Wear diagnostics of industrial material using RI beams (RNBs) of 7Be and 22Na

～ Beam & performance study ～

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＊Wear diagnostics using RNB (history)
＊Available RNBs at RIKEN
＊Measured surface and depth profiles of the implanted activity

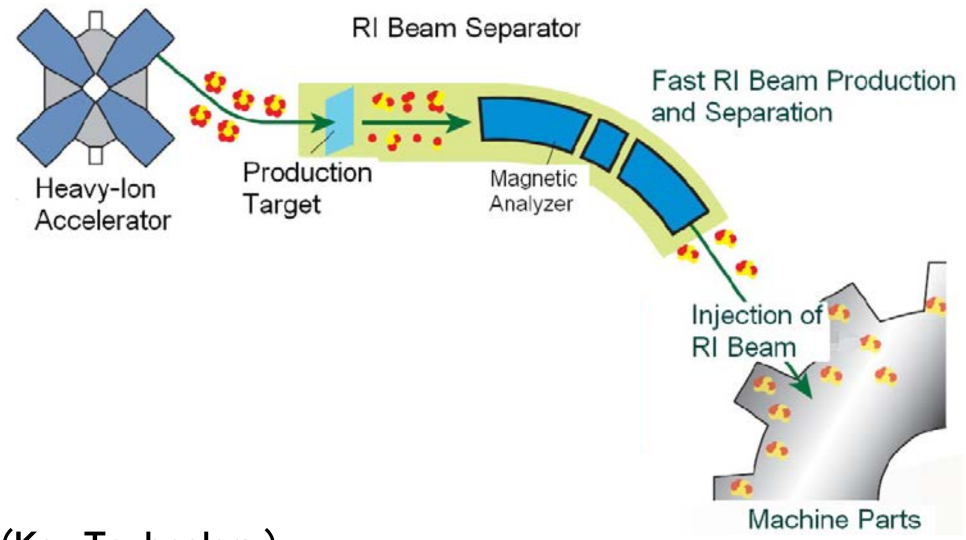
Collaborators

SHIEI S.H.I.Examination & Inspection,Ltd 住重試験検査株式会社
INTEGRATED INSPECT ENGINEERING COMPANY
Sumitomo H.I. Exam & Inspect. Ltd.
R.Uemoto, H.Uno, A.Nagano http://www.shiei.co.jp/

RIKEN NiSHiNA CENTER
A.Yoshida, T.Kambara, A.Nakao,
Y.Yanagisawa, T.Ohnishi, N.Fukuda, D.Kameda,T.Kubo : ^{22}Na

Univ. of Tokyo CNS Center for Nuclear Study
H.Yamaguchi, T.Nakao, D.Kahl : ^{7}Be

RNB utilizing for wear diagnostics

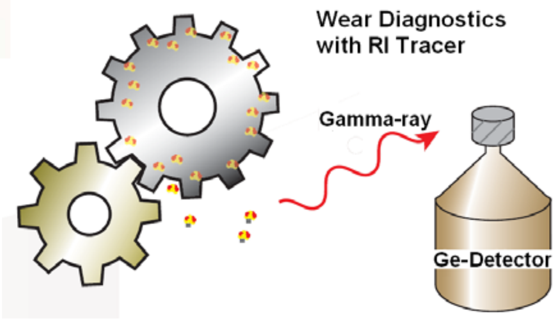


"Tribology" : friction, wear, lubrication

use R I tracer
for wear diagnostics

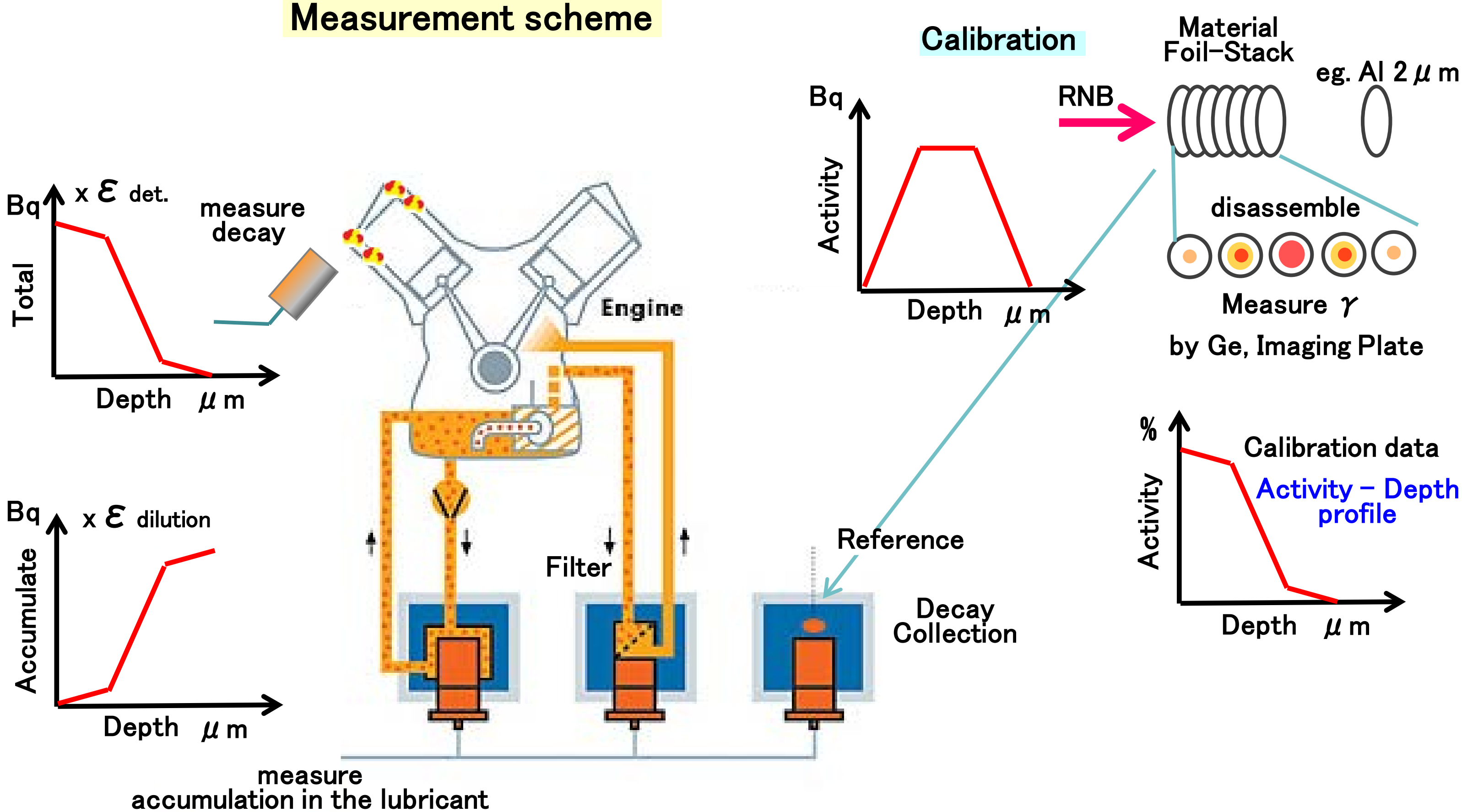
Automobile (Engine, bearing, etc.)
Railway, Nucl. power plant, Space Tech.

