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Collection of uranium from seawater

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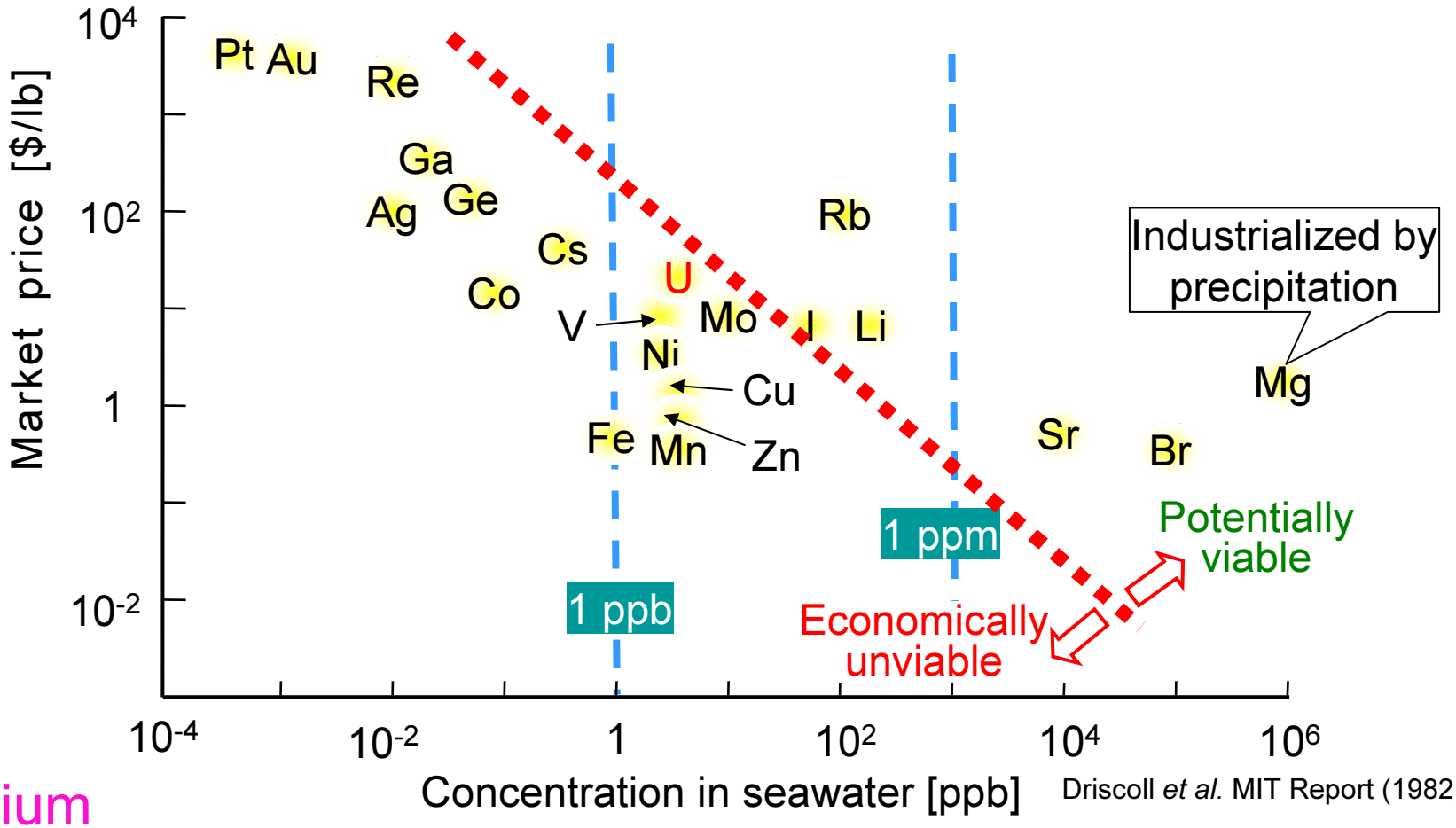
Mineral resources in Seawater

Cost-effectiveness of minerals in seawater



Driscoll *et al.* MIT Report (1982)

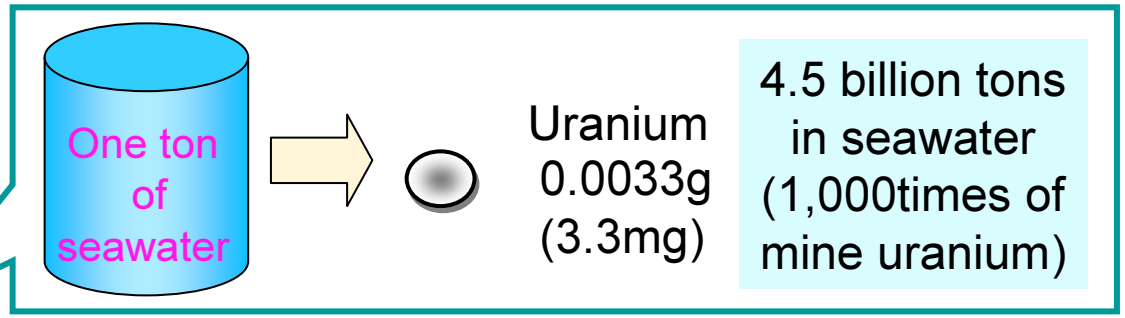
Uranium

- 3.3 ppb in seawater
- near boundary of cost-effectiveness

Commercialization of uranium collection from seawater:

How do we develop a cost-effective methods?

Uranium Resource in Seawater



Resources with Japan current 5.2×10^6 t/y ~0.2% Demand of Japan in a year 8×10^3 t/y

Current state of uranium collection from seawater.

