Nanomaterial Production and Application From Viewpoints of Health and Safety

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Synthesizing process of nanomaterials

- **Metal Nanoparticle production:**

  Ni particles -> $NiCl_2$ + H_2 = Ni + HCl

  Al particles -> Arc or RF Furnace heating of source materials in inert gas atmosphere (H_2)

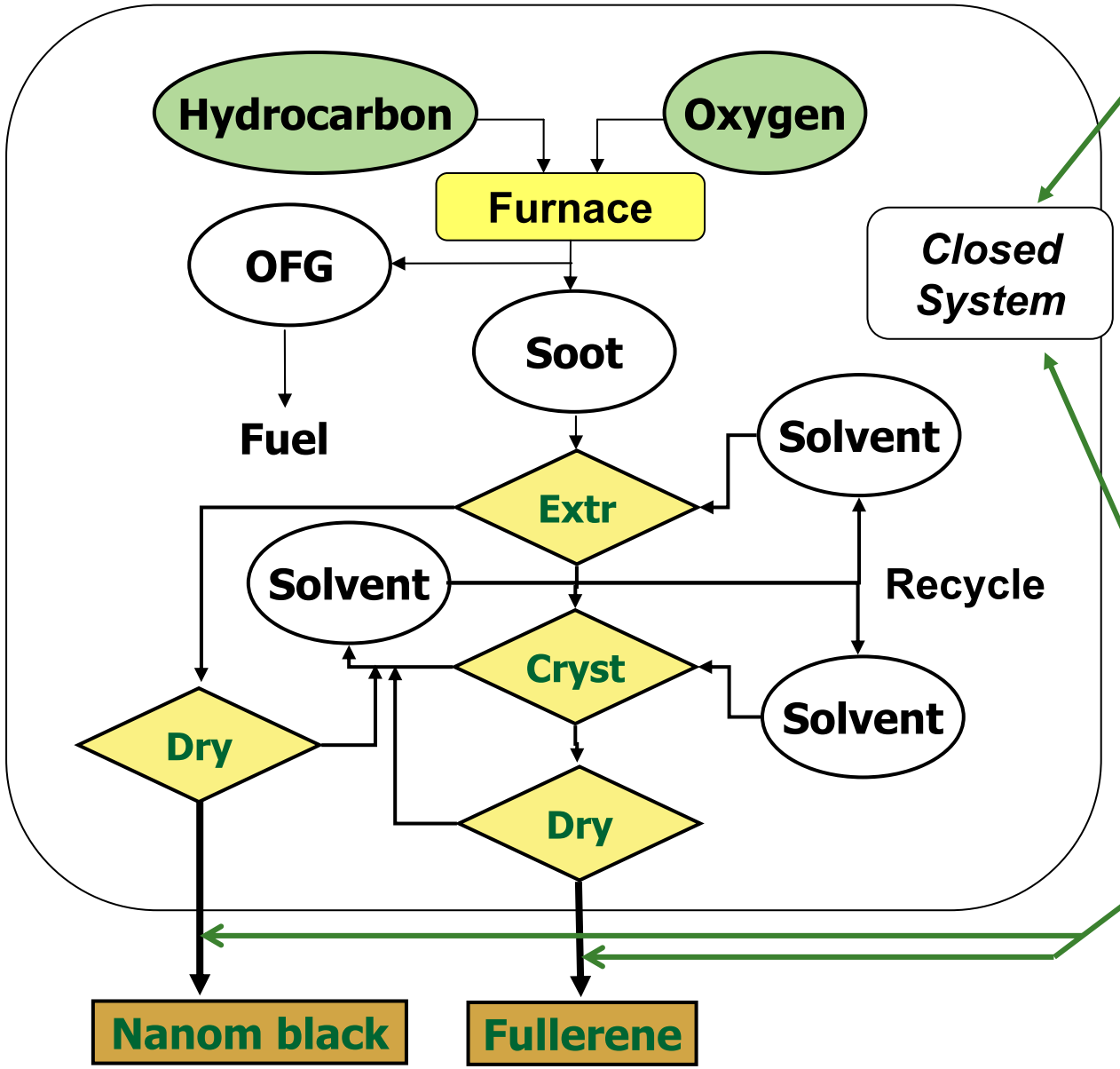
- **Carbon nanomaterials such as fullerenes and nanotubes: in CVD,**