(Key Technology)
∗ long life R.I. (weeks ~ years) near stablility line
∗ implant to Surface ~ a few 100 μm
∗ with high density ＞kBq / μm



of course,
High-intensity ISOL + post-accelerator facility
may be the best for this application.

Measurement scheme



(Advantages)

* On-line & real -time test under working condition changing test parameters
* need not disassemble for wear measurement
  → "real test" saving time & cost

(Disadvantages)

* need unsealed RI source treatment facility
* facility & beam cost

Activation method (history -1)

* neutron activation
  entire component is activated (> 100 MBq), fugue RI waste, needs thick shielding

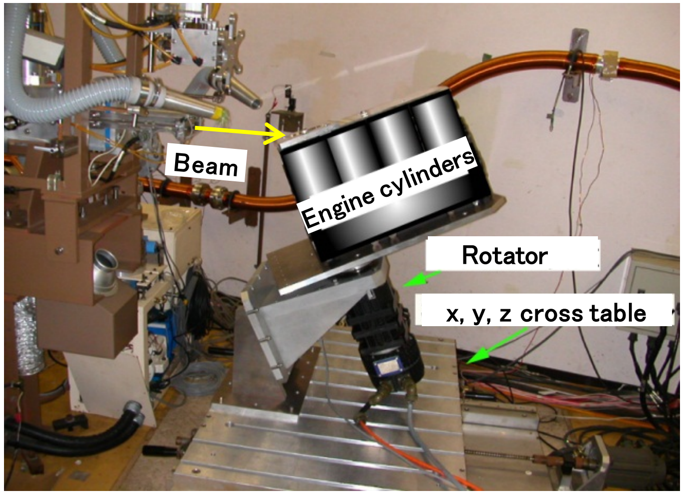
* ion-beam activation ; only near surface

mid. '1970 ~ ref.) M.Yamamoto, JRIA Radioisotopes, 45(1996)700

Radionuclide Technique in Mechanical engineering (RTM)
Karlsruher Institute (FZK,KIT) , Germany
Thin Layer Activation method (TLA)
A.E.R.E., Harwell , England
Surface Layer Activation method (SLA)
Spire Corp., USA

14N 17-35MeV/u, 100pnA + Carbon -> 7Be, 22Na
W.C.McHarris, M.L.Mallory (MSU, NSCL), et.al
Nucl.Phys.A353(1994) 583, N.P.A299(1990)593, N.P.B40/41(1989)579

* direct beam activation



SHIEI Ltd. "irradiation service"
beam : p 18MeV, d 10MeV, 3He 24MeV

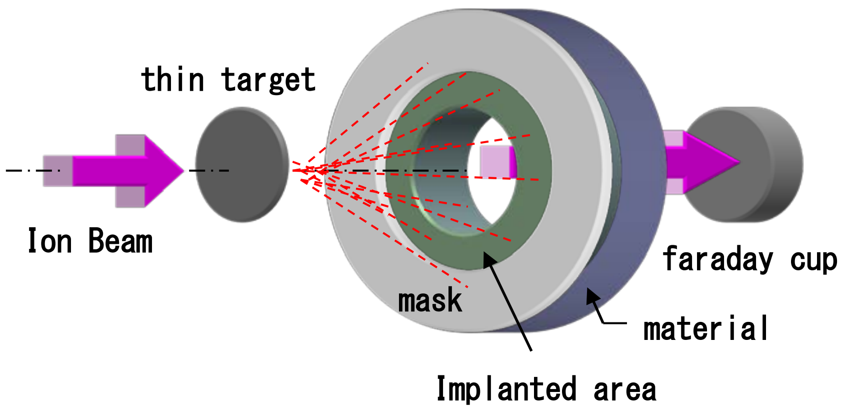
Activation ~MBq
Sensitivity ~0.1 μg/h
~10 nm/h

Material	^{56}Fe	^{27}Al	^{65}Cu	^{52}Cr	^{48}Ti	^{120}Sn
RI produced	^{56}Co	^{22}Na	^{65}Zn	^{51}Cr	^{48}V	^{120m}Sb
Life time	78.8d	2.6y	244.1d	27.7d	16.0d	5.8d

limitation for material component
* long-life RI should be produced
  for metal : OK for organic : difficult
* interference from unnecessary contaminant RI
* material damage
  by heat up & irradiation damage

Activation method (history-2)

→ Recoil RI implantation



C(3He,2 α) 7Be recoil
T.Sauvage (CNRS-CERI, France) et.al.,
NIM B143(1998)397-402
M.F.Stroosnijder, et.al.
NIM B227(2005)597-602

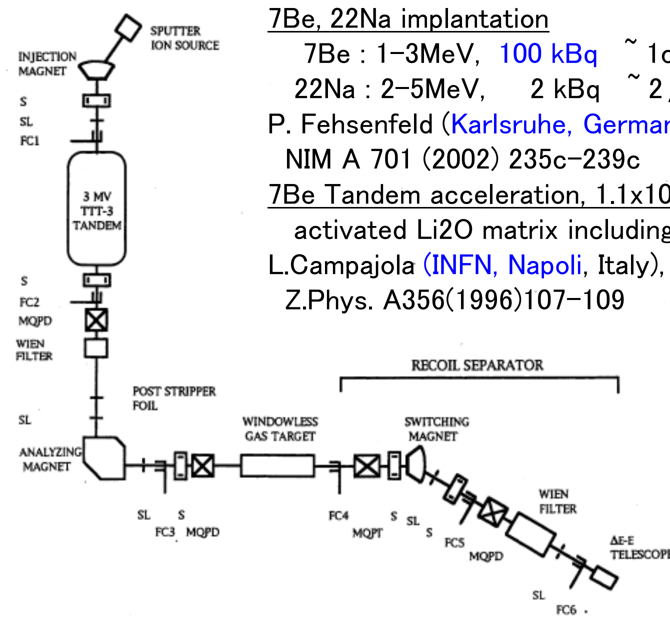
difficulties

*** scattered primary beam implanted, also**
*** recoil RI ; angular distrib. & low-energy**
difficulty for controlling implantation depth