- Adsorbent synthesis: High affinity against uranium in seawater
- Demonstration of uranium collection: Marine experiment
- Cost estimation and Future planning
- Research activities in the world

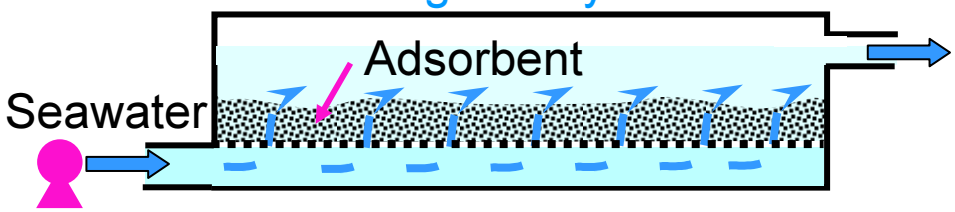
Uranium Adsorbent

~1960 Hydrous titanium oxide adsorbent

Inorganic material

Pumping for preventing adsorbent from sinking

Moving bed system



Pumping

Costly process

Low mechanical strength

Radiation induced graft polymerization

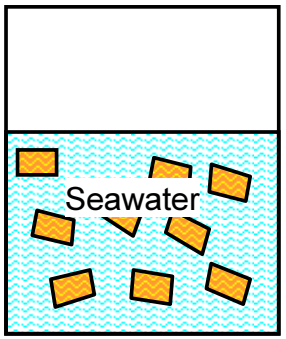
~1980 Amidoxime adsorbent

-C=N-OH
|
NH_2

Organic polymer

Density is close to that of seawater

No agitation

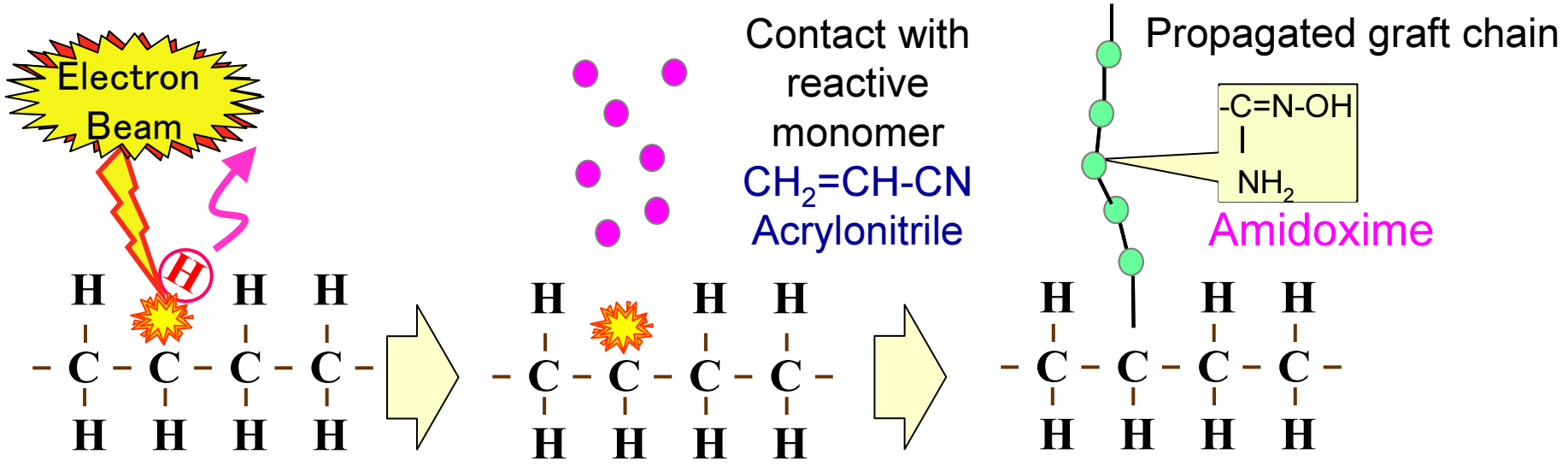


Effective contact by tide and wave motion

Expecting cost reduction

Radiation-induced Graft Polymerization

Imparting desired functional group into trunk polymer

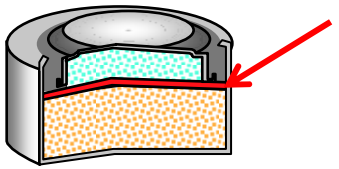


Polyethylene

High mechanical strength

Uranium adsorbent

Industrial applications of graft polymerization



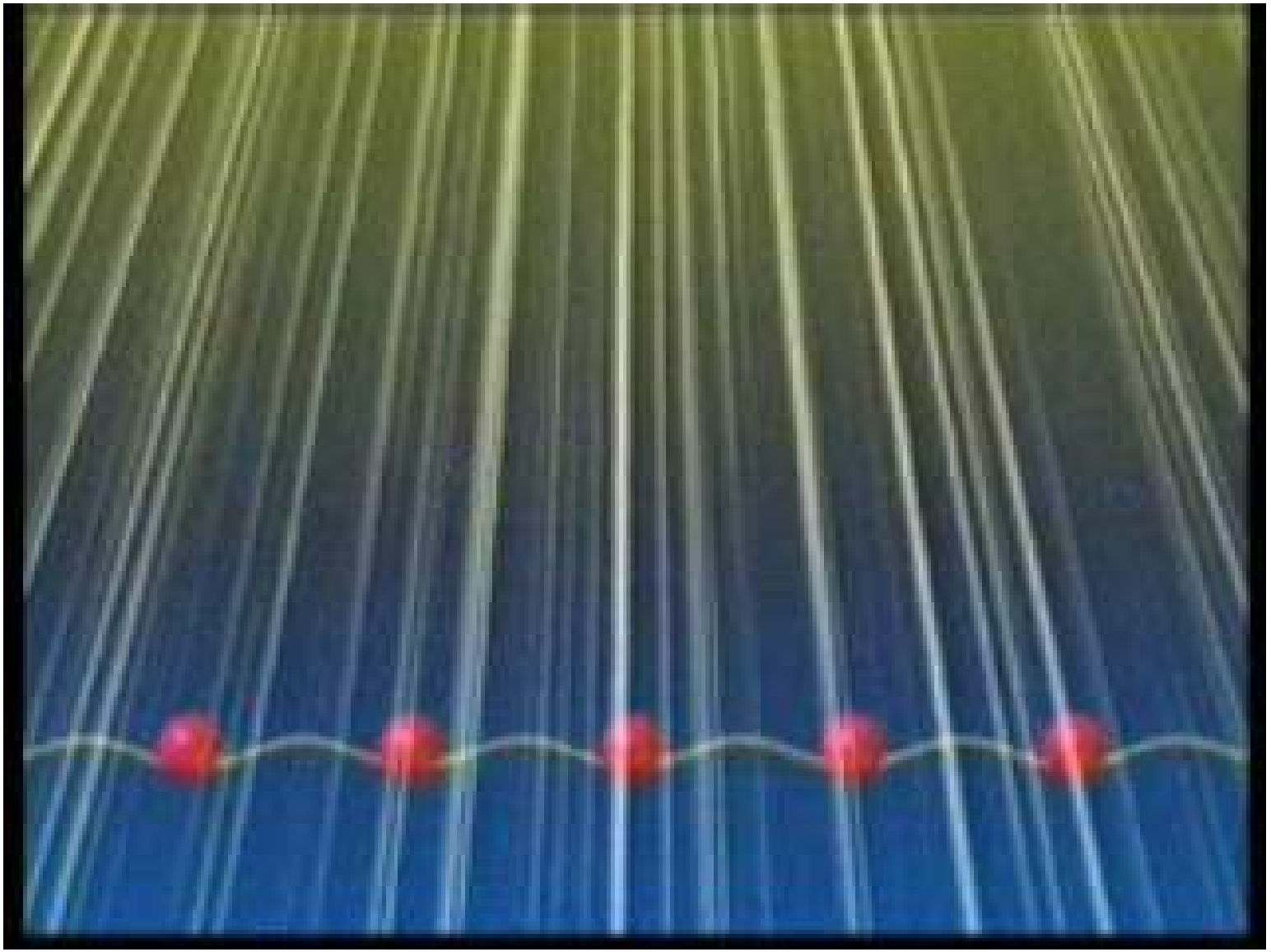
Electro conductive diaphragm membrane

Button shaped buttery

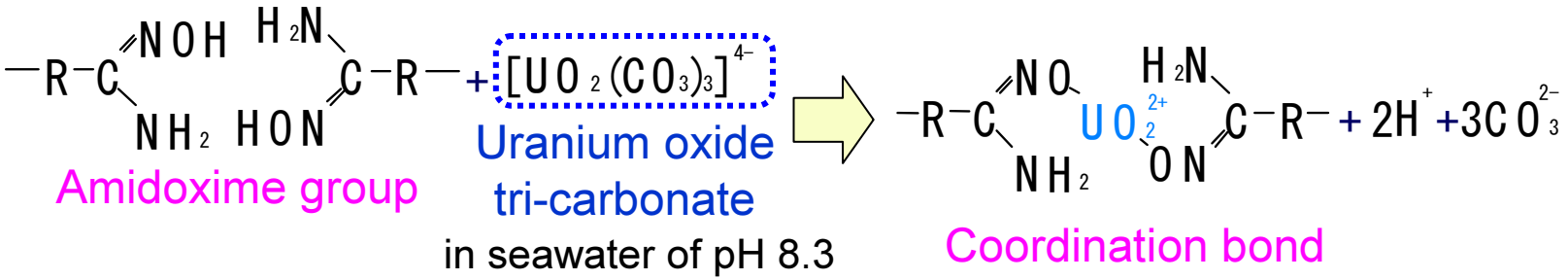
NH_3 gas adsorbent for semiconductor factory