  Hydrocarbon + dilute oxygen and/or inert gas, reduction gas (catalyzer) =

  Carbon nanomaterials + H_2 and/or H_2O

Fullerene Production Flow

Frontier Carbon Corporation



Designed for Zero Emission (no industrial waste)

- no liquid waste from the factory
- normally gas is sent to power plant as clean fuel
- no environment hazard due to NOx, SOx
- vapor from tanks is condensed and recovered
- noise : not relevant
- soil : not relevant

Closed System

Designed for Minimum Exposure (closed system)

Safety Measures for open air works
(such as packaging)

- **personal protective equipments**
- **local exhaust ventilation system**

The important issue in the mamufacturing process of nanomaterials

- **Vacuum tight sealing of production system from outside is absolutely necessary to avoid combustion of hydrogen or oxidation of nanomaterials.**

The leakage of nanomaterials is very low.

Other issue to handle to avoid accidents

- In case of metal nanoparticles, special shipping containers should be prepared to avoid burning due to static electrical spark or frictional heat in the containers.

Good design of containers with vacuum tight sealing, eliminating static electricity and inert gas packaging in order to avoid oxidation

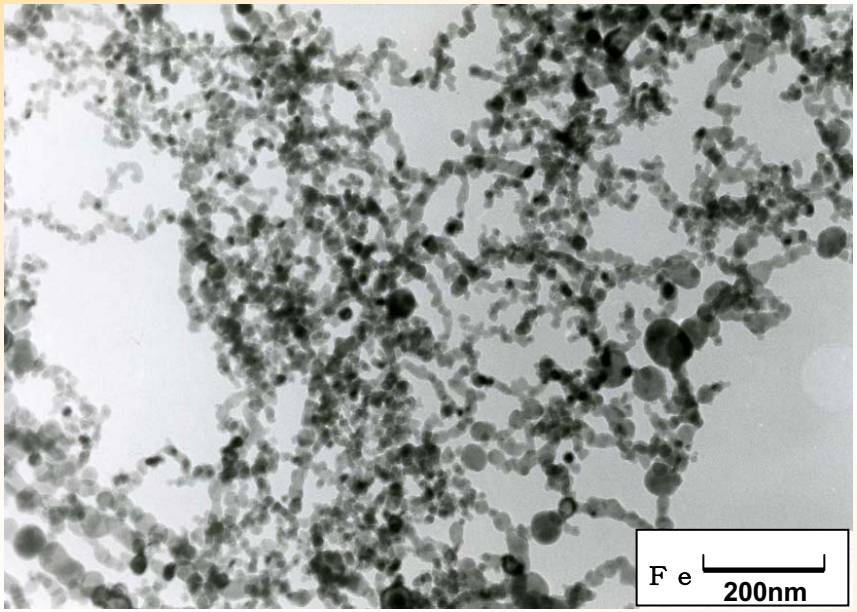
Nanoparticle-related accidents

- Burning of products during opening production chamber when taking them out
- Vacuum cleaner burning during cleaning nanoparticles on the floor
- Fire caused by back diffusion of air into gas line because of silicon nanoparticle deposits in the exhaust gas line of semiconductor device production system

