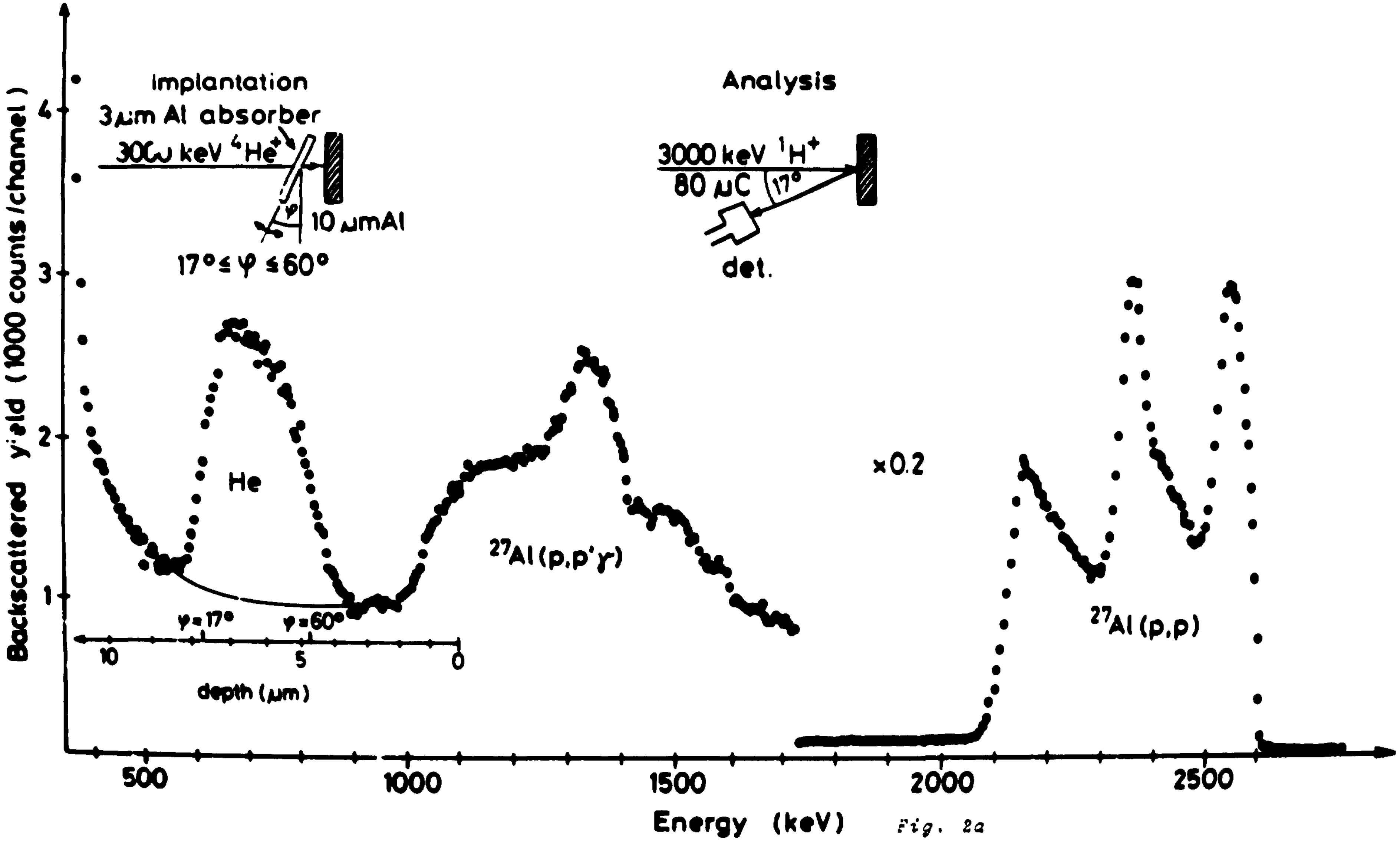
Implantation
3μm Al absorber
300 keV $^4He^+$
10 μmAl
17° ≤ φ ≤ 60°
Analysis
3000 keV $^1H^+$
80 μC
17°
det.
He
$^{27}Al(p,p'\gamma)$
×0.2
$^{27}Al(p,p)$
φ=17°
φ=60°
10
5
0
depth (μm)
Backscattered yield (1000 counts/channel)
1
2
3
4
500
1000
1500
2000
2500
Energy (keV)

