Diamond from Soot

NanoCarbon Research Institute

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1. Nanodiamond qualifies the ‘Four Requirements’.

Four requirements for any nanocarbon material to fulfill in order to survive the race:

1. Ordered atomic structure — crystallinity
2. Production cost — <¥1000/kg
3. Marketability — timeliness
4. Biocompatibility — health risk

Which nanocarbon material is most likely to succeed in nanotechnology?

Requirements for success	Nanocarbon materials				
	Carbon blacks	C_{60}	CNT	DND*	CVD diamond film**
1. High crystallization (ordered structure in molecular level)	××	◎	◎	◎	◎
2. Cost below \1000/kg	◎	△	△	○	○
3. Prospect of big market	×	◎	◎	◎	◎
4. Biocompatibility	○	?	?	◎	○

*Detonation nanodiamond or single-nano diamond.
**CVD diamond films are polycrystals composed of UNCD

Diamond is an old but new supermaterial for nanotechnology!

2. Cost-saving *Soot Route*

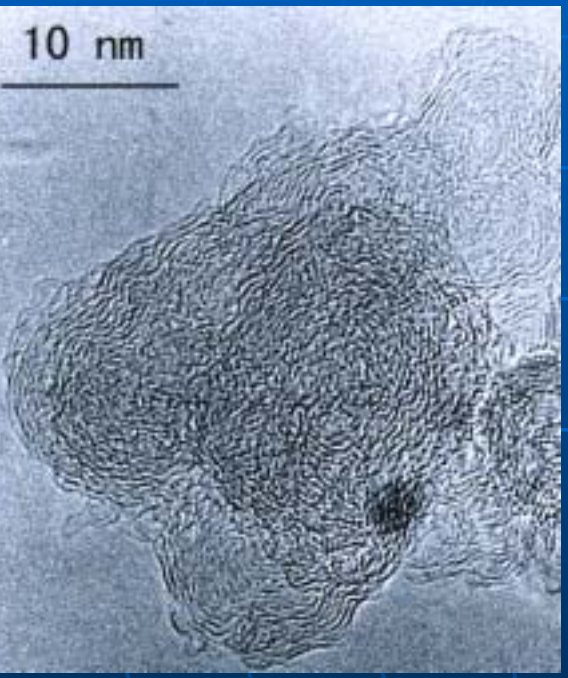
Cost of single-nano diamond (NanoAmando™) is still uncertain (previous table)

The present project, ‘Diamond from Soot’, has more sound cost strategy

Carbon blacks→nanoönions → nanodiamond

nano-carbons	manufacture		Proj. sales in 2007, M$
	raw material	cost k$/kg	
C_{60}	hydrocarbons	1	300
carbon nanotubes	graphite(arc)	500	50
	hydrocarbons(CVD)	10	
Detonation nanodiamond	TNT-RDX	3	-
carbon blacks	**carbon. ind. waste**	**0.001**	**10,000**
carbon nano-onions	carbon blacks	0.005	-
nanodiamonds	carbon nano-onions	0.05	-

