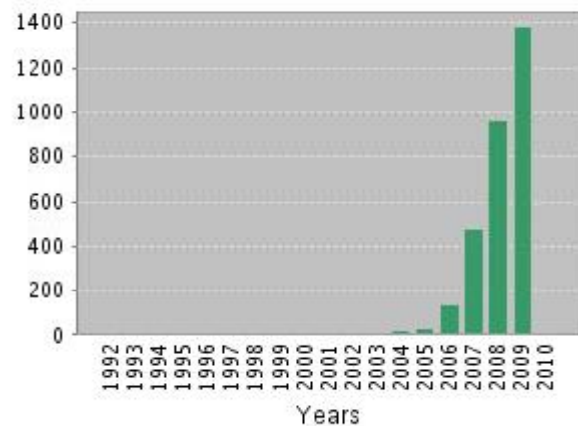


Idea: From nanolab to reality

Jari Kinaret, Chalmers University of Technology, Sweden

Volume production of advanced nanomaterials, *e.g.* graphene, is necessary to enable research on their applications.

Published Items in Each Year



Exponentially increasing research, initiated in Europe.



Production today: small scale, mostly academic and for private use.



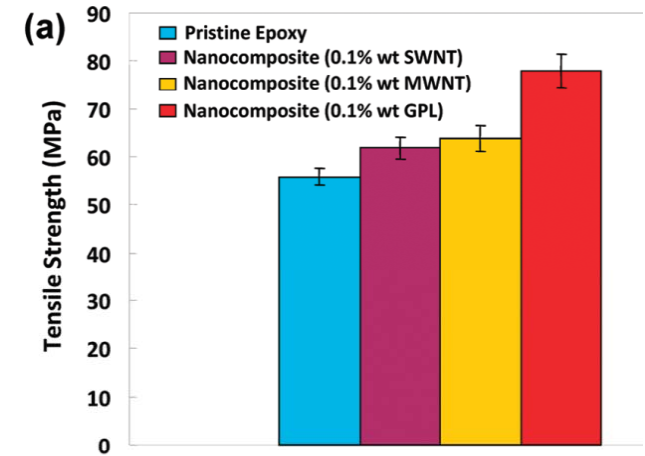
Vision: **industrial scale**, enabling new application-oriented research in several fields.

Production of graphene:

- i) "Scotch tape method" (mechanical exfoliation) – strictly lab only
- ii) Chemical exfoliation – low quality, small flakes
- iii) Conversion of SiC to graphene – high quality, hard to detach
- iv) CVD on copper – large volumes possible



Impact



Transparent electronics

- *crucial for electronics industry* (LCD displays, touch screens)
- ITO dominates but In price has increased 10-fold since 2003
- enables also flexible electronics

Ultrafast electronics

- 100 GHz transistor demonstrated; THz attainable
- mostly analog systems
- direct interface to cells as bioelectrodes

Optical components

- photodetectors, OLEDs, metamaterials
- solar cells with 100% quantum efficiency
- applications in telecom and energy production