Air purification filter

Image of Radiation induced Grafting



Characteristic of Amidoxime Adsorbent

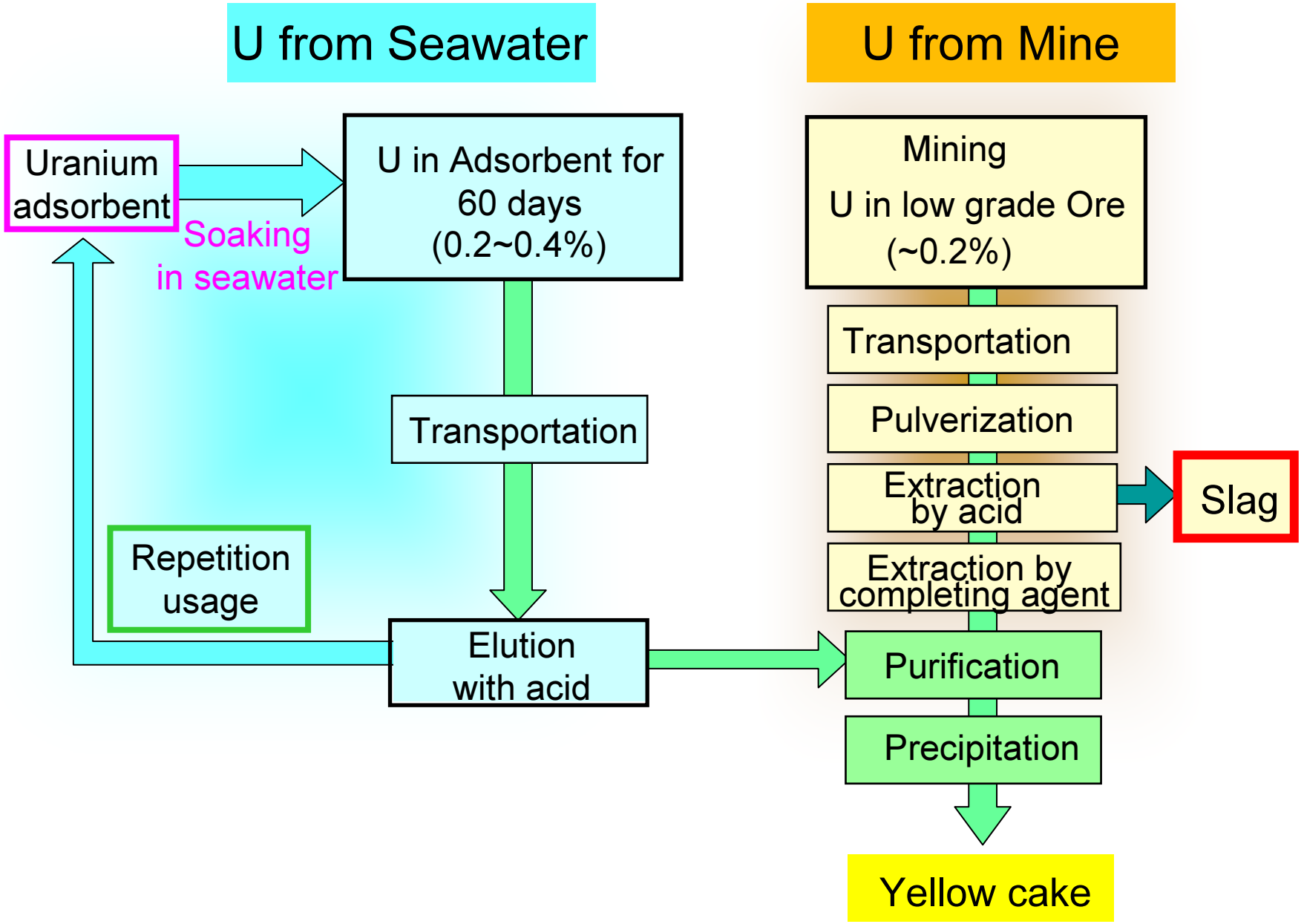


Selectivity of amidoxime adsorbent

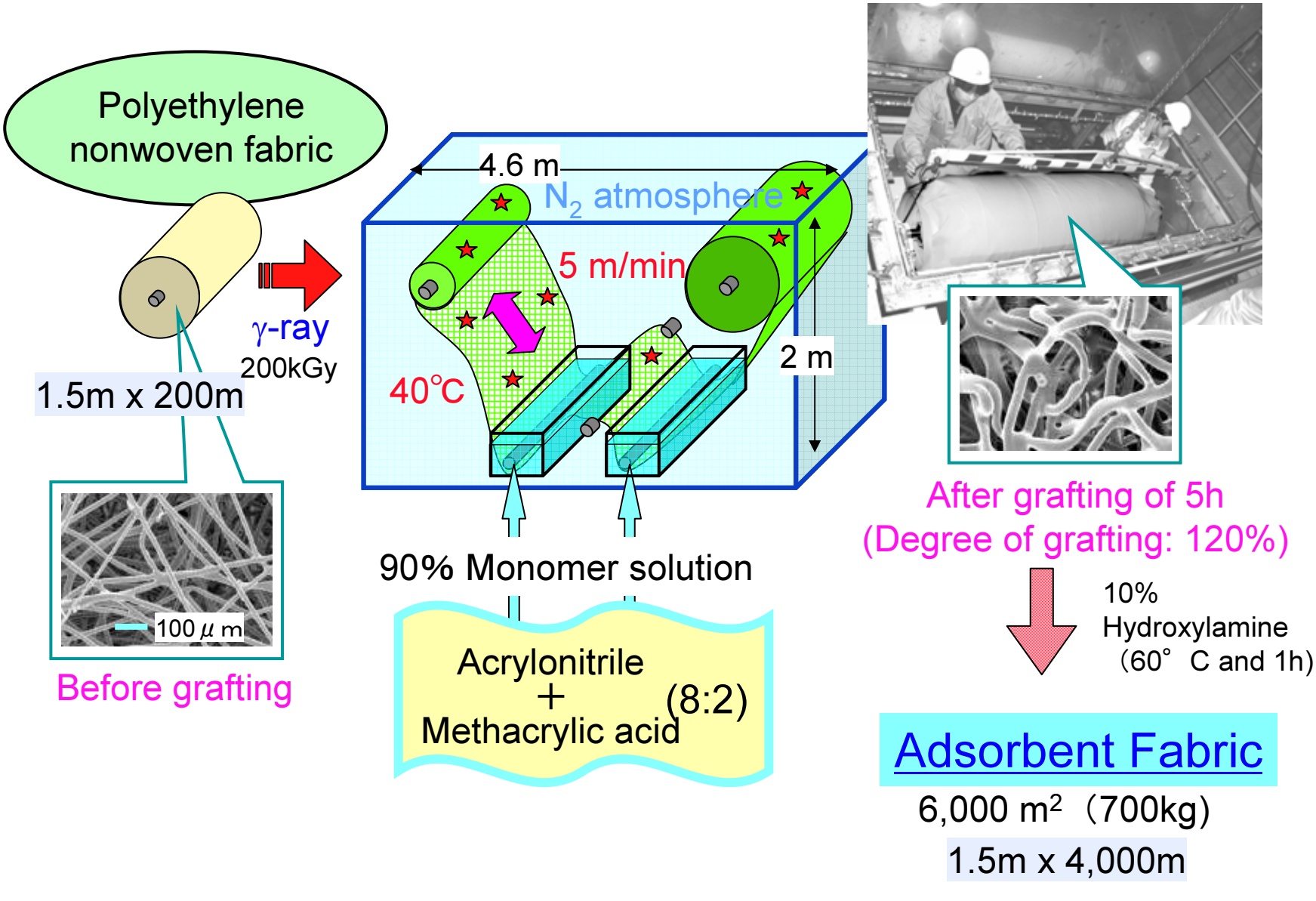
Elements	Concentration in seawater[a] [μg/L]	Concentration in adsorbent[b] [μg/g-ad]	Distribution coefficient (b/1000a)
Na	1.08×10^{7}	618.5	0.057
K	3.80×10^{5}	45.9	0.12
Al	2	86.94	4.35×10^{3}
Pb	0.03	108.82	3.62×10^{6}
Ti	1	1.49	1.49×10^{3}
Fe	2	414.44	2.07×10^{5}