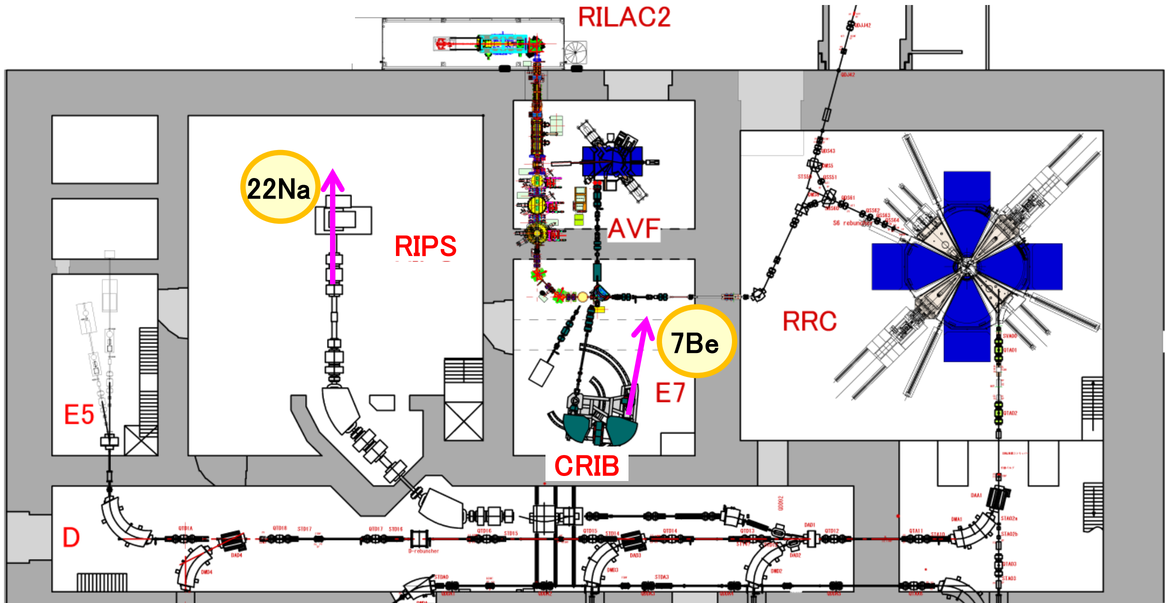
→ RNB separator implantation

* for any component material
* lower radiation & heat damage
* variation of RI tracer

7Be, 22Na implantation
7Be : 1-3MeV, 100 kBq ~ 1cm2
22Na : 2-5MeV, 2 kBq ~ 2 μ m depth
P. Fehsenfeld (Karlsruhe, Germany) et.al.,
NIM A 701 (2002) 235c-239c
7Be Tandem acceleration, 1.1x10^8 cps
activated Li2O matrix including 7Be
L.Campajola (INFN, Napoli, Italy), et.al.
Z.Phys. A356(1996)107-109



available RNB for industrial applications @ RIKEN



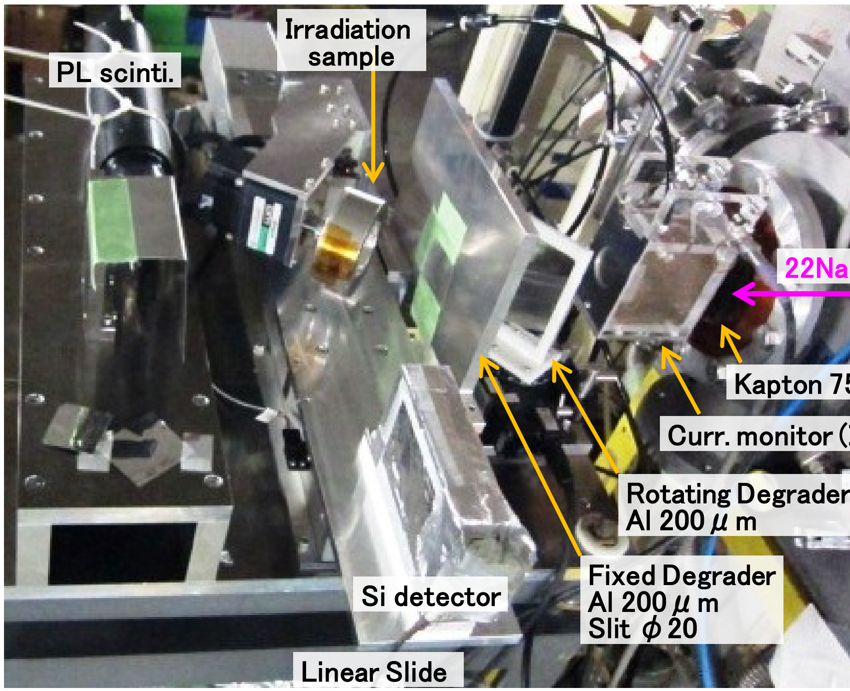
	22Na : E6-RIPS	7Be : E7-CRIB	
Primary Beam	23Na^{11+} 63.4MeV/u ～1pμA	7Li^{2+} 5.7MeV/u ～1pμA	
Target ; Reaction	Be 1.5mm ; fragmentation	H2gas 90K 1atm ; p(7Li,7Be)n	
Radionuclide Beam (RNB)	26.6MeV/u 1.5x10^8cps φ～3cm	4.1 MeV/u 1.9x10^8cps φ～1cm	in Vacuum
RNB purity	22Na(100%)	7Be(80%) 6Li(20%)	in Vacuum
Life time	2.60 y	53.2 d	
Decay scheme	γ1274.5keV (99.96%), γ511keV	γ477.6keV (10.52%)	
Irradiation environment	in Air 27cm	He (1 atm) 14cm ; 6Li stopped	
Activation (achieved)	4～6 kBq/1h irradiation	9～11 kBq/1h irradiation	in φ16mm
Range in Al	～685μm	～67μm	in Vacuum
Range width (dP/P=±3%)	～±8μm	～±1.5μm	calculation
Purposes	for Metalic materials long-term measurement	for Plastic materials short-term, Lower irradiation damage	