Shapes of nanomaterials

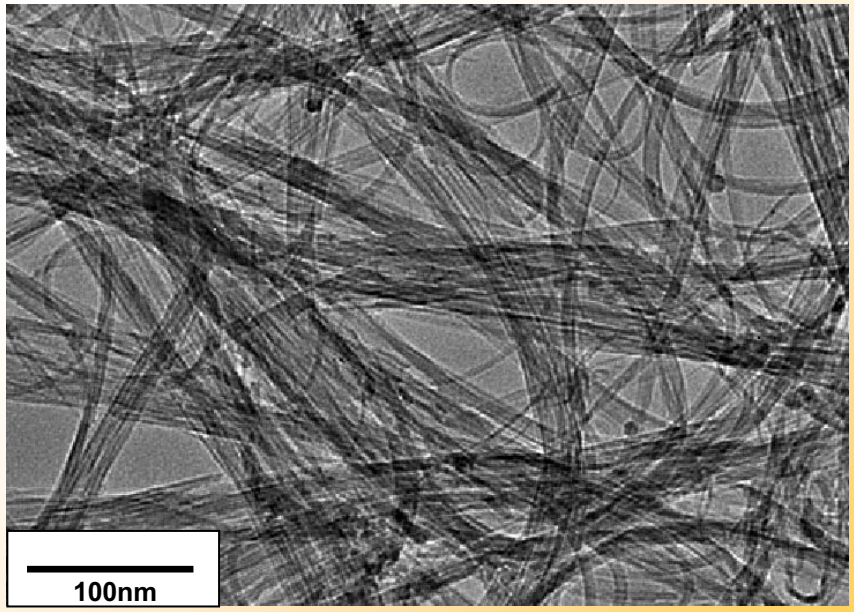
- Most of nanomaterials form agglomerates.

Fe nanoparticles



(NIMS)