Co	0.05	23.57	4.71×10^{5}
Ni	1.7	78.17	4.60×10^{4}
U	3.2	63.72	1.99×10^{4}

Adsorption conditions:0.2g adsorbent 25℃、3L/min seawater, and 7 days.

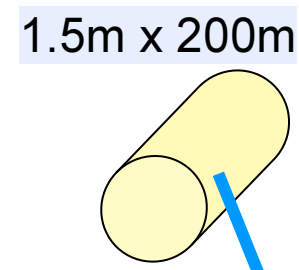
Process of Uranium collection with Adsorbent



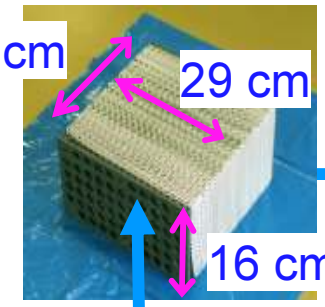
Mass Production of Adsorbent Fabric



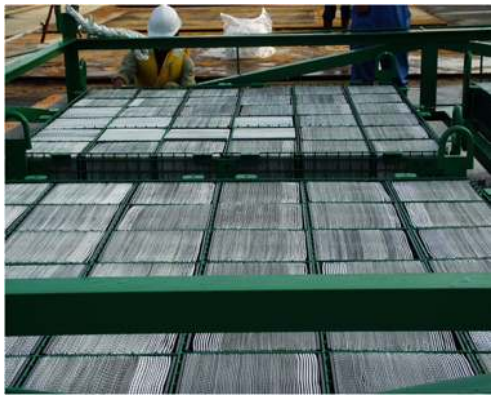
Adsorbent fabric stacks and cages



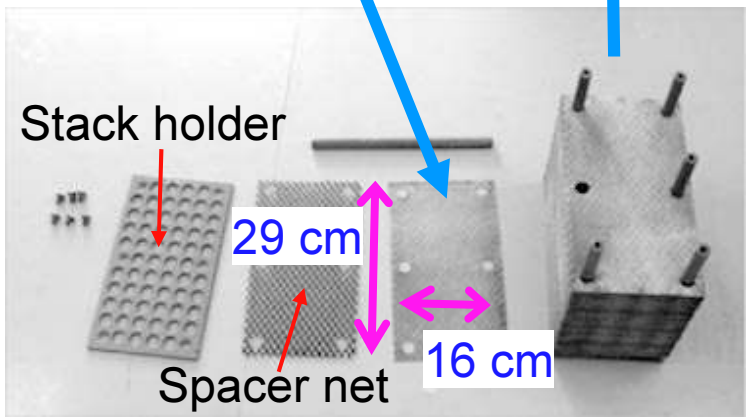
Adsorbent fabric



Adsorbent stack (800g adsorbent)



