

# **Growing Industrial Applications of Electron Accelerator in Japan**

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**Topical Meeting AccApp09, IAEA  
Satellite Mtg. Application of Electron  
Accelerator  
May 4-8, 2009**

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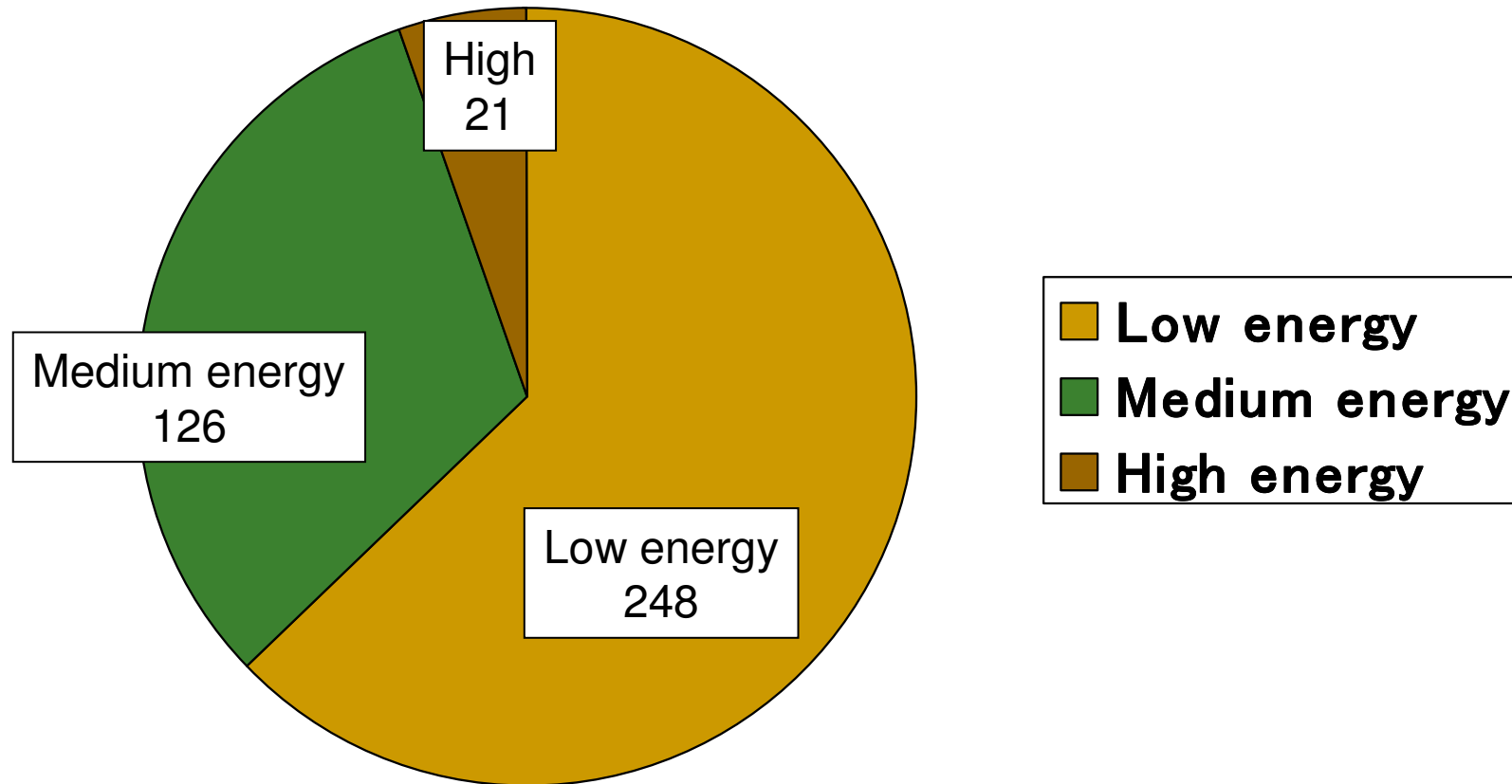
# Radiation Application Growing in Japan

- **Economic scale** of radiation application: **\$39billion** in 2005 for industry, medicine, and agriculture being **comparable to that of nuclear power**
- **National institute** devoted to radiation processing application was established in **1963**
- **The first commercial application** of electron accelerator is cross-linking of wires in **1971**

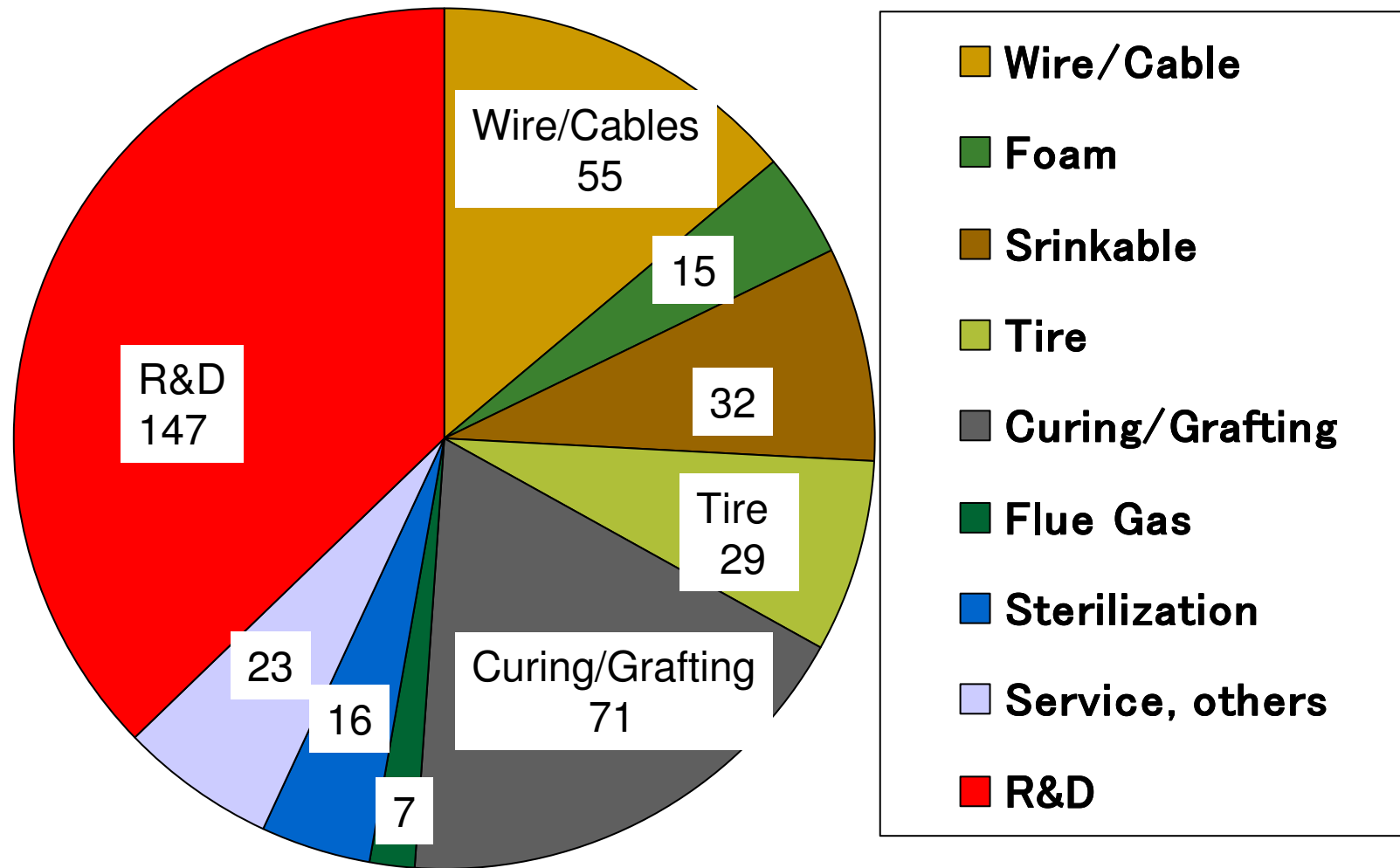
# Number of EB Accelerators by Energy in Japan