Fig. 2a

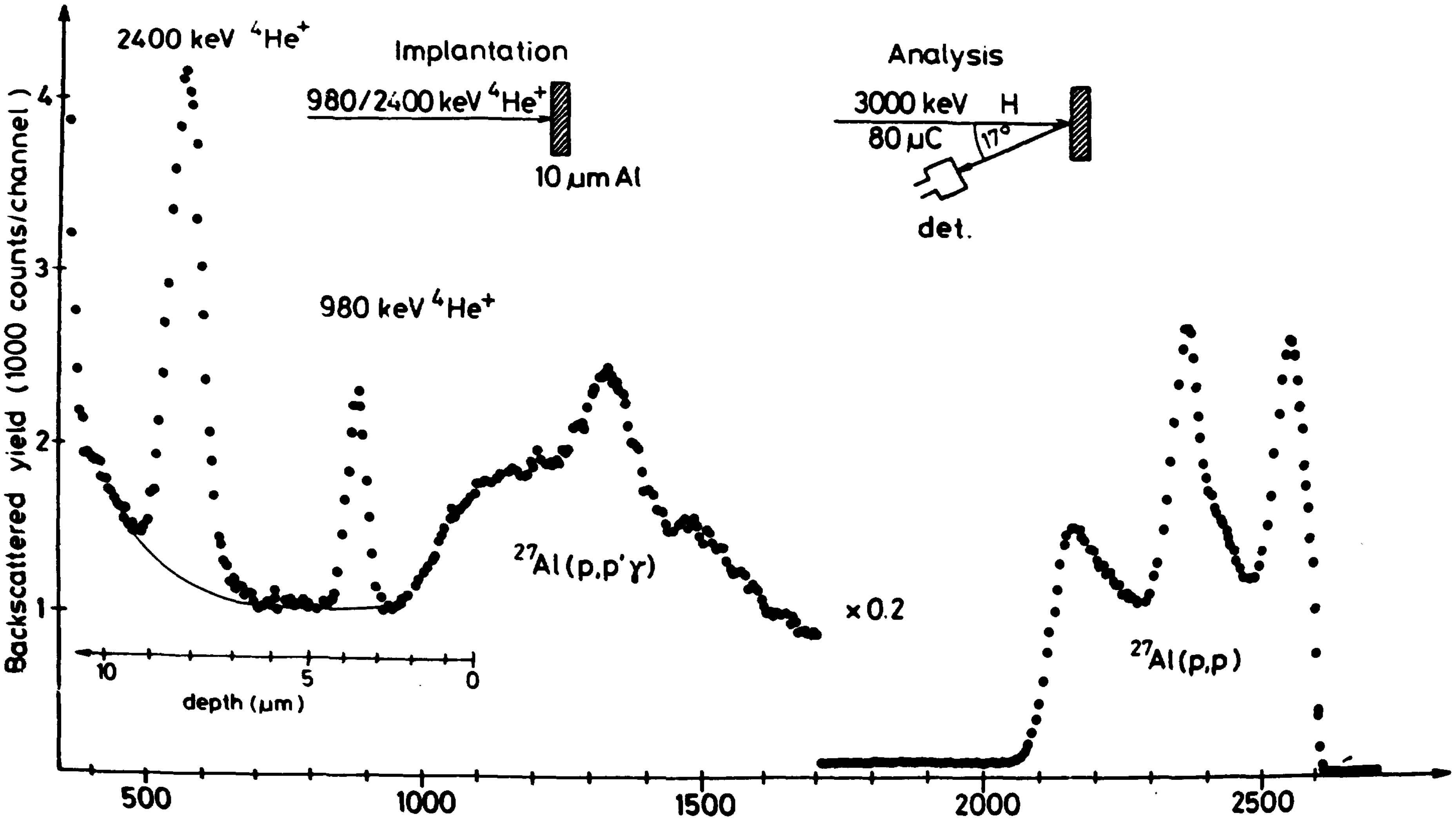
2400 keV $^4He^+$
Implantation
980/2400 keV $^4He^+$
10 µm Al
Analysis
3000 keV H
80 µC
17°
det.
980 keV $^4He^+$
$^{27}Al(p,p'\gamma)$
× 0.2
$^{27}Al(p,p)$
Backscattered yield (1000 counts/channel)
4
3
2
1
10
5
0
depth (µm)
500
1000
1500
2000
2500
Energy (keV)

Fig. 2b

Kiadja a Központi Fizikai Kutató Intézet
Felelős kiadó: Szegő Károly
Szakmai lektor: Hrehuss Gyula
Nyelvi lektor: Hrehuss Gyula
Példányszám: 420 Törzsszám: 82-589
Készült a KFKI sokszorosító üzemében
Felelős vezető: Nagy Károly
Budapest, 1982. november hó