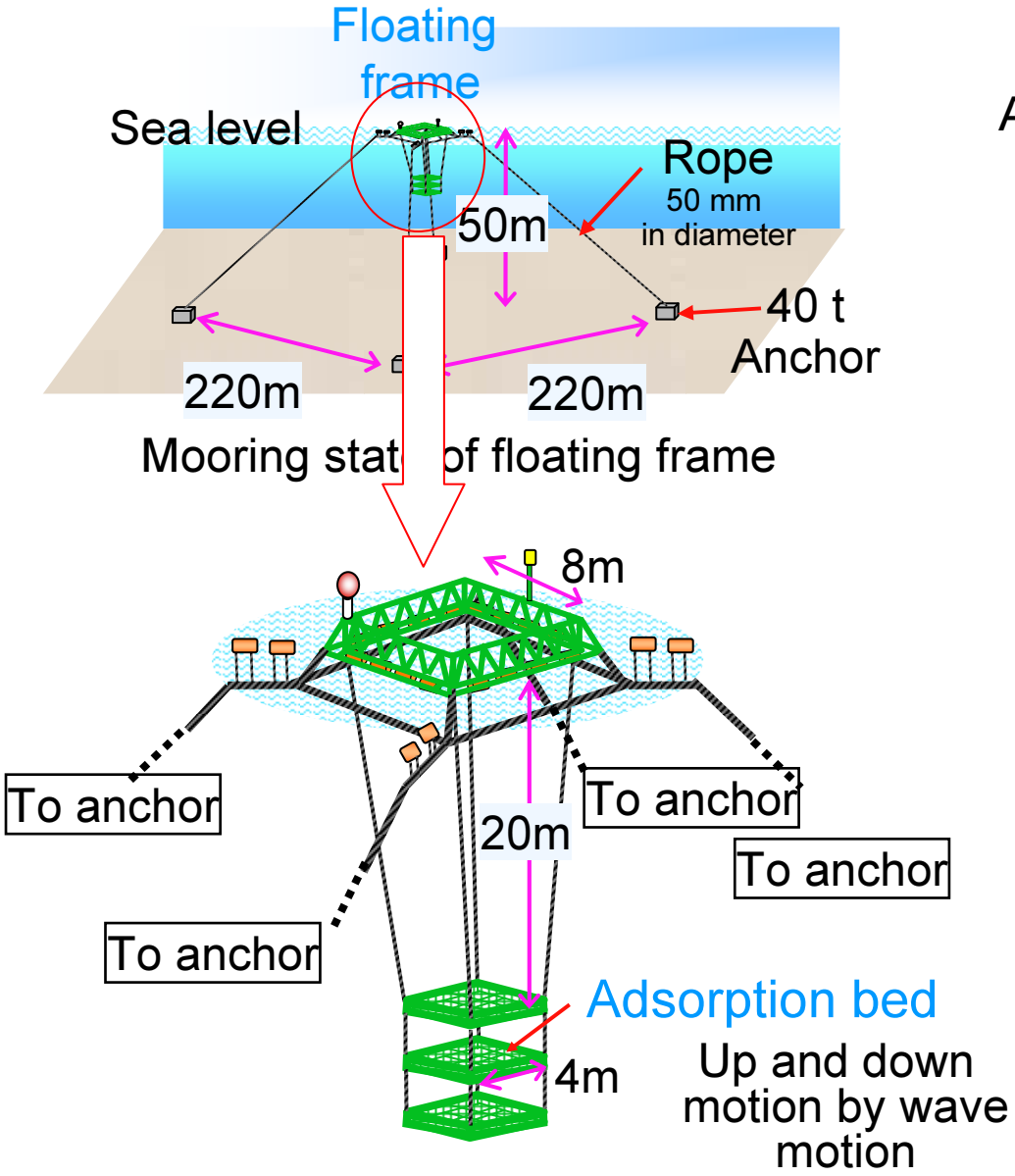
Cage (Adsorbent bed)

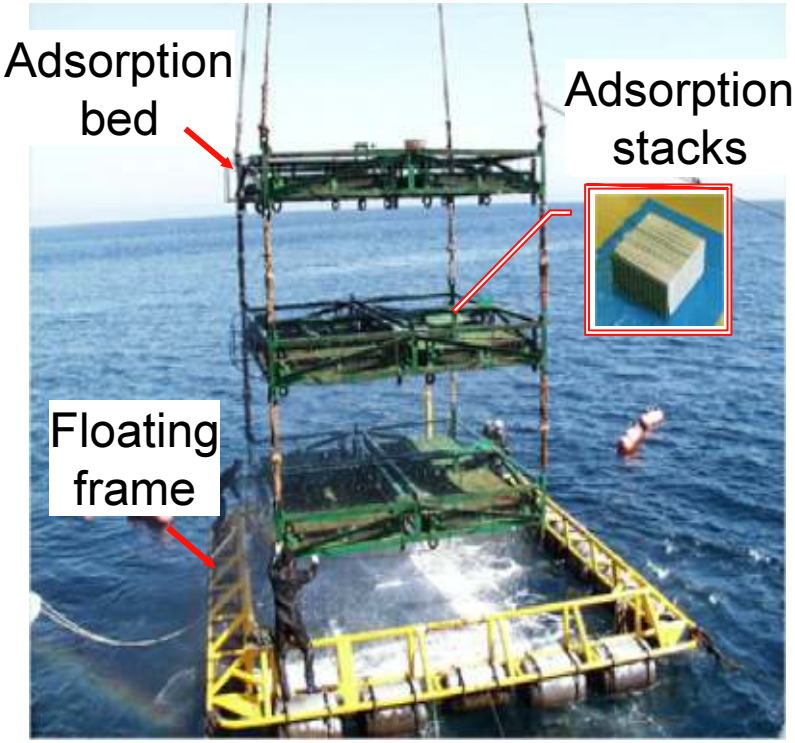


Alternate stack of adsorbent fabric and spacer net (120 stacks)

144 stacks (115 kg) in an adsorbent bed → 432 stacks in three adsorbent beds

Marine equipment for uranium recovery





Drawing up of adsorption bed packed with adsorbent stacks at northern sea in Japan