## Total: 395 Units 2007

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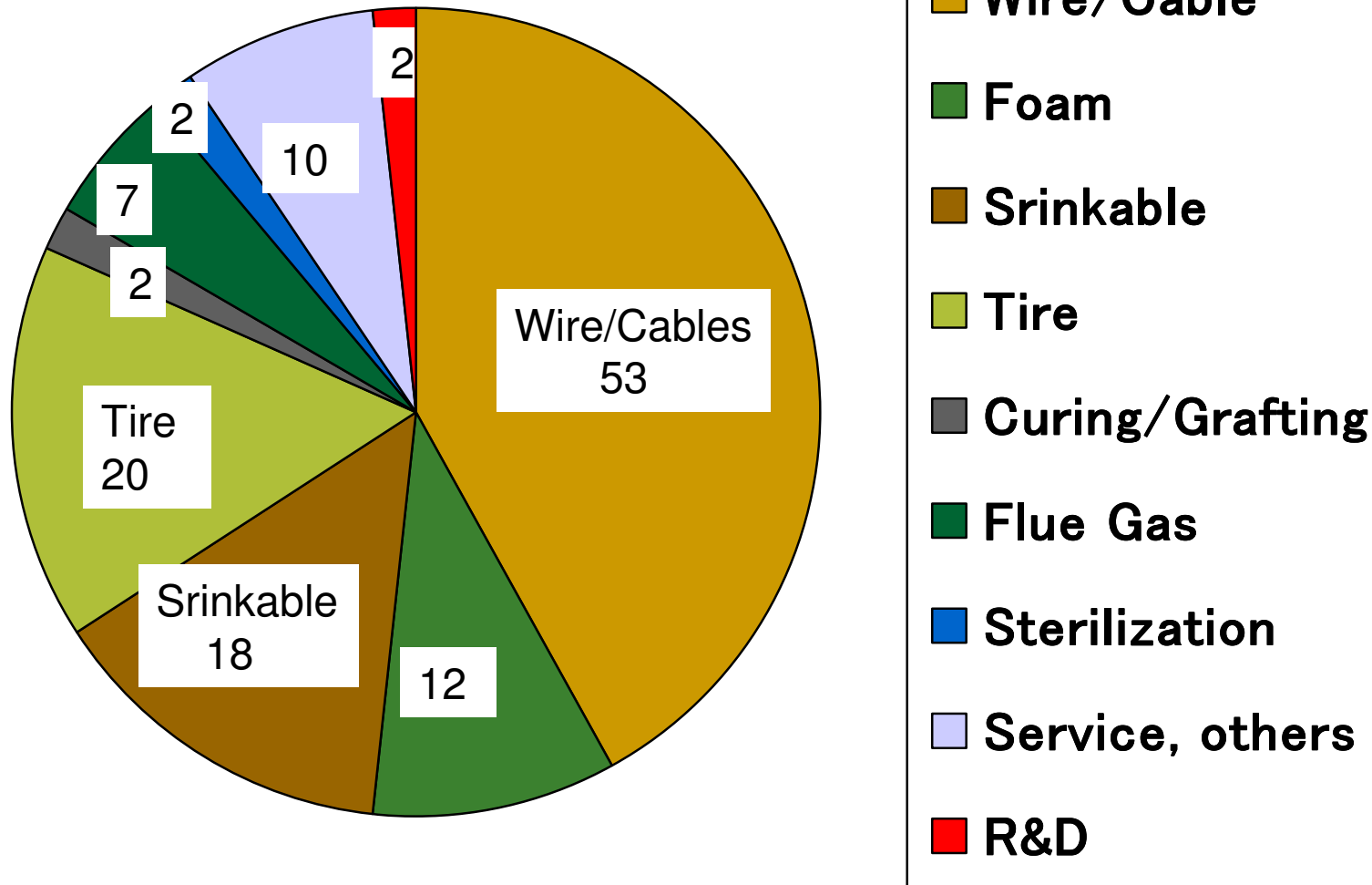


# Major Applications of EB Accelerators in Japan 2007



# Applications of Medium Energy Electron Accelerators in Japan 2007

Total 126 units



# Major Applications and Products of Electron Accelerator Processing in Japan

(1)