22Na beam at RIPS

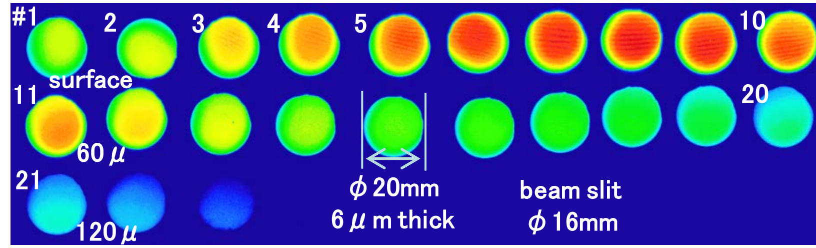
ref) T.Kambara et.al, AIP Conf. Proc. 1412, 423(2011)
R.Uemoto et.al, JSAE Annual Congress, 143-20115142

Primary : $^{23}Na^{11+}$ 63 MeV/A ~1 pμA
Target : Be 1. 5 mm, dE = 300 Watt
Separator : F1 deg Al 1. 2mm F1 slit dP/P = ±1.5%
RNB : E(^{22}Na) = 26.6MeV/A 1.5E+8cps φ ~3cm

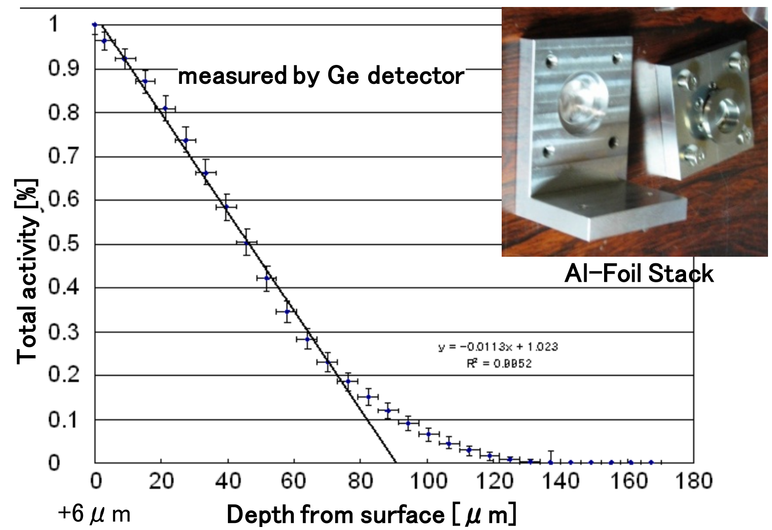
Irradiation in Air



Depth profile in Al-Foil (6um) stack



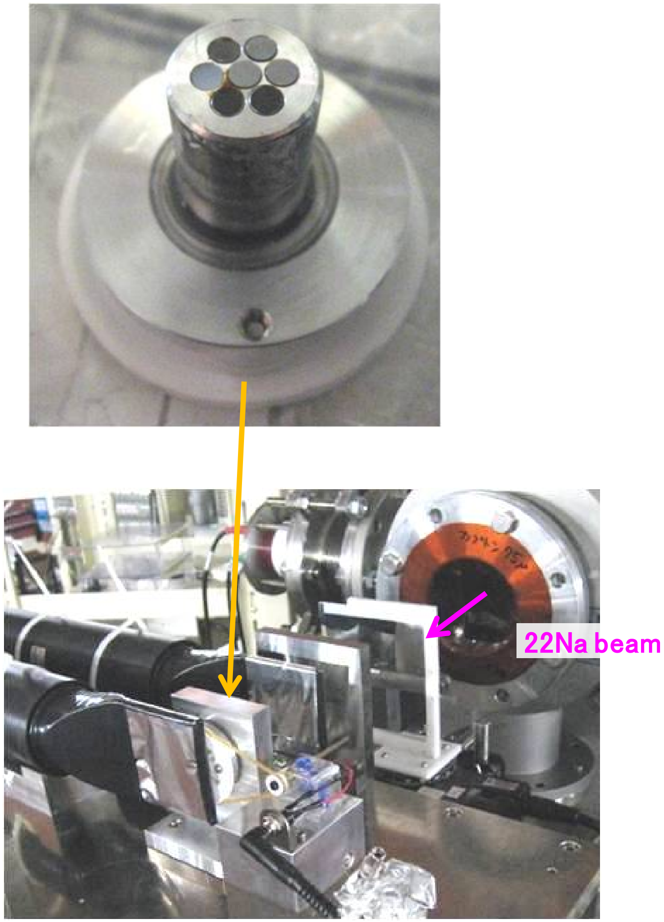
measured by Imaging Plate (IP-SR)

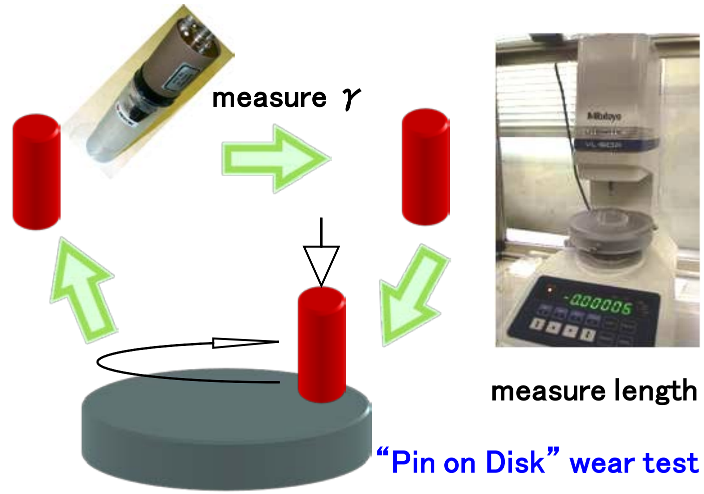


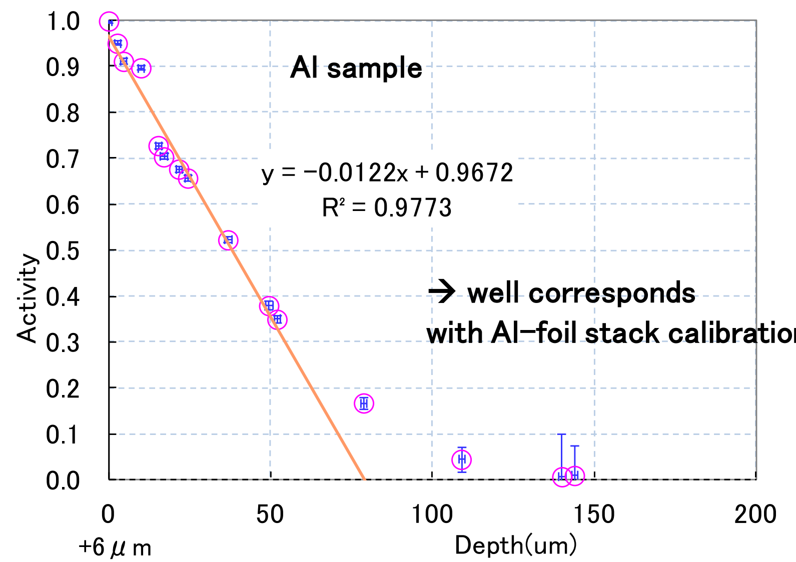
Implantation : 2x10^8 cps * 26 hour = 172 kBq

22Na beam at RIPS

rig test sample ϕ 3x15mm
Al, Fe, Bi, Mo, etc.