(350 kg in three adsorbent beds)

Lifting of adsorbent stacks in Marine Experiment

Demonstration of uranium collection

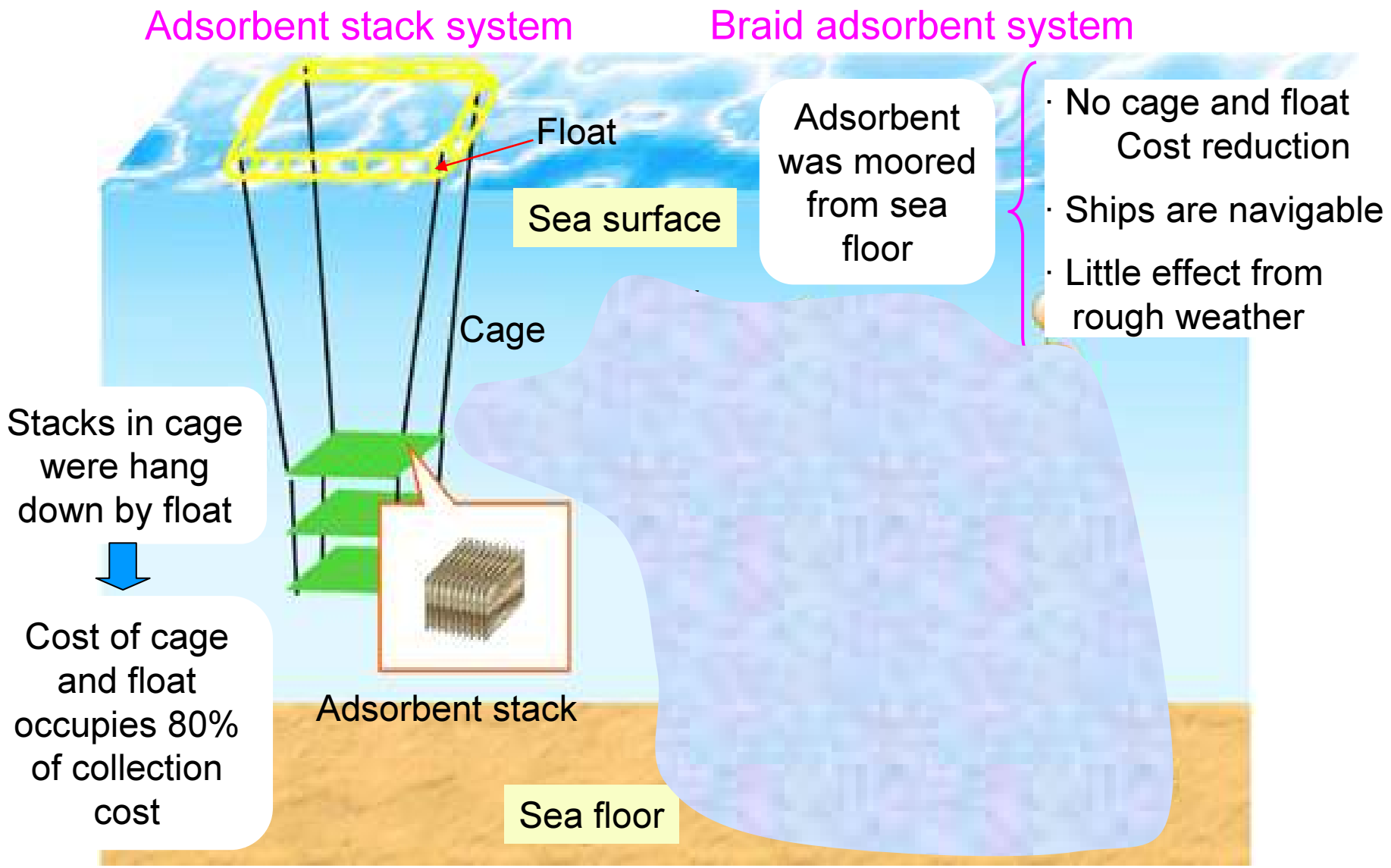
Adsorption stacks → Fractional Elution of Uranium by dilute acid → Purification Solvent extraction → Uranium (Yellow cake)

Submersion period	Submersion days	Seawater temperature [° C]	Number of stacks	Adsorbed uranium [g]
1999 29 Sep.-20 Oct.	21	19 - 21	144	66
2000 8 Jun.-28 Jun.	20	12 - 13	144	47
28 Jun.-8 Aug.	40	13 - 22	144	66
8 Aug.-7 Sep.	29	20 - 24	144	101
7 Sep.-28 Sep	21	24 - 22	144	76
28 Sep.-19 Oct.	21	20 - 18	144	77
2001 15 Jun.-17 Jul.	32	13 - 18	216	95
18 Jul.-20 Aug.	32	18 - 20	216	119
15 Jun.-20 Aug.	65	13 - 20	72	48
20 Aug.-21 Sep.	31	20 - 19	216	118
18 Jul.-21 Sep	63	18 - 19	144	150
15 Jun.- 21 Sep.	96	13 - 19	72	120
				1083

Purified yellow cake made of uranium from seawater

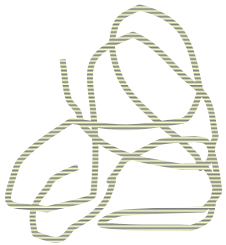
The factors which affect the uranium adsorption were the temperature of seawater and the average height of significant wave.