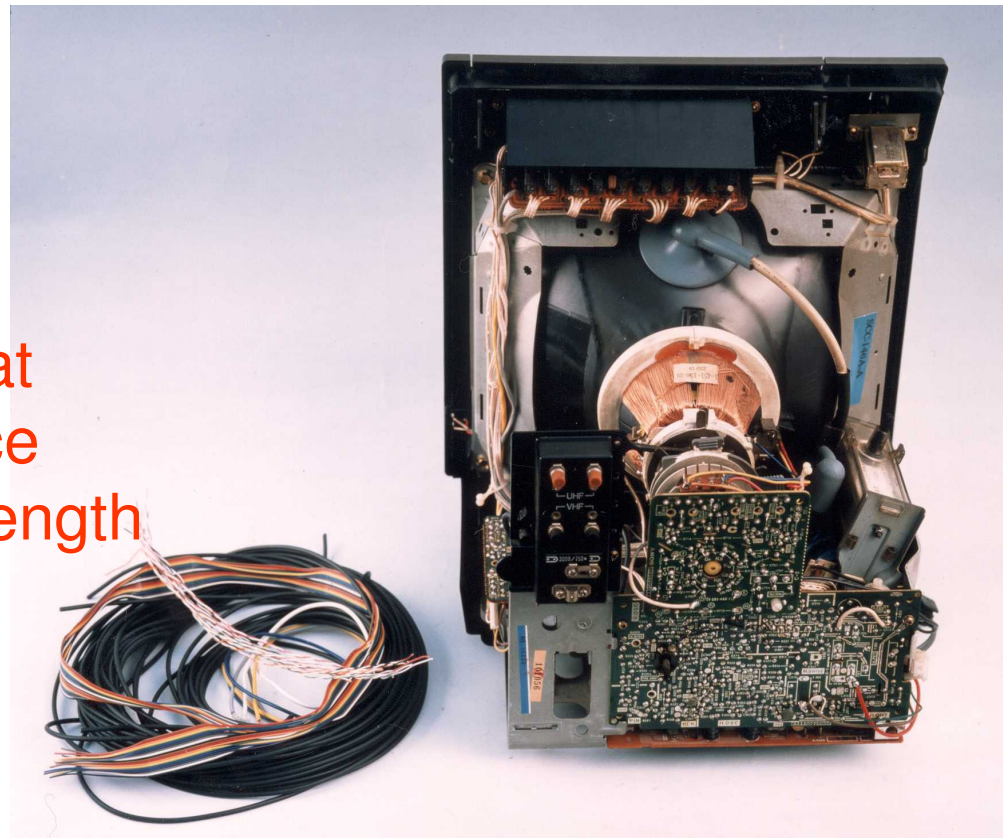
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- Cross-linking:
  - Heat resistant wire and cable
  - Heat shrinkable tubes and sheets
  - Automobile tires
  - Foamed polyethylene
  - Wound dressing hydrogel
  - Chemical resistant automobile parts
  - Cross-linking of PTFE (high abrasion resistance)
  - Super heat resistant SiC fiber

# Heat Resistant Wire and Cables by Radiation Cross-linking

Wires used at higher temperature for home appliances, automobiles and, equipments

Cross-linking brings about heat resistance, chemical resistance and increased mechanical strength



# Electron Accelerator for High Quality Tire Production

Radiation cross-linking of rubber sheets before molding to tire with final vulcanization

- 90 % of tires in Japan are produced using radiation processing
- Material and cost saving





# Super Heat Resistant Ceramic Materials

## SiC fiber Processing

Si-Polymer Fiber

↓ EB Curing

Non-melt Fiber

↓ Pyrolysis (1500°C)

SiC ceramic fiber

[Specifics]

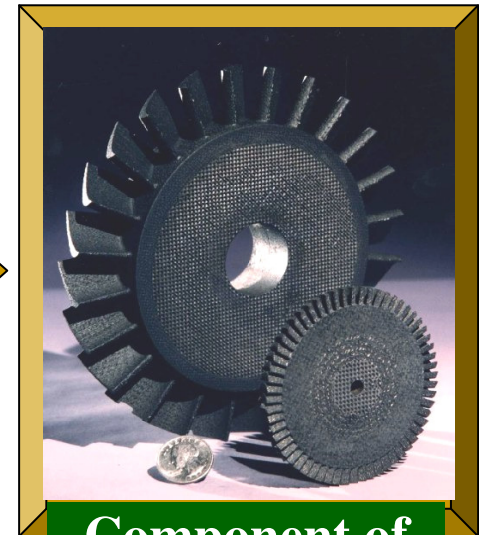
- Strength 30 t/cm<sup>2</sup>
- Heat Resist 1700 °C
- Lightweight 2.7 g/cm<sup>3</sup>

