

Three tier blistering tolerant neutron target for iBNCT by using 80kW proton linac.

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Outline of i-BNCT

Spin off of J-PARC frontend injector linac technology, RF design based on J-PARC To build patient friendly BNCT facility born in Ibaraki, Japan (i = Ibaraki)

DTL: Drift Tube Linac
RFQ
i-BNCT linac

Why beryllium is the only solution?

In case of Li, the cross section is very attractive,
 ◆ Sharp rise below 2.5MeV
 ◆ Neutron energy spectrum is fine (< 300keV)
 Serious demerits: Production of radioactive elements
 ◆ ⁷Li(p,n)⁶Be → ⁷Be is radioactive (53 days)
 ◆ Tritium production → ⁶Li(n,t)³He
 Further serious demerits: chemical problems
 ◆ Melting temperature is only 180 °C
 ➢ No way of water cooling
 ◆ Very active and hydrogen gas production with H₂O

Lithium target is too dangerous for the hospital use.

Heat issue

Nukiyama curve In 1930s

Fig. 1: The Nukiyama curve.

Target thickness of i-BNCT : 0.5mm not enough mechanical strength as a beam window

Bragg peak depth for various proton energy

Target thickness of Kyoto: 5.5mm
 → Mechanical strength is enough as a beam window

Candidate of Target related materials

Experimental Studies of Blistering of Targets Irradiated by Intense 200 keV Proton Beam

Element	Yield point, 10 ⁷ Pa	Diffusion energy, eV	Dislocation energy, eV	Blistering, 10 ¹⁷ cm ⁻²
Cu	20-50	0.4	0.37	0.4-0.1
W	50-90	0.39	1.03	2-4
Fe	12-15	0.05	0.27	80-150
Pd	20	0.23	-0.11	200-300
V	31	0.045	-0.34	not observed up to 120
Ta	57	0.14	-0.35	not observed up to 230

Direct measurement of heat conductivity with laser-flash method
 → 200 W/(m/K)
 → Good enough for the practical use

Blistering mitigation metal

Yes, we can overcome blistering problem and high heat density!!!

Laser flashing

Direct measurement of heat conductivity with laser-flash method
 → 200 W/(m/K)
 → Good enough for the practical use

Thermal diffusivity measurement

Surface observation with PLDM

Incident angle dependency of reflectivity of s, p polarized light

Polarizing Long Distance Microscope (PLDM)

In situ observation of blistering

Laser Light Reflectivity Measurement (LRM)

Blistering observation using reflection laser light

Copper: Equivalent to 3.5 hour operation

Research will be continued

Direct observation of proton induced blistering using light-polarization and -reflectivity

1mm
 20min interval
 180min video recorded formaMon, growth and rupture of blisters

Design of the blistering tolerant neutron target

Ibaraki target (separated function)
 Target thickness is 0.5mm
 needs backup plate for beam window

Backup layer
 Be
 Blistering mitigation metal
 Heat sink with cooling water channel

White powder on Be Target Sample

Sample in transparent case 2013.5.30
 Something powder like was found.
 Be powder is extremely dangerous.

As fabricated 2012.11.4
 No powder was found.

Cross sectional observation of candidate materials

Cross sectional observation of diffusion bonded layers

Be-X2 ×500
 Reaction layer
 Be-X2-Cu サンプル ×50
 X2-Cu ×500
 Reaction layer

Three tier blistering tolerant neutron target

- iBNCT is introduced
- Why Be was selected
- Heat issue
- Blistering-Detection
- Blistering tolerant target
- Diffusion bonding
- Be related affairs
- Be related affairs

Neutron target