New collection system for cost reduction



Production of braid type adsorbent

Trunk polymer fiber

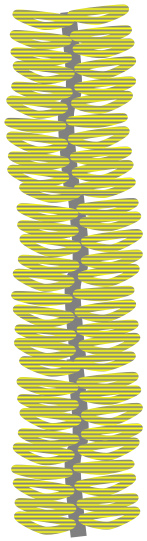


Imparting amidoxime group by grafting

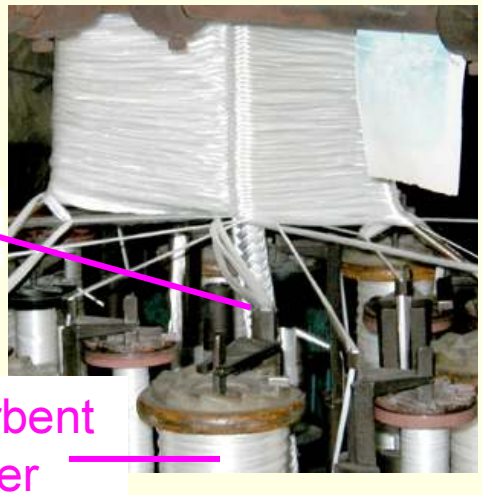
Amidoxime adsorbent fiber

Processing to braid

Braid adsorbent



Fit to mooring system



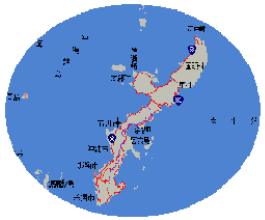
Float

Adsorbent fiber

Braid adsorbent

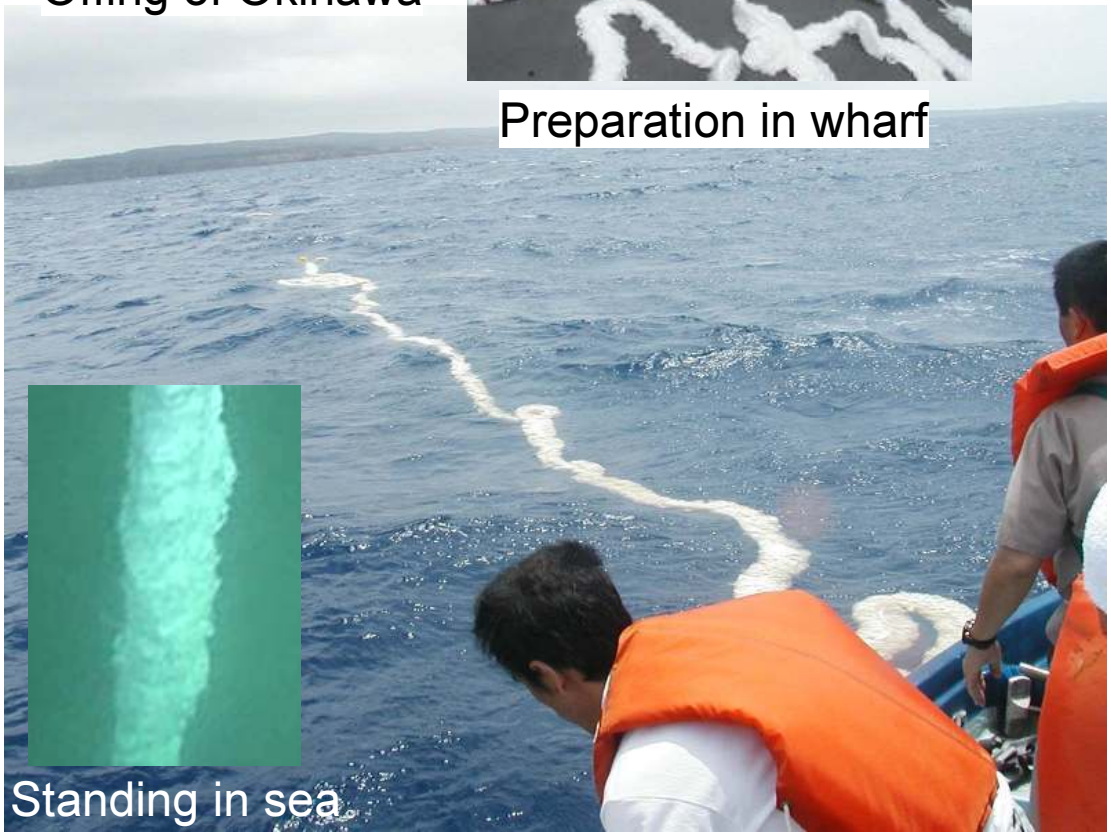
Arbitral length of braid adsorbent can be produced.