Commercialized by Nippon Carbon Co.Ltd



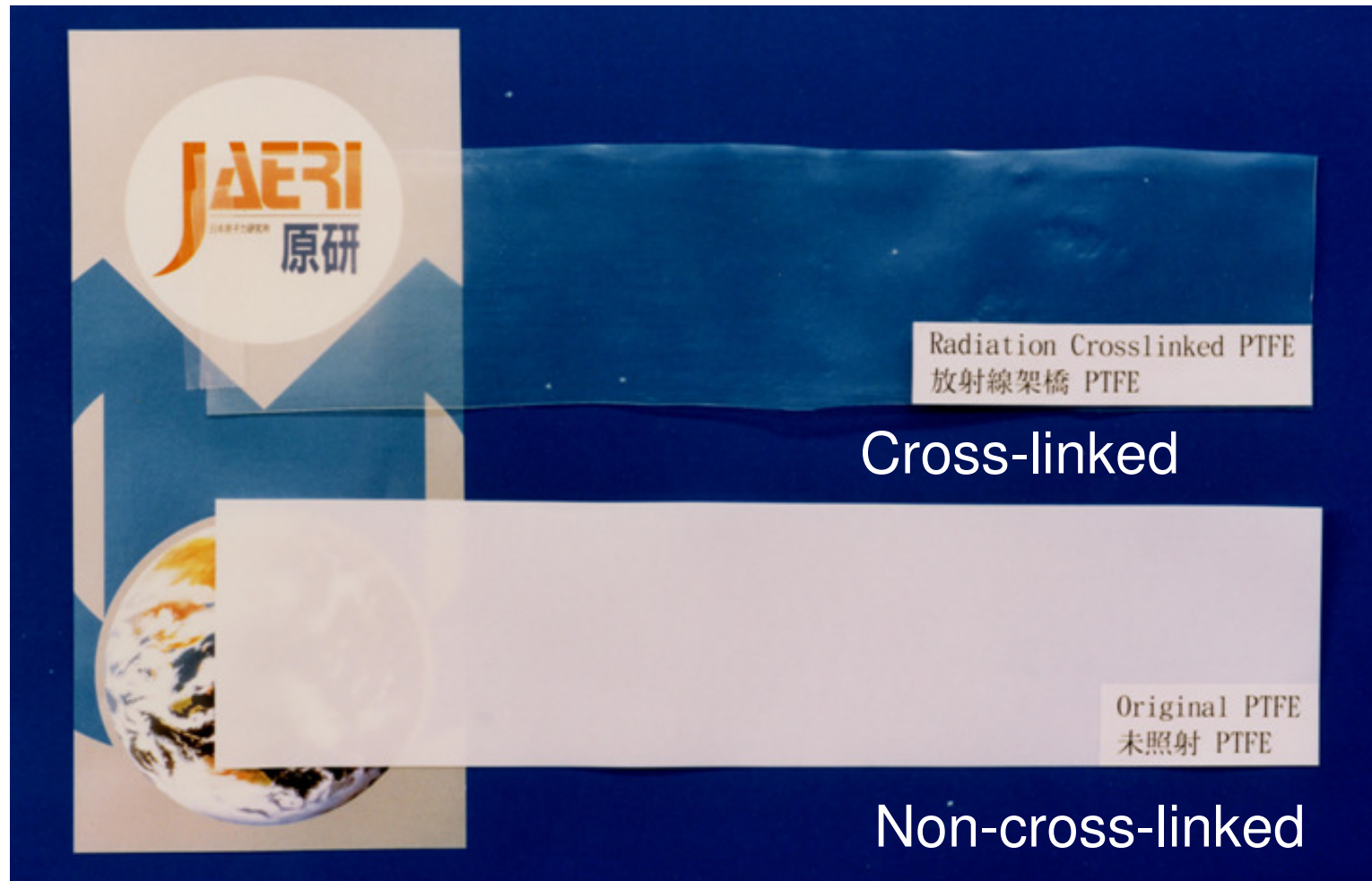
SiC fiber  
Hi-Nicalon®

Ceramic Composites



Component of  
Jet Turbine

# Radiation Cross-linked PTFE (Teflon)



# EB Cross-linking of Teflon and Improved Properties

Teflon (PTFE): –  $\text{CF}_2 - \text{CF}_2 -$  Mn  $> 10^7$

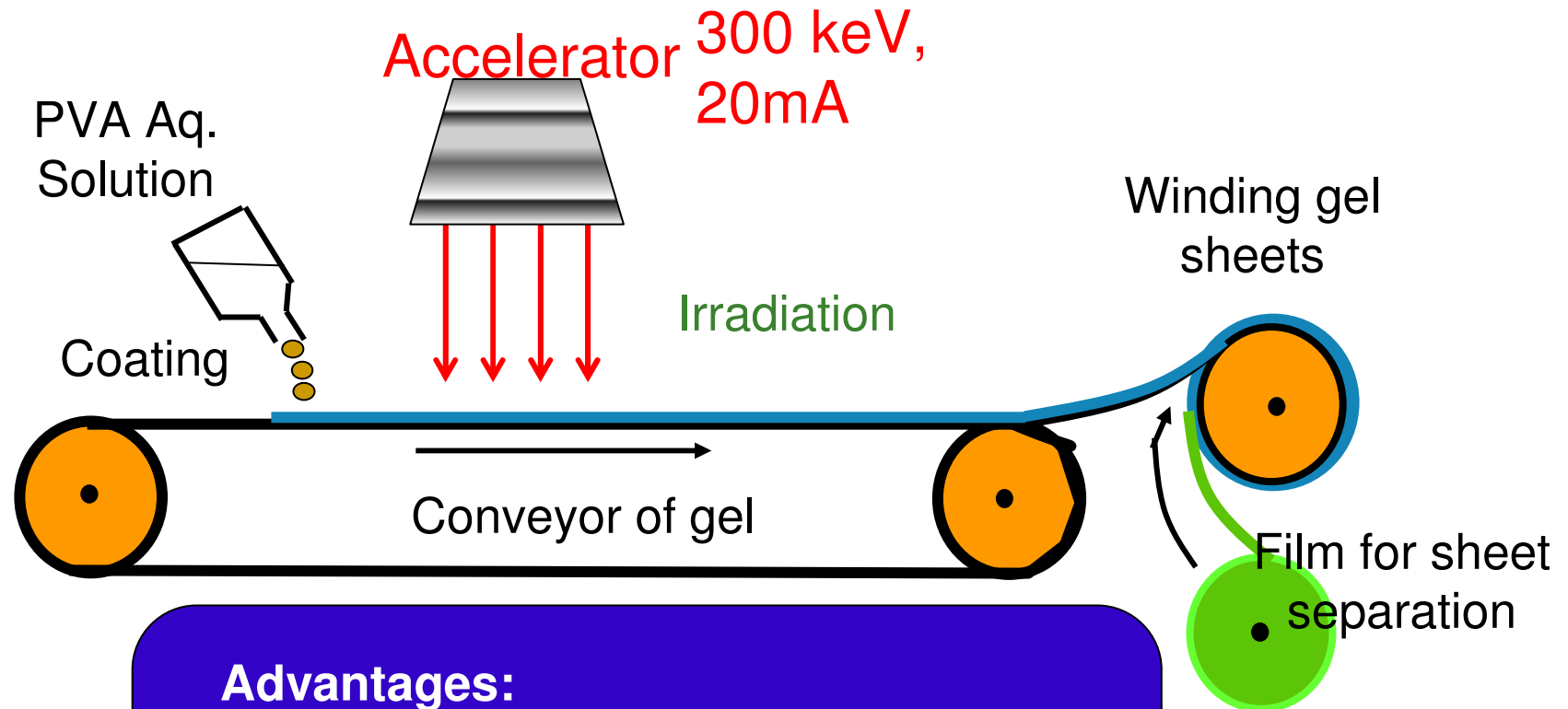
**Irradiation:** High temp. (330-340°C)  
in inert gas atmosphere

**Properties:**

- Tensile strength: 2 times up
- Radiation resist: 2-3 order up
- Wear resist: 3 order up**
- Transparency (amorphous)

**Application:** Production by Hitachi Cable Co.  
Roller, Sliding parts.

# Hydrogel Wound Dressing Production Line by Electron Accelerator



## Advantages:

- Continuous production
- High purity product
- High mechanical strength product

# Treatment of Wound by Hydrogel Dressing Produce by Electron Beams



2 days after accident : **Treatment started with hydrogel**



**Applying hydrogel to wound and fixing it by adhesive film**

**Observe everyday. If exudate leaked, the hydrogel was changed**

# Eleven Days after Treatment



11th day of hydrogel treatment : Healing completed



**Effective moist healing by hydrogel**

# Major Applications and Products of Electron Accelerator Processing in Japan

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(2)

- **Graft polymerization**

- Battery separator (AAc onto PE film)
- Absorbent for cleaning air and deodorant (PE fiber)

- **Curing and printing (polymerization/cross-linking)**

Energy saving and no solvent emission

- High quality surface coating
- High quality printing
- Over-coating (high scratch resistance)

# EB Grafting onto Polymers in Japan

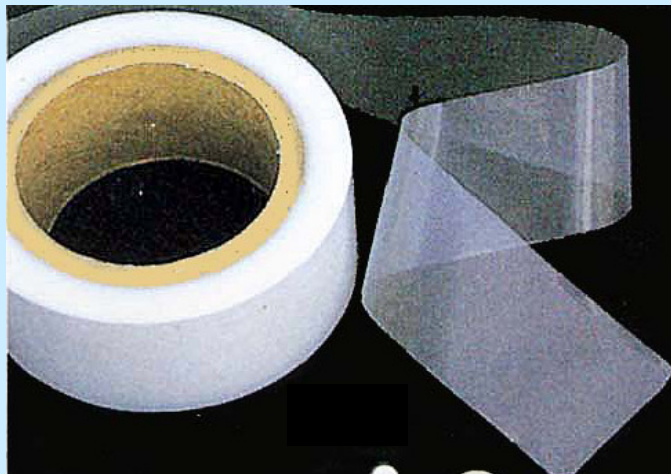
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- **Battery separator**: grafting acrylic acid onto polyethylene film (pre-irradiation method)
- **Functional fibers**:
  - grafting GMA onto **polyethylene** fiber followed by sulfonation & amination; absorption of ammonia, **filter for clean room, deodorant, and antibacterial fabric with iodine**
  - grafting onto **cotton fiber** for antibacterial and deodorant functions used for wears