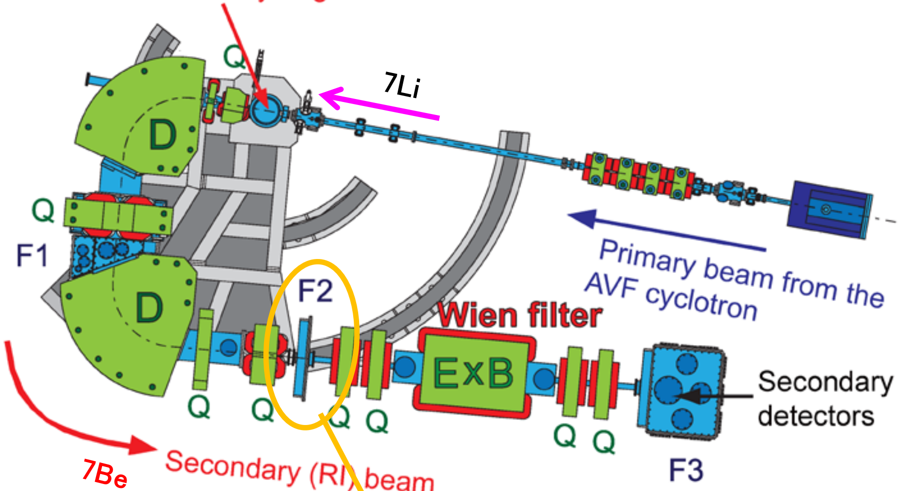


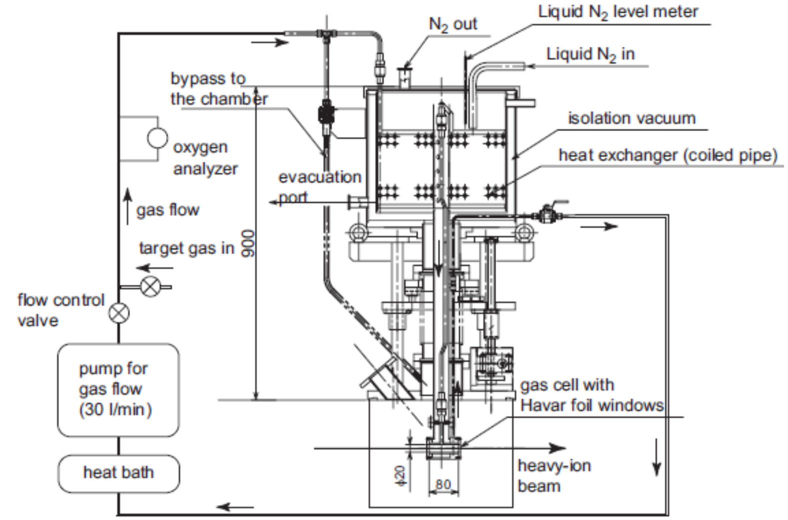




7Be beam production at CRIB

CRIB
CNS Radio-Isotope Beam Separator

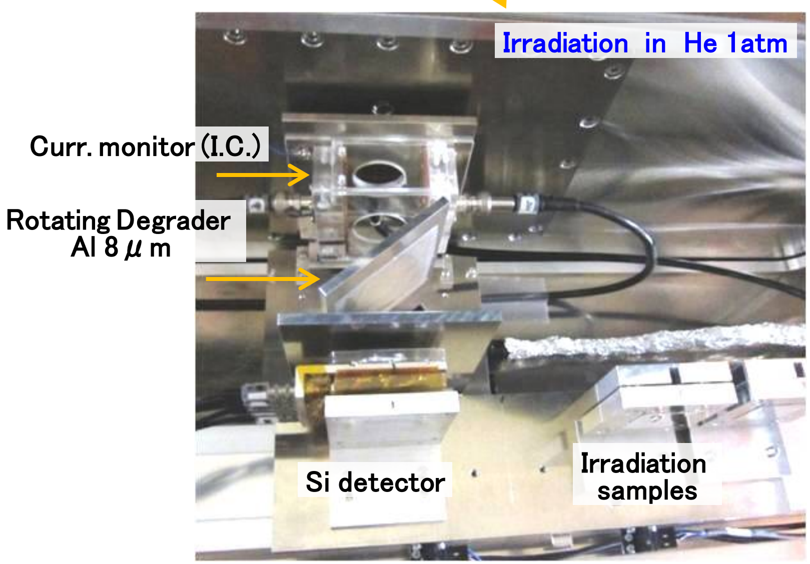




Cryogenic Gas-Target system

H.Yamaguchi et.al. NIM A589(2008)150-156

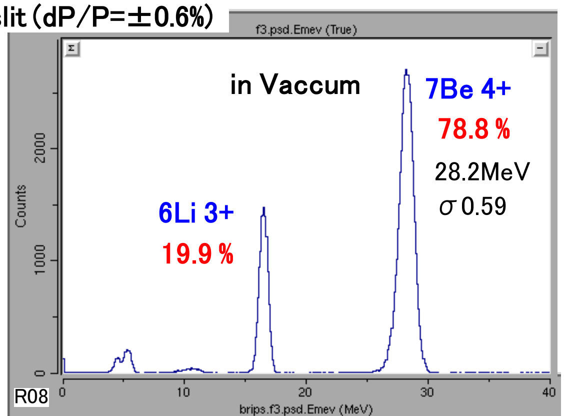
H2 gas (90K 1atm 8cm) Havar 2.5 μ m

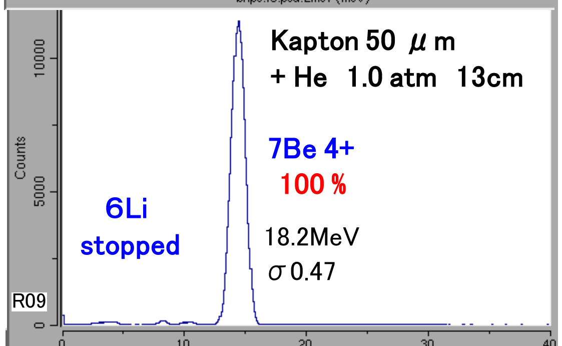


Primary : $^{7}Li^{2+}$ 5.7 MeV/A 1.0～1.2 pμA
Reaction: p (^{7}Li, ^{7}Be) n
Target : Cryo. H2-Gas target dE = 5 Watt (H2)
Separator : F1 slit dP/P = ±3.1%
RNB : E(^{7}Be) = 4.1MeV/A 1.9E+8cps ϕ ～1cm