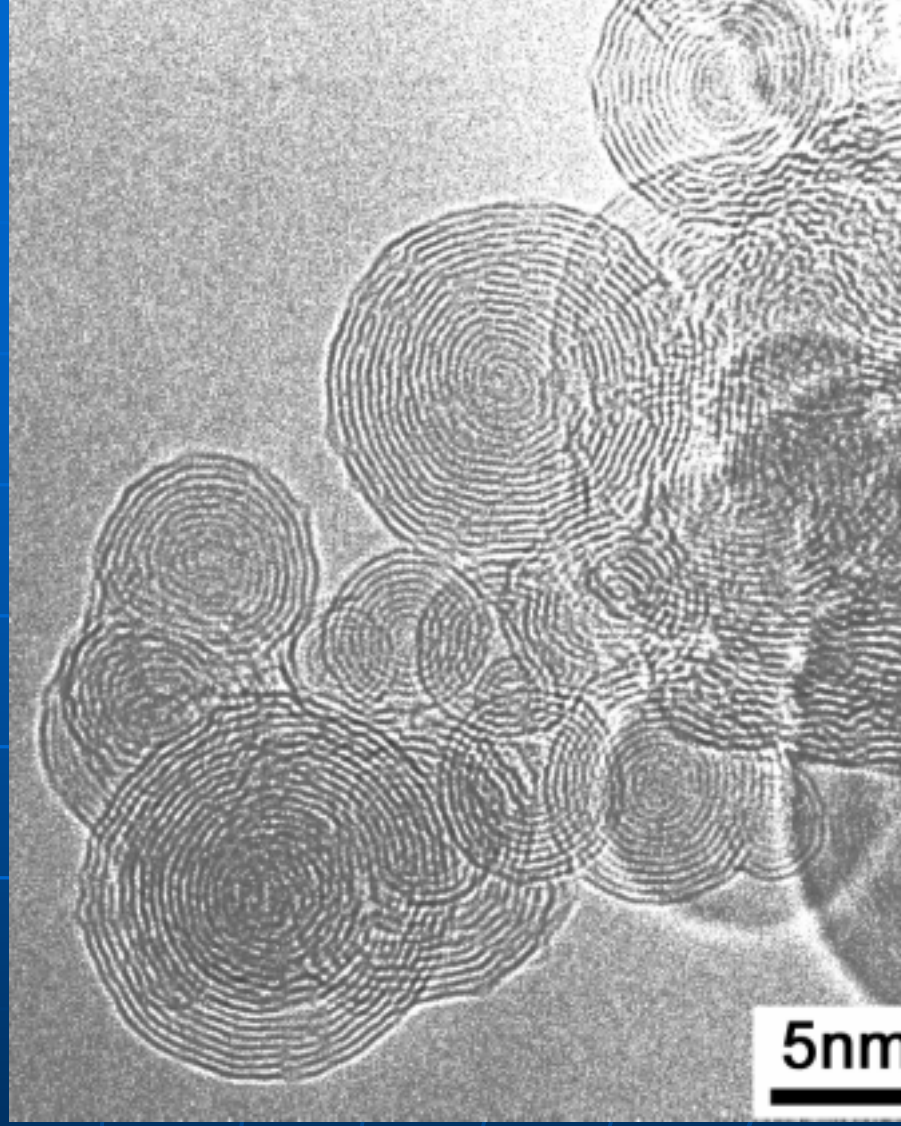
Conversion of soot into carbon nano-onions



Electron beam focused in 200KeV TEM

Current density: 150A/cm^2

15 min



Carbon black（Tokablack #8500F MCF)

Carbon nano-onions (multishell fullerenes)

Ozawa, Kusunoki, Osawa 2002

Painted delicacy

- Can we carry out the conversion, soot-to-nanoönion, outside TEM?