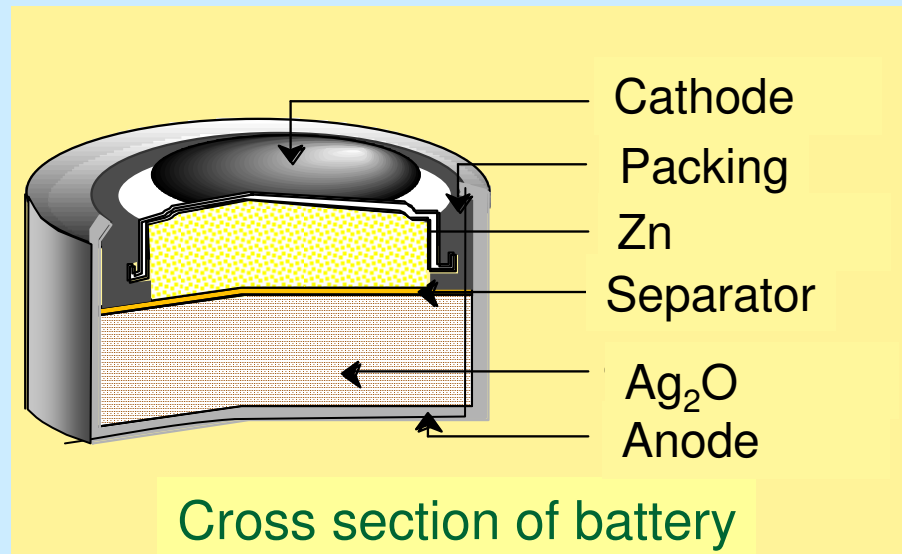


# Separator Membrane for Button-shaped Battery (1985)

Annual production: 1 billion pieces



Separator membrane



Cross section of battery

Electro conductive membrane synthesized  
by grafting on polyethylene, 25  $\mu\text{m}$  thick

# Industrial EB Irradiation and Grafting Plant (Continuous Process) Japan

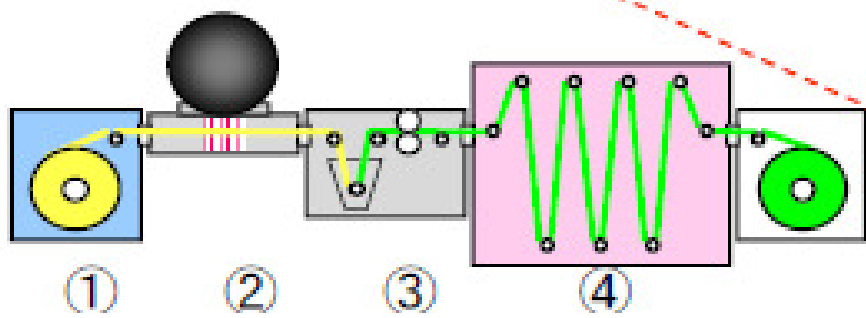


④ Reaction zone

③ Monomer impregnating zone

② EB power : max.12kW  
 Accelerating voltage : max.300keV  
 Current : max.40mA

① Base material fitting zone



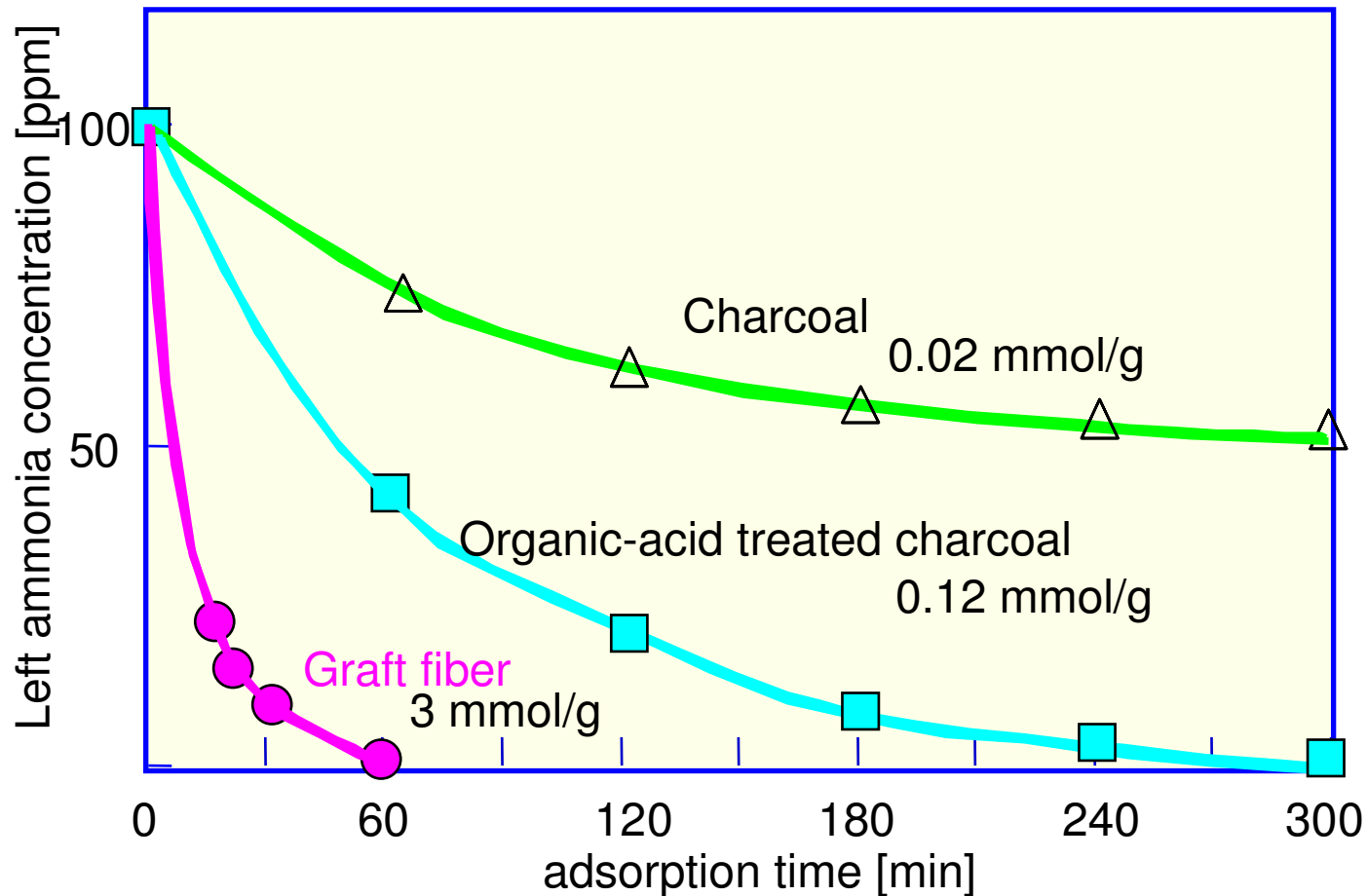
EB: 300keV,12kW

Non-woven cloth: grafting speed; 1.5m width, 0.8 ~ 20m/min

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 Mach. IAEA CM on EB for Industry