Marine Experiment for Braid Adsorbent

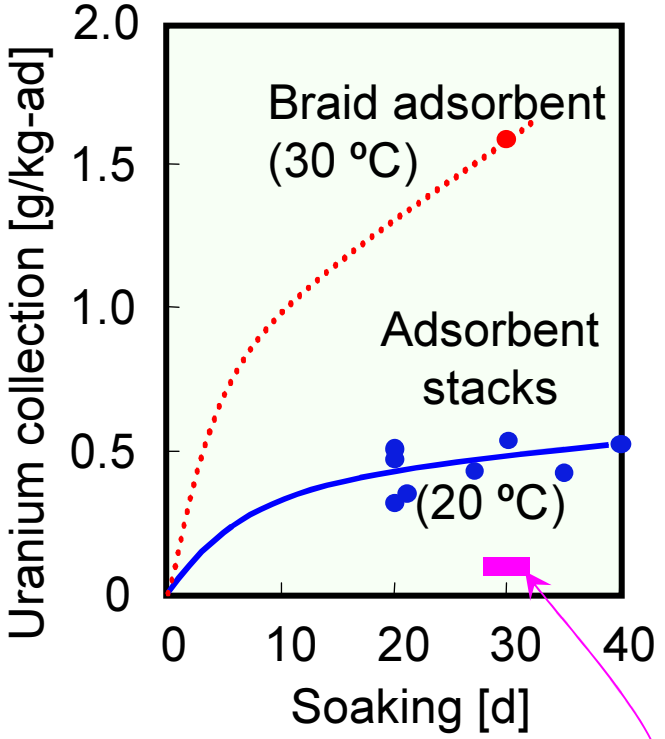


Offing of Okinawa

Preparation in wharf



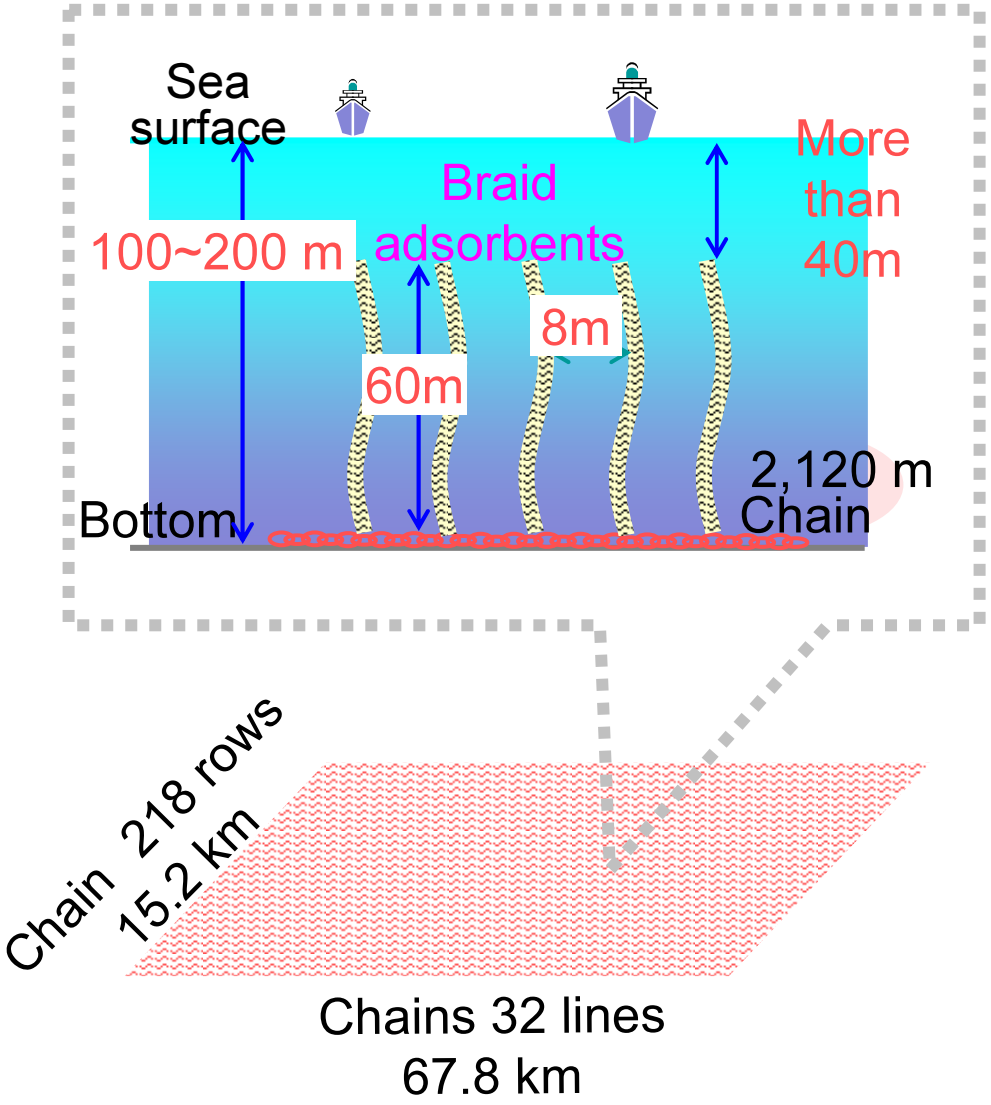
Recovery operation of adsorbent

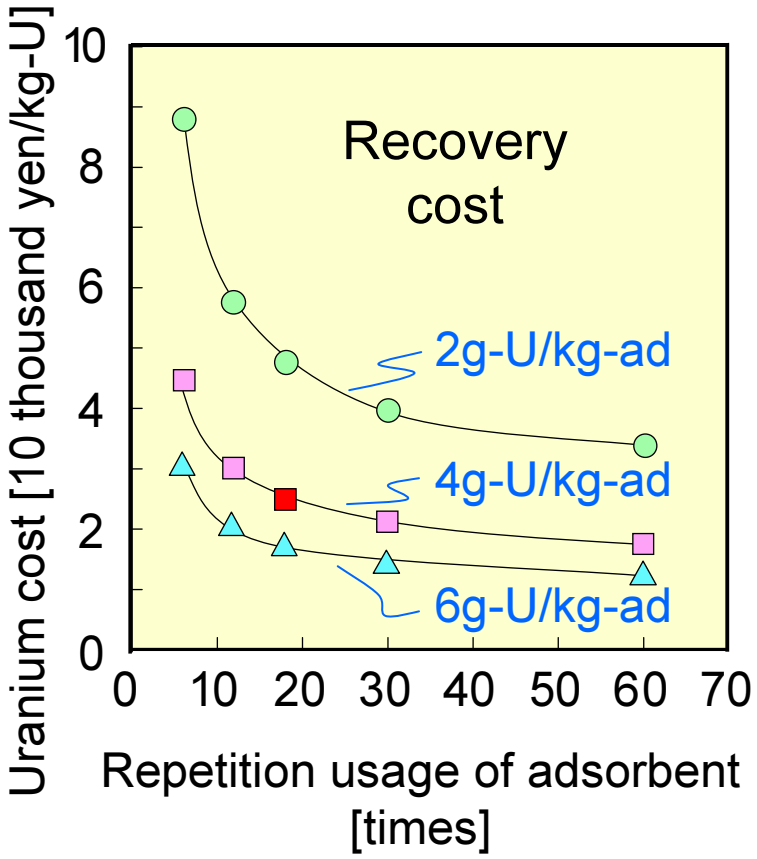


- 10 ºC enhanced 1.5 times
- Efficient constant with seawater: 2 times

Hydrous titanium oxide adsorbent

Cost estimating for 1200 t uranium in a year





- Weekly spot price \$48/lb-U_3O_8 at October, 2009 is 12,000 yen/kg-U.
- Promising collection cost is 25,000 yen/kg-U. This price is twice of spot price.

Recent publications of uranium collection from seawater（Search by Uranium & Seawater）

India, Bhabha Atomic Research Centre(BARC), S. Das *et al*. "Chemical aspects of uranium recovery from seawater by amidoximated electron-beam-grafted polypropylene membranes" Desalination 232（2008）243-253.

S. Das *et al*. "Adsorptive preconstruction of uranium in Hydrogel from seawater and aqueous solutions Ind. Eng. Chem. Res. 48 (2009) 6789-6796.

France(CEN Cadarache) & India 2008 H. Sodaye *et al*. "Extraction of uranium from the concentrated brine rejected by integrated nuclear desalination plants "Desalination 235 (2009) 9-32.

Japan, Niigata University, N. Sakamoto *et al*. "Biosorption of uranium and rare earth elements using biomass of algae", Bioinorganic Chemistry and application (2008) 706240

Japan, Kibi International University, K. Oshita *et al*. "Adsorption behavior of uranium(VI) and other ionic species on cross-linked chitosan resins modified with chelating moieties, Talanta 79 (2009) 1031-1035

Conclusions

Adsorbent synthesis

Radiation-induced graft polymerization cloud realize uranium adsorbent which has enough high mechanical strength for mooring and 15 times higher adsorption performance.

Demonstration of uranium collection

One kg of uranium as yellow cake was collected by marine experiment using graft adsorbent.

Cost estimation

Expecting collection cost is 25,000 yen/kg-U which is twice of weekly spot price \$48/lb-U_3O_8 at October, 2009 spot price.

Future planning

- To confirm the number of repetition usage of adsorbent in adsorption and elution of uranium.
- To consider the simultaneous collection of other minerals.

Thank you for your attention.

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