Carbon nanotube

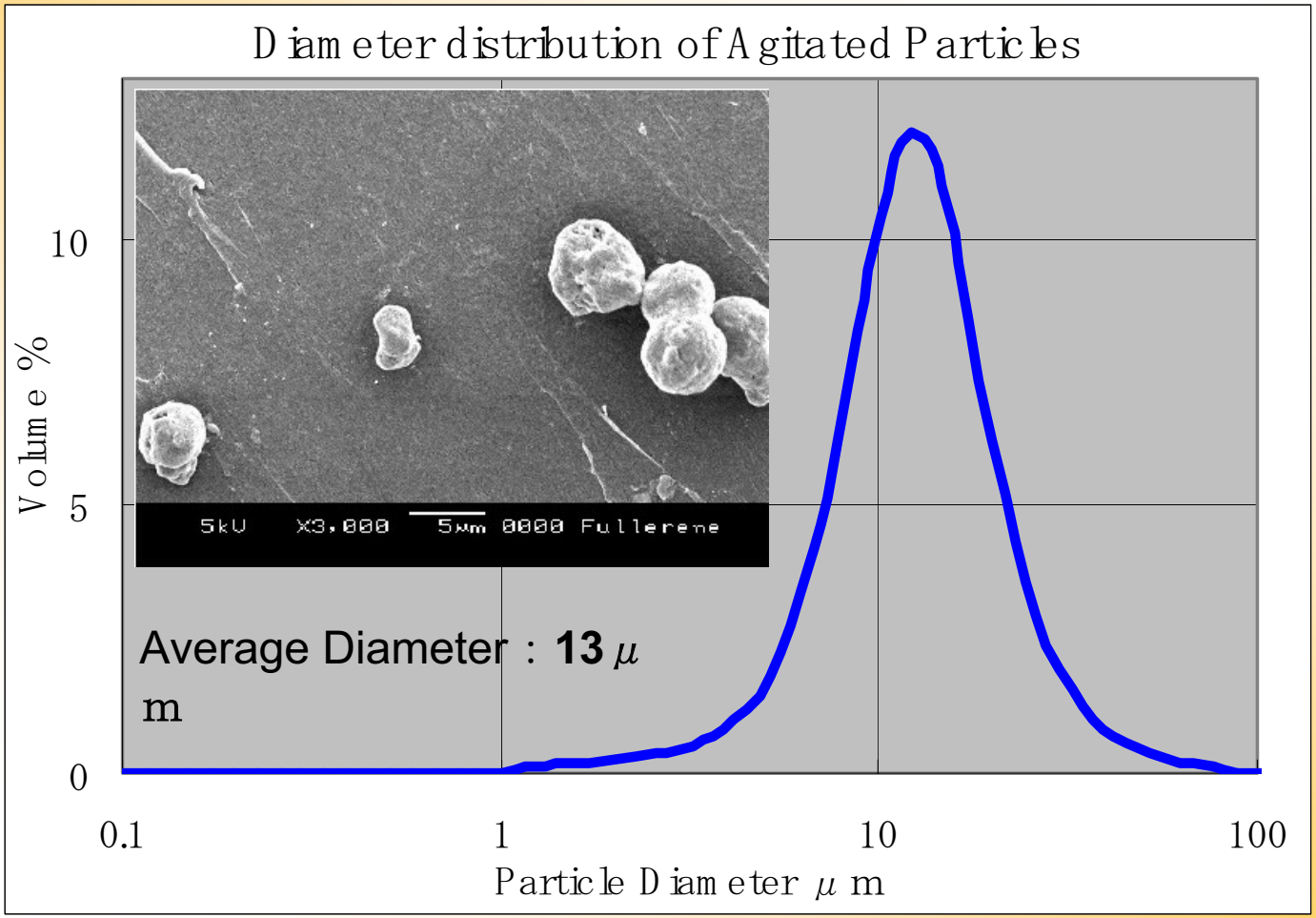


(Microphase Co.)

Laser Diffraction and SEM Analysis of Trapped Particles

Intentionally agitated mix-fullerene particles are trapped into DBS*/H2O

***=Dodecyl bezene sulfonic acid**



Fullerene aggregates **(Frontier Carbon Co.)**

Where are they being released into the air?

Collection process of products (Package)

Cleaning process of systems (metal nanoparticles)

Manufacturing process of commercial products using nanomaterials

Since nanomaterials are produced in closed systems, the possibility of leakage of nanomaterials is very low during production.

Countermeasures for manufactures dealing with hazard

- Workers wear masks, goggles, gloves and hard hats
- Monitoring dust in the workplace

  (e.g.) less than 50 μ g/m^3 in Frontier Carbon Co.
- No emission system (Waste water and gasses are detoxified) in the factory.
- Better design of shipping containers

Mass production now and tomorrow

Nanoparticles: Several t/month

> 200nm Ni, Magnetic powder,Rare earth powder

< 200nm Al, Cu (past like), ZnO,TiO_2

Many manufacturers can produce these on the order of ton. However, there are very few companies producing particles less than 10nm. Markets: IT parts, Cosmetics, Catalyst etc.

Fullerenes: 40 t/y, possible more, Frontier Carbon Corporation

Markets of Fullerenes: Sporting goods, Cosmetics, IT parts Capacitors

Nanotubes: 100 t/y, Hyperion Catalysis Int.

>20 t/y, Showa Denko Co.,Ltd.

>20 t/y, Bussan Nanotechnology Research Inst.