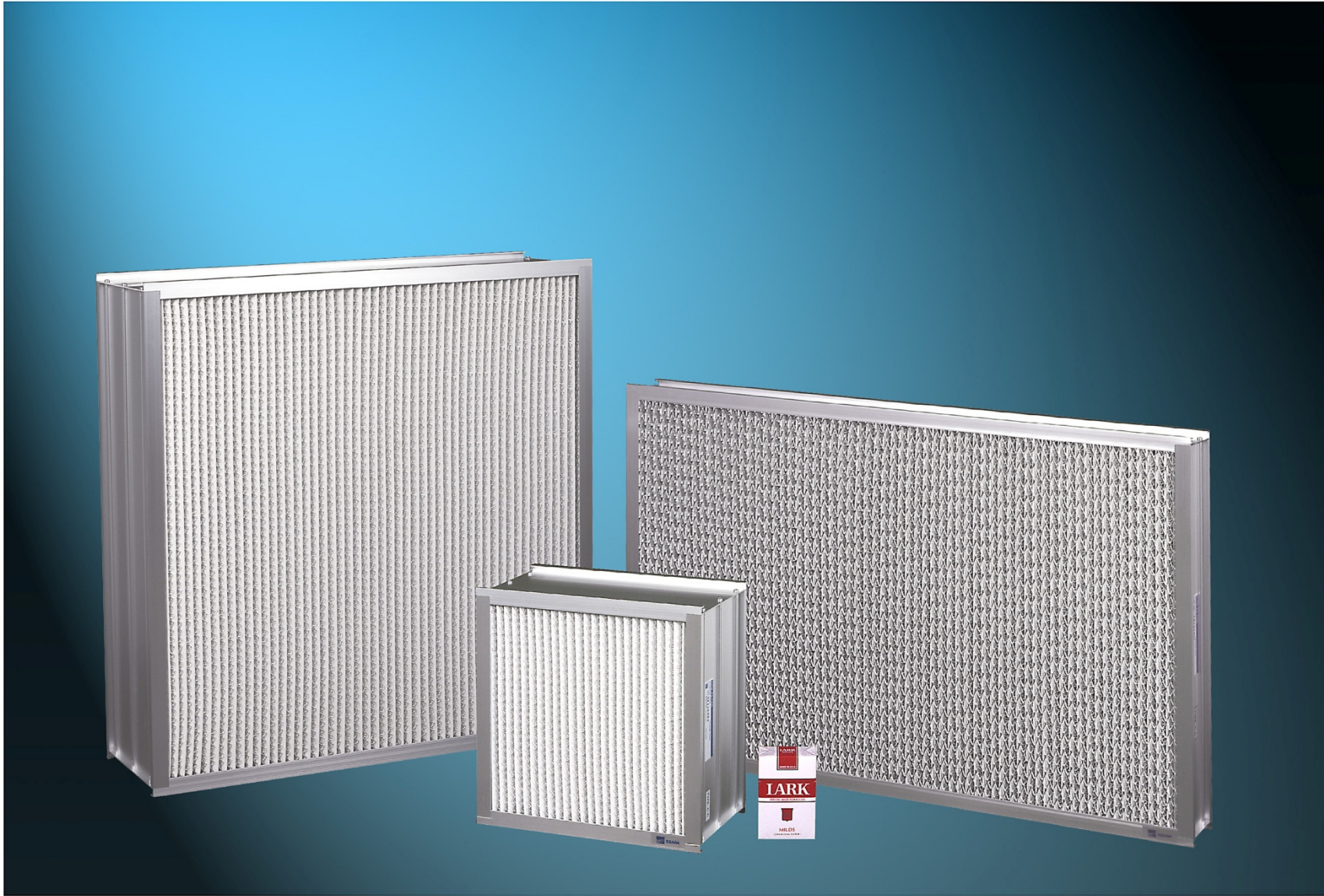
# Performance of Gas Adsorption

## Adsorption rate in removal of NH<sub>3</sub> gas



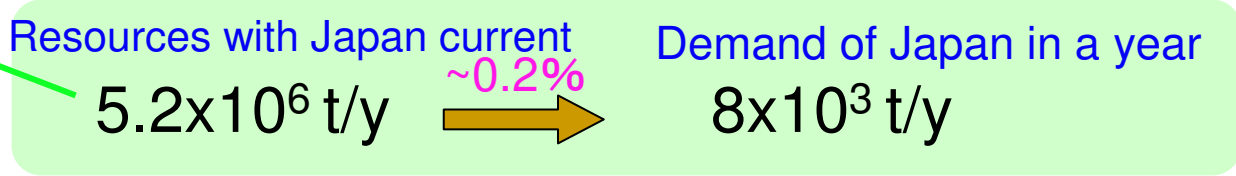
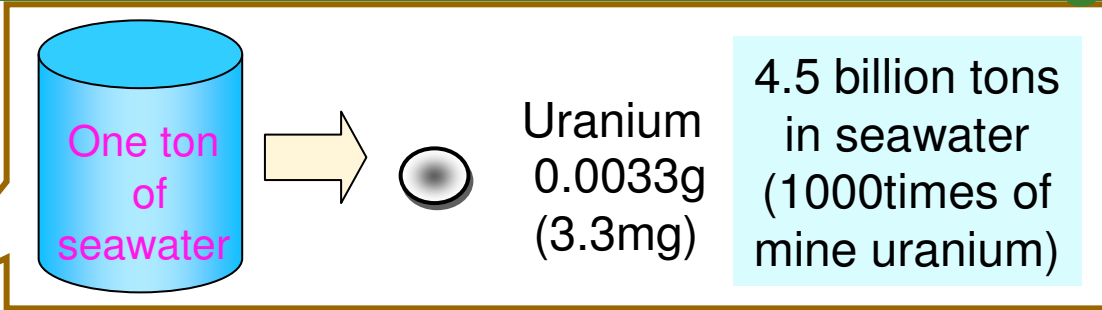
Graft fiber : Chemical filter for clean room in LSI fabrication facility