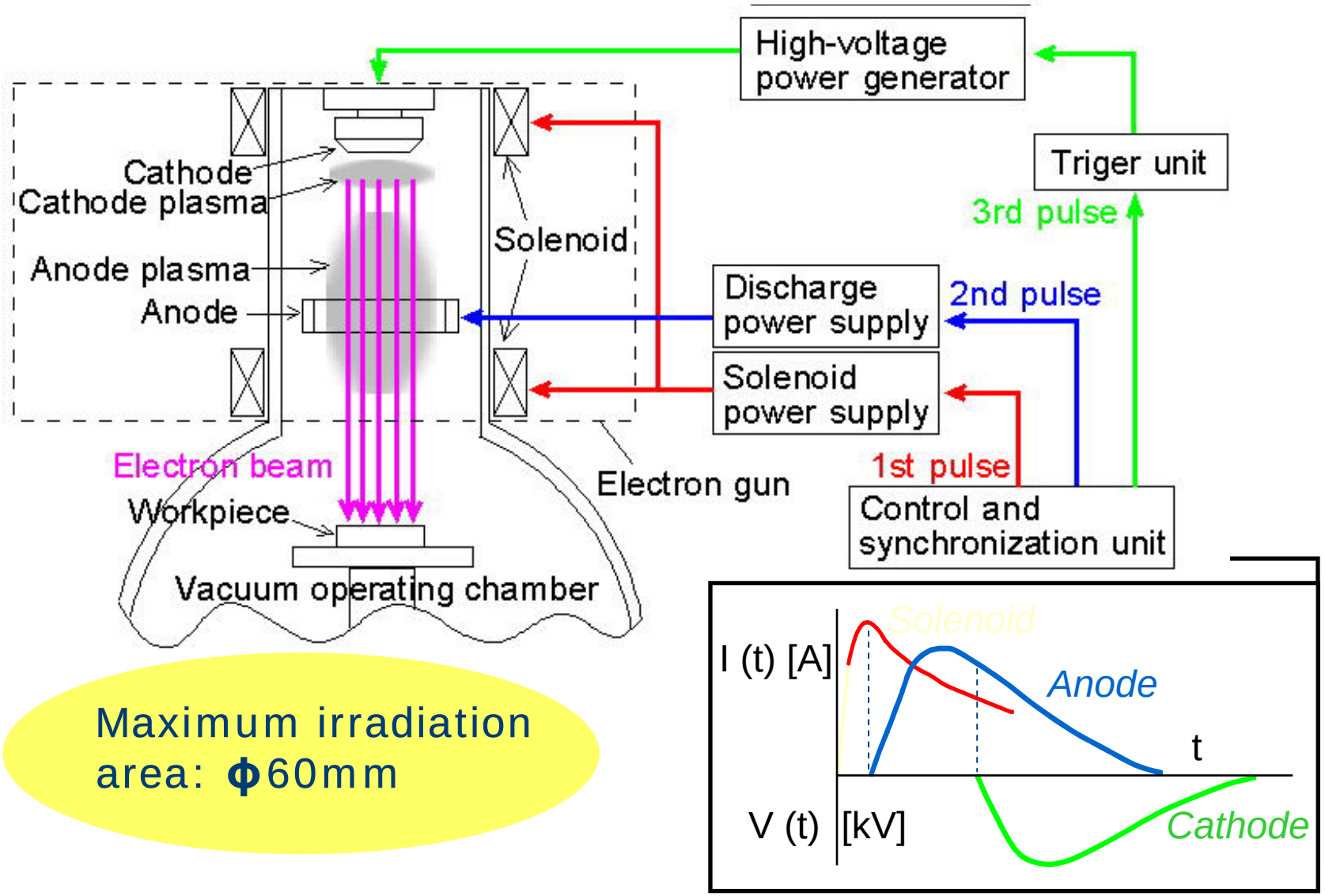
- No, because no electron gun was powerful enough:
  - The highest available electron density was 7A/cm^2,

…… until 1999.