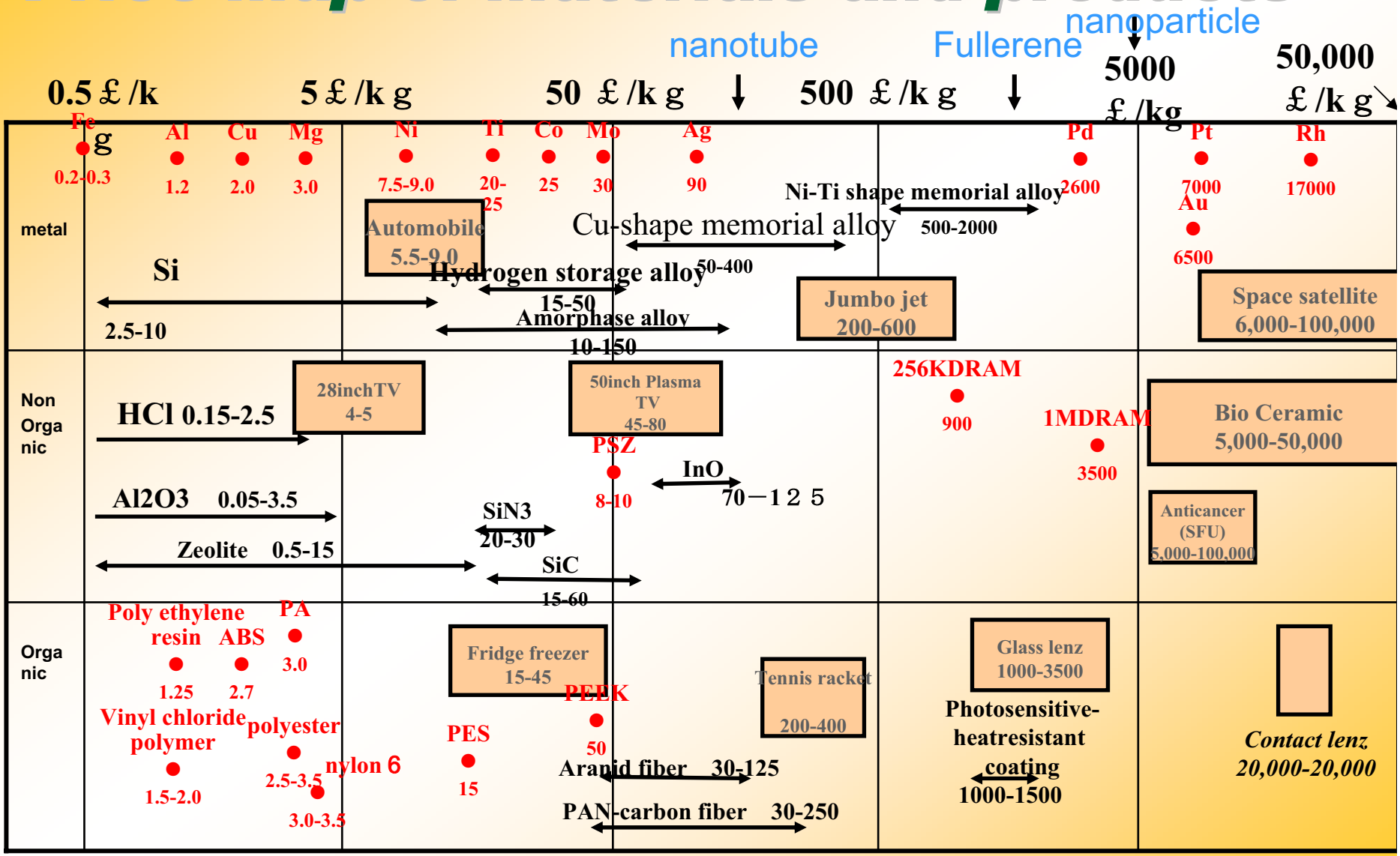
Markets of Nanotubes: Li batteries, Trays for carriage(Si D.), Automobiles, FEDs, White light sources in very near future

Summary of nanomaterial issues

- Production facility: No emission system
- Toxic characteristic: Not clear
- Products: Used in polymers,ceramics as a filler
  Not used mono-dispersed state of them
- Small markets at present: Sporting goods, Cosmetics
- Risk level for health: Very low.
  Asbestos >>> nanomaterials
- Firing and explosion might occur during manufacturing process when oxygen is introduced.

Conclusion

- For the time being, combustion and firing are main concerns from the safety point of view as long as mass production of nanomaterials is limited.
- We had better manage waste based on PRTR criteria since there are some manufactures already controlling waste severely.
- It is necessary to set up safety standards depending on the increment of waste amounts in near future.

Let us have an opportunity now to clarify how nanomaterials affect our health.

Price map of materials and products