# NH<sub>3</sub> Removal Filter for LSI Facility

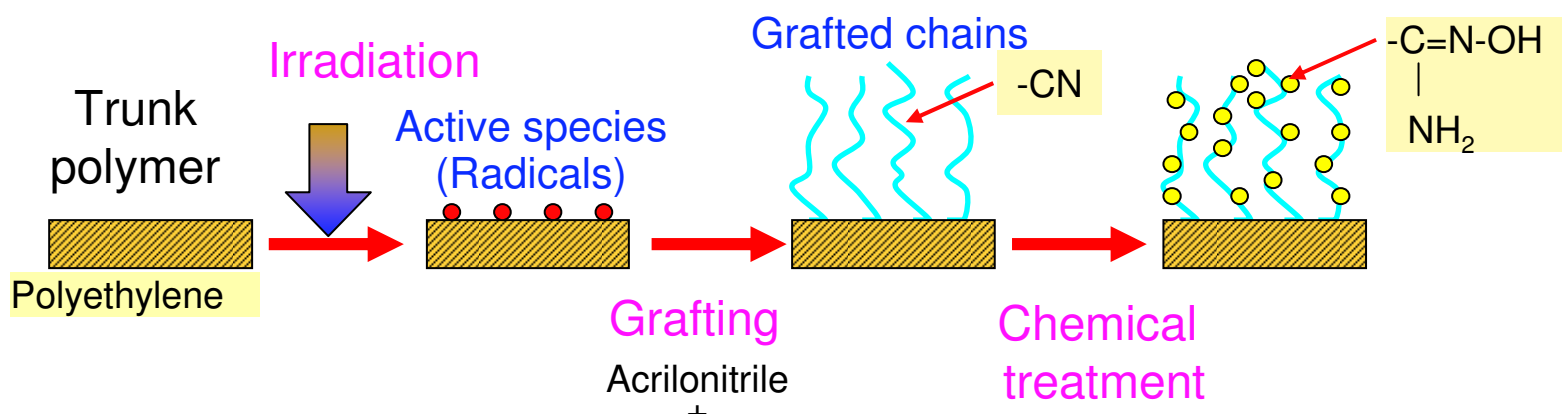


**E B A R A   E P I X   F I L T E R**

# Uranium Recovery from Seawater by Adsorbent Produced with Radiation Grafting

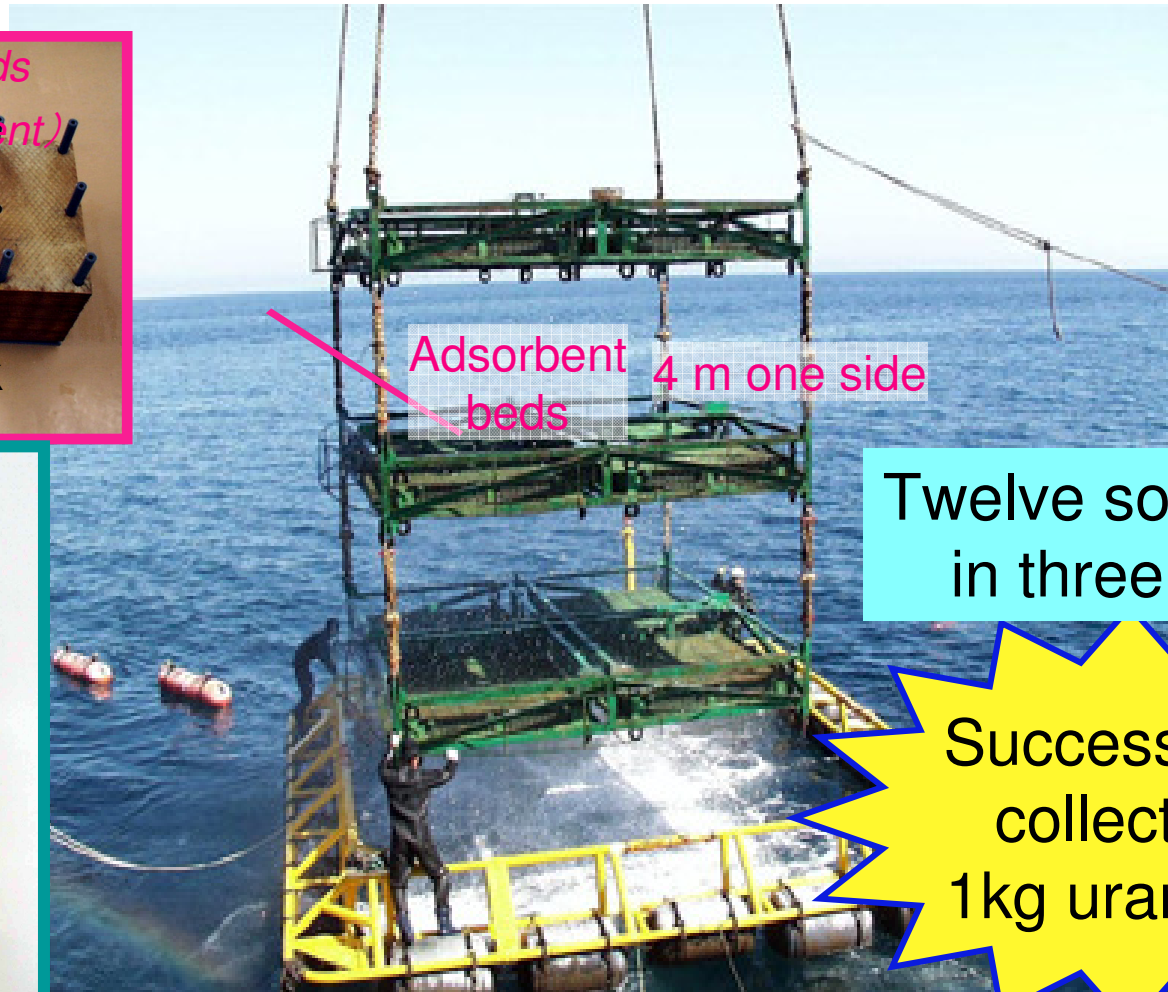


## Synthesis of amidoxime adsorbent with radiation-induced grafting



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# Marine Experiment of Uranium Recovery with Graft Adsorbent



Twelve soakings in three year

Successfully collected 1kg uranium

Pulling out of adsorbent beds  
Packed with fibrous adsorbent

OECD/IAEA Technical Meeting on Uranium Recovery, May 08  
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# EB Over Coating Decorative Paper for Furniture and Flooring in Japan