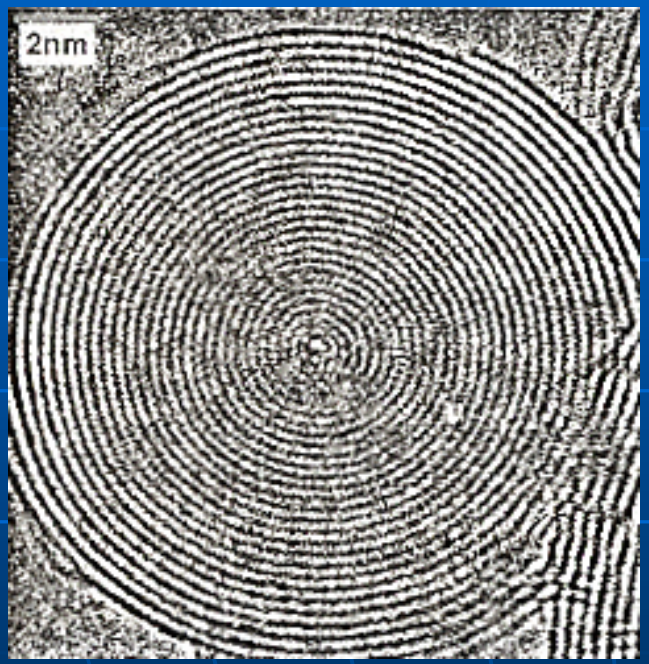
Explosive electron emitter

- Explosive electron emission (EEE) phenomenon discovered by Mesyats/Fursey in 1966.
- First practical EEE generator assembled by Uemura in 1999.
- Test production of Large-Area Electron Gun, or Corrosion Resistant System (CRS), began in Japan in 2003.
  - 10^2–10^6 A

High Density Electron Emitter (HDEE)

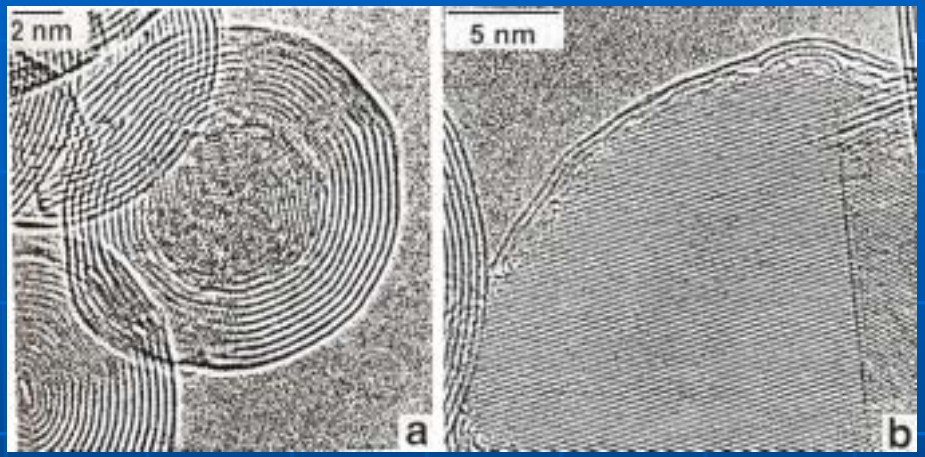


Conversion of carbon nano-onions into bucky diamonds



E-irr.

heat



Bucky diamond

Electron beam irradiation:
>200 keV, ~100A/cm2
Heating: >600 ℃
Time: 1-2 h

Banhart, Ajayan 1996

Overall process

carbon black

20-1000 nm
1$/kg

EEE

rt, 15min

carbon nano-onion

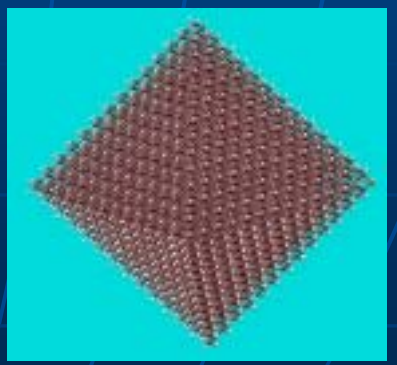
20-1000 nm

EEE

700℃, 2h

bucky diamond (nanodiamond)

15-600 nm



3. Interim report

- Irradiation of isomorphous graphite crucible with HDEE unexpected produced carbon nano-onions (2006, to be published).
- Irradiation of carbon blacks with HDEE expectedly produced carbon nano-onions (May 2007, to be published).
- A HDEE system was acquired by NEDO Grant (Feb. 2007).

4. Perspective

- Commercial production of bucky-diamonds with narrow size-distributions between 15-100 nm will begin in foreseeable future.
- Unique core-shell structure of bucky-diamond will open new applications.