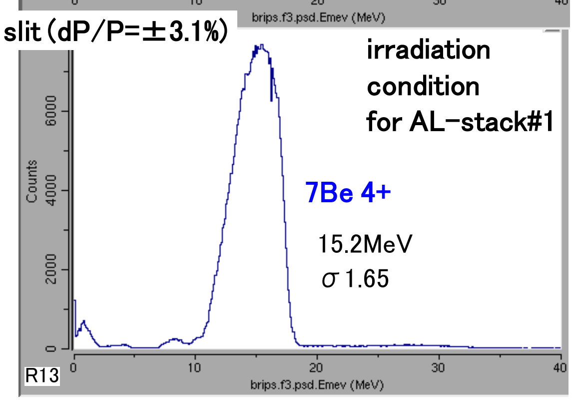
7Be beam production at CRIB

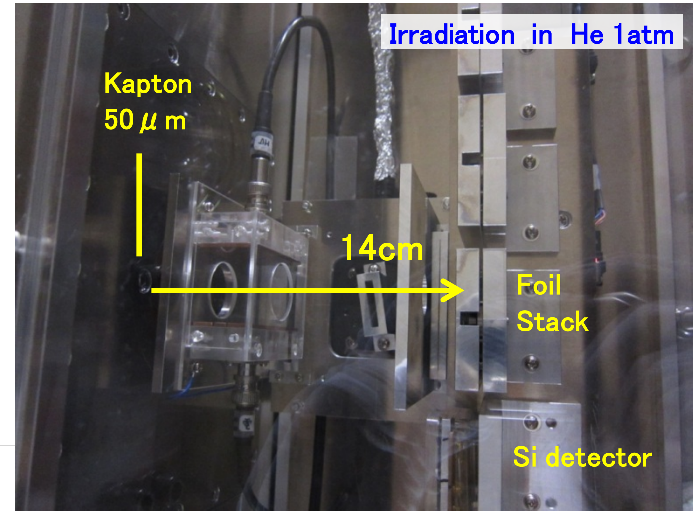
F1slit (dP/P=±0.6%)

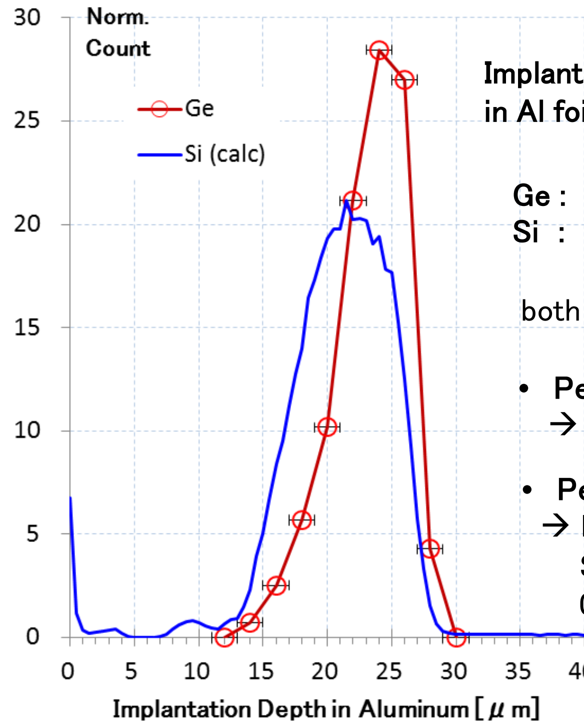




F1slit (dP/P=±3.1%)





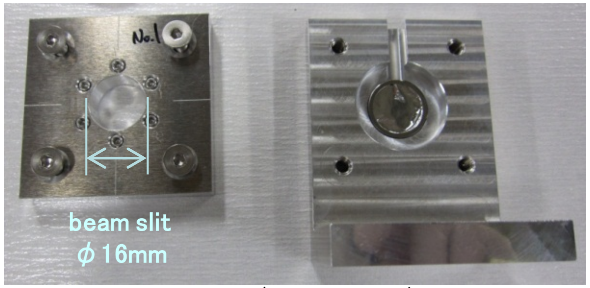


Implantation Depth in Al foil (2 μ m) stack- #1

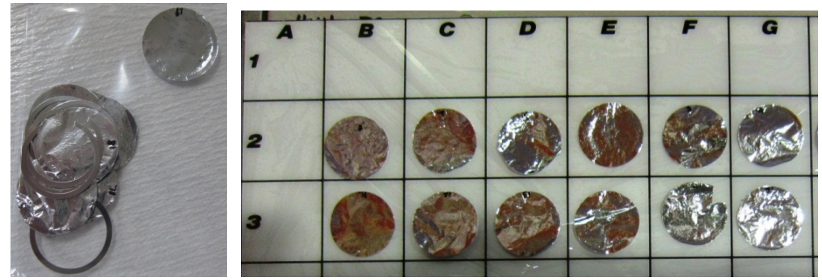
Ge : measure each foils
Si : E → Range conversion using SRIM 2011code
both are normalized by total count

- Peak shift ～2 μ m
  → Si dead layer ?
- Peak width
  → longitudinal struggling ～3 μ m ?
  Si energy resolution @ 28MeV
  0.4% in σ -> 1.4 μ m in fwhm ?