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- **EB processing has following advantages over UV or thermal curing :**
  - **Higher hardness and scratch resistance**
  - **Higher chemical resistance**
  - **Less energy consumption**
  - **Non-solvent process**



# EB Over-coating in USA

- Protection of printings
- Surface control (gross/mat). Control of friction coefficient of the surface



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# Major Applications and Products of Electron Accelerator Processing in Japan

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(3)

- **Sterilization:**

- Medical supplies
- PET bottles of drinks and food packages

- **Cleaning flue gases;**

- Removing SO<sub>2</sub> and NO<sub>x</sub> from power plant
- Removing dioxin from municipal waste incineration plant (R&D)
- Removing stinking gas of drying sewage sludge
- Removing VOC (toluene, xylene) (R&D)

# Electron Accelerator for PET Bottle Sterilization in Japan

## Advantages

- In line sterilization for filling process
- No residual chemicals
- Running cost reduction by 10-25 %
- Compact system-less space



**PET bottle sterilization system in Japan Accelerator 300 keV**

**Capacity: 600 bottles of 500 ml**

IAEA Topical Mtg. Elec. Acc. Mar 09  
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**per minute**

# Mobile EB Treatment System for Gases (Nanao, Japan)

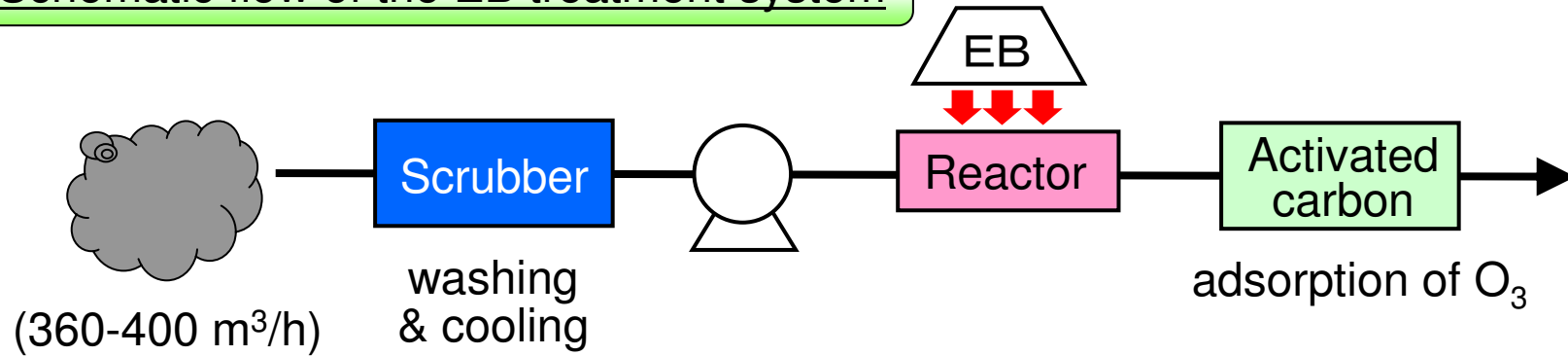
The treatment of **odorous gases** from drying process of sewage sludge (target residents: about 2,000、 maximum treatment amount: 740m<sup>3</sup>/day)



Overview of Mobile EB treatment system for treating the odorous gases generated in the process of drying sewage

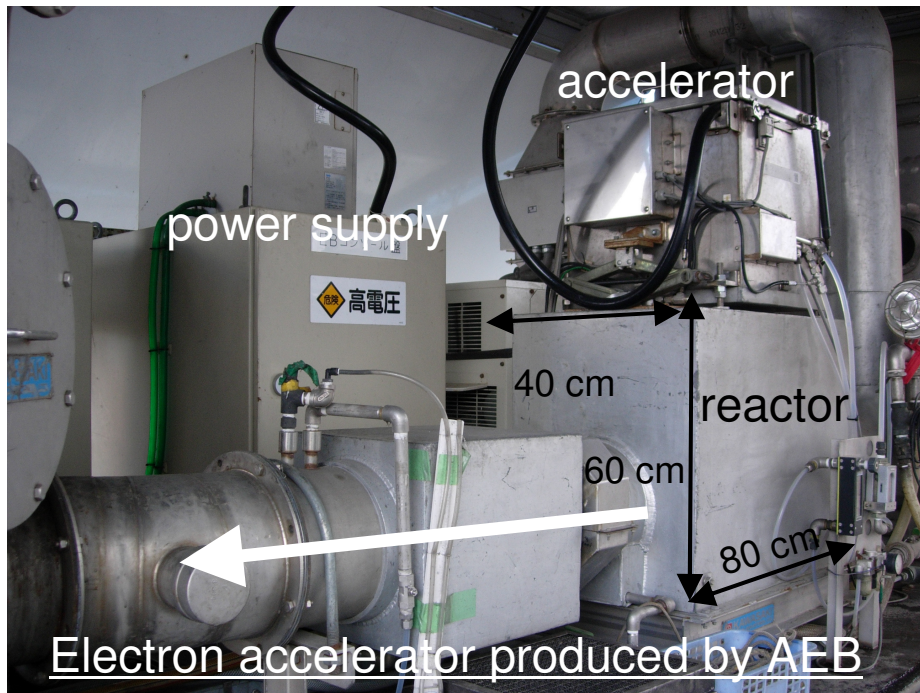
- Specification of vehicles: **4t、 air suspension**
- Vehicle for drying sewage can generate **60 kW electricity** using gas turbine for operating the EB system.
- The system can treat odorous gases at a flow rate of **360-400 m<sup>3</sup>/h**

## Schematic flow of the EB treatment system



## Results of the treatment of odorous compounds

	Before EB (ppm)	After EB (ppm)
H <sub>2</sub> S	0.44	0.01
(CH <sub>3</sub> ) <sub>2</sub> S	0.007	0.002
CH <sub>3</sub> CHO	0.04	0.02
C <sub>2</sub> H <sub>5</sub> COOH	0.036	0.004
C <sub>3</sub> H <sub>7</sub> COOH	0.008	< 0.001
NH <sub>3</sub>	< 0.1	< 0.1
CH <sub>3</sub> SH	< 0.01	< 0.01



operated on 125 kV, 7.5 mA

# Trends in Application of Electron Accelerator in Japan

- Increasing high energy accelerator for sterilization of medical products
- Increasing low energy accelerator for curing of coating and printing
- Increasing low energy accelerator for sterilization of PET bottles and food packages
- Increasing export of accelerator to Asian developing countries (100 Units past 10 years)

# Challenges of Electron Accelerator Application

- Development of accelerator with energy ranging 20-30 keV (currently 80 keV is lowest) available at lower cost for coating
- Development of accelerators with large capacity and good reliability for one year continuous operation for environmental application
- Enhanced dissemination of information on possible applications to potential end-users