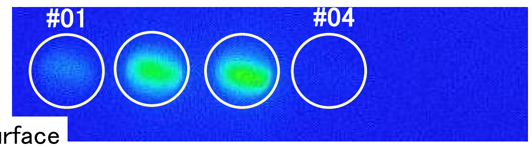
7Be beam at CRIB

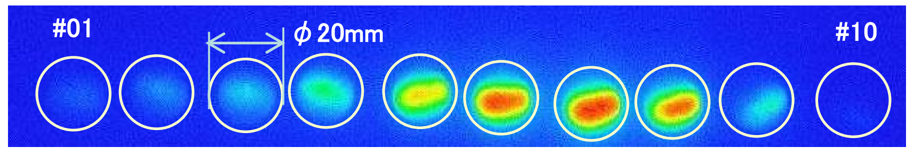


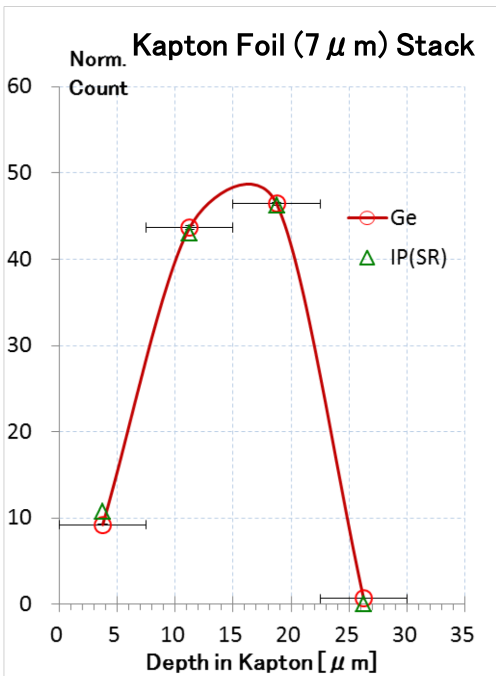
Aluminum Foil (2 μ m x 20) Stack

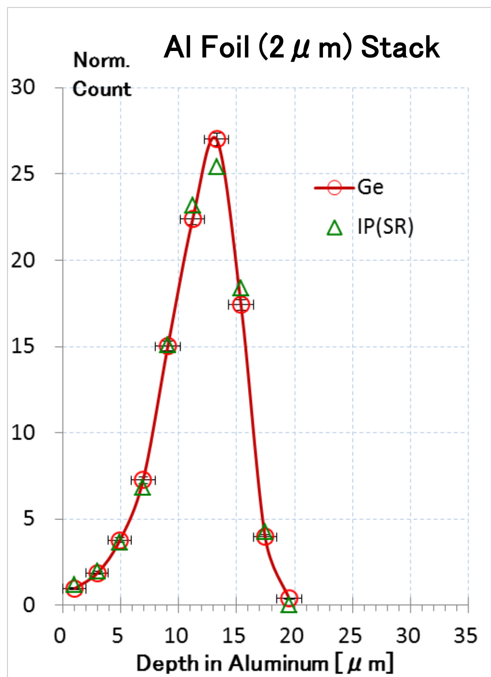


after irradiation, put them on a I.P. film









Imaging Plate (IP) : Ba F Br :Eu 2+
Photostimulated luminescence film

I.P. film : GE health care, BAS IP (SR/MS) 2040E

IP image analysis
ref.) K.Takahashi et.al. JAEA-Tech 2008-028

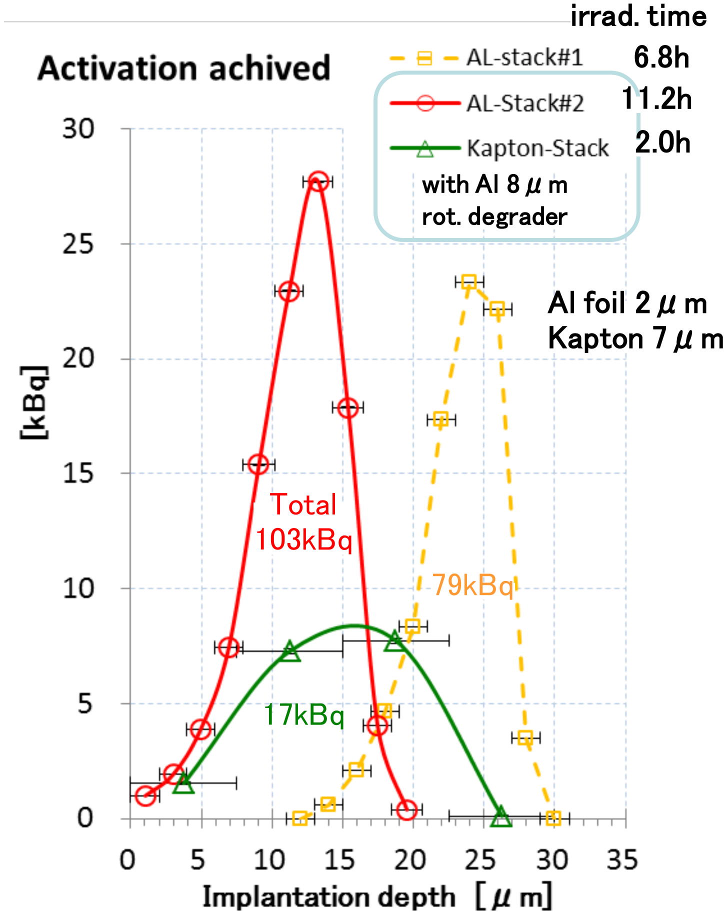
intensity of 7Be- γ ray (477keV) was measured by Ge & I.P. detectors , then compared.
normalized by total intensity of all films.

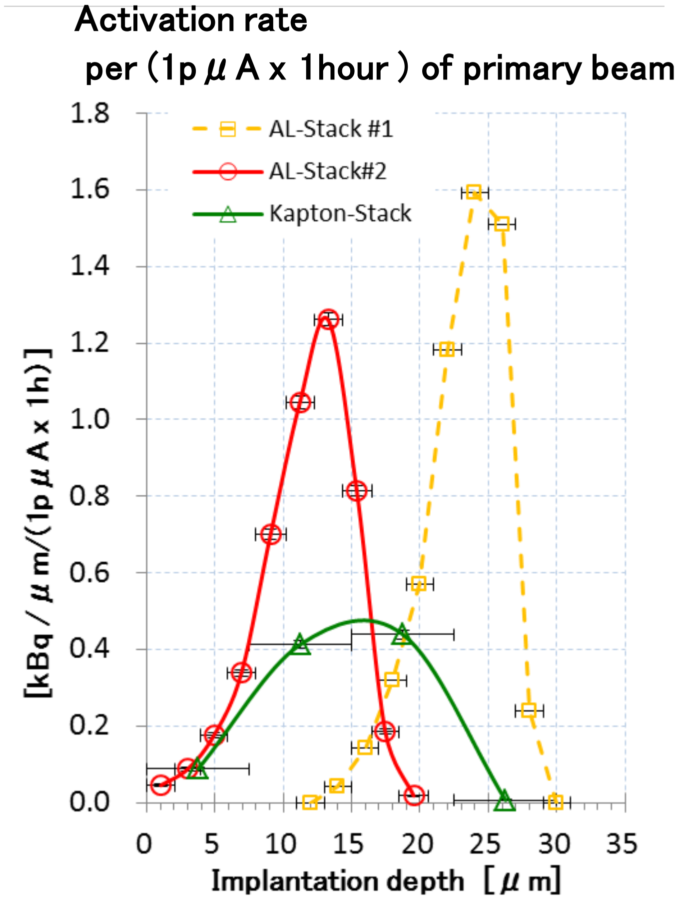
→ * "relative " intensity of Ge & I.P. well correspond.

*** using I.P. data implanted RNB spot-profile can be analyzed**
(nominal resolution < 50 μ m)

7Be beam at CRIB

prim. beam current 0.9～1.2 pμA





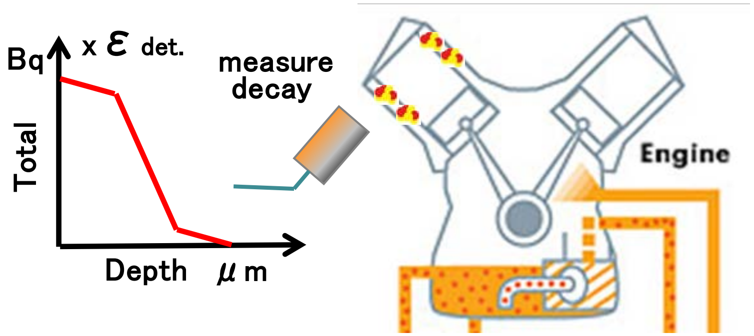
→ Total activity ～10 kBq / 1 hour irradiation was achieved.

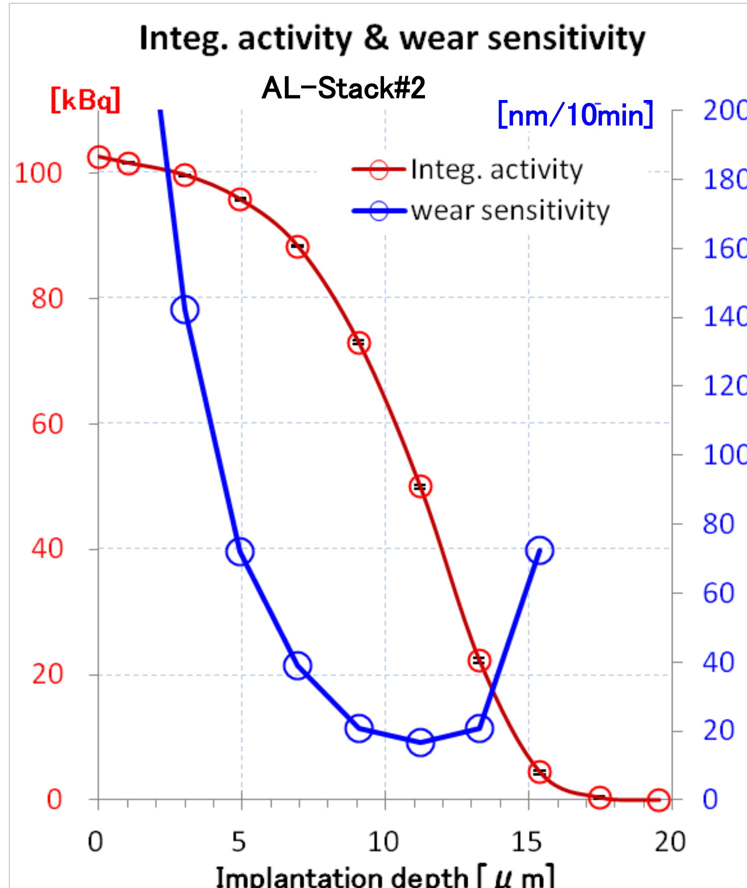
→ for 1 day irradiation,
density : ～30 kBq / μm
depth : max. 25 ± 5 μm (in Al)

wear loss sensitivity (estimation)

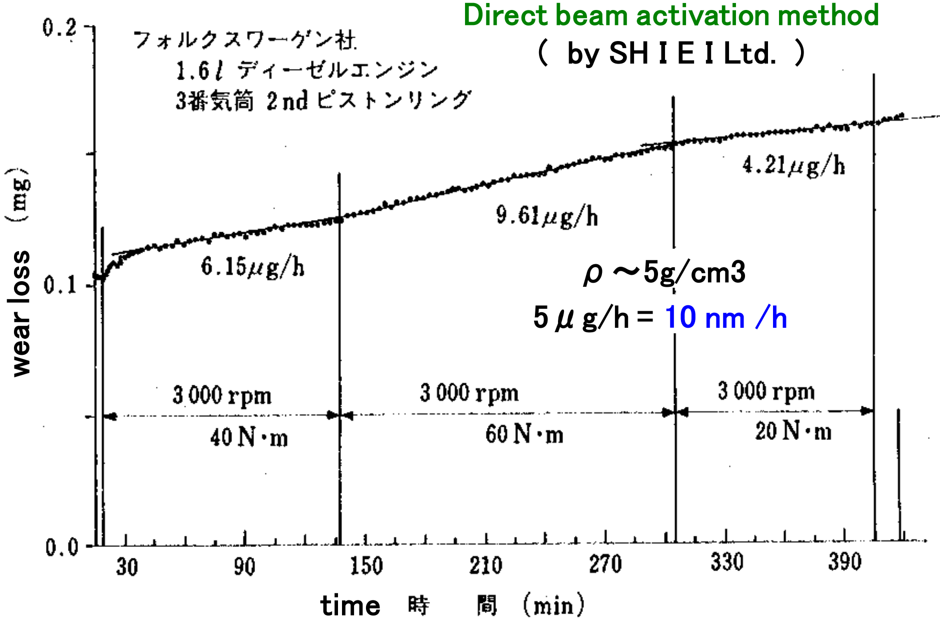
assume : ε det = 1%,
measuring time = 10min each

count rate reduction → wear loss
considering statistical error





Direct beam activation method
(by SHIEI Ltd.)



ρ ～5g/cm3
5 μg/h = 10 nm /h

→ Approaching to same order of the sensitivity.

Summary

* Two intense RNBs are available for wear diagnostics.
  22Na : 26.6 MeV/u 1.5x10^8 cps ~ 5 kBq / 1 hour irradiation
  7Be : 4.1 MeV/u 1.9x10^8 cps ~ 10 kBq / 1 h

  they can be utilized for wear diagnostics of metal, ceramic, plastic, etc.

* for 7Be
  1 day irradiation : peak 30 kBq / μm , max. depth 25±5 μm in Al is available.

  I.P. can be used for beam-spot shape analysis of each implantation depth.

Thank you for your attention