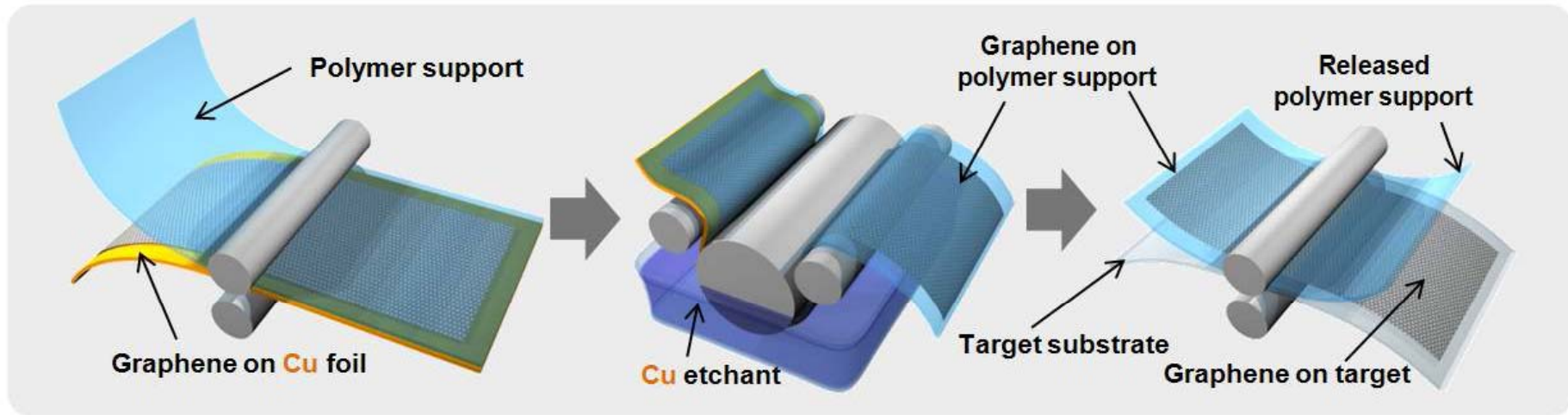
Mechanical components

- graphene is ideal for tunable resonators: *stiff and light*
- applications in electronics and as environmental and biomedical sensors

Composites

- graphene increases strength and stiffness of composites
- wide range of applications from aerospace to medical implants
- *even research requires large quantities*

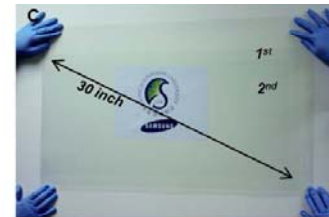
Plausibility



Continuous flow CVD production demonstrated

(S.Bae *et al.*, 2010)

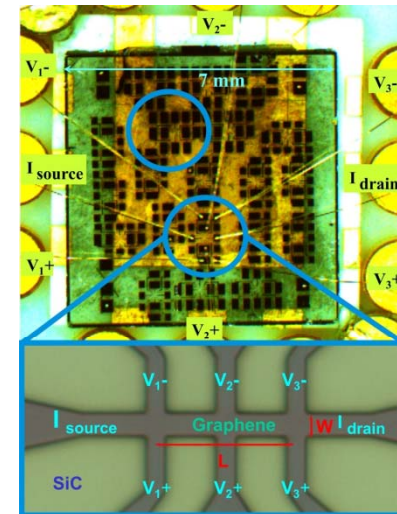
- 70 cm roll at present, can be increased
- sufficient quality for transparent or flexible electronics
- Korea; batch process also in Europe



SiC conversion demonstrated

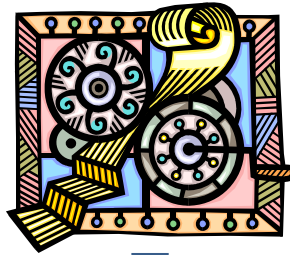
(many, *e.g.* Georgia Tech, IBM)

- dm-size, sufficient for electronics
- very high quality
- also in Europe (U. Linköping; A. Tzalenchuk *et al.*, 2010)

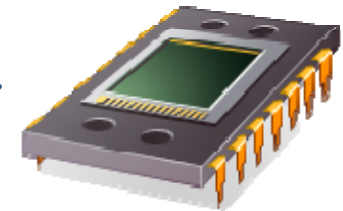
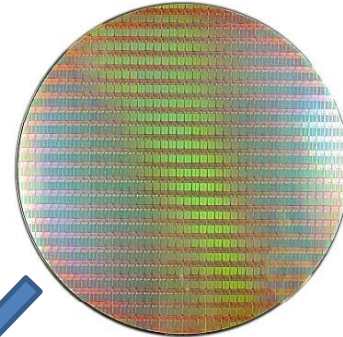


Ambition

Two production lines:
concentrated academic
and industrial research
on volume production
of graphene



Diversified graphene
supply aimed at
applications such as
electronics and
composite materials.



Advanced academic and
industrial research on
components and systems.



Return on investment:
15 years – IPR,
new industries,
better products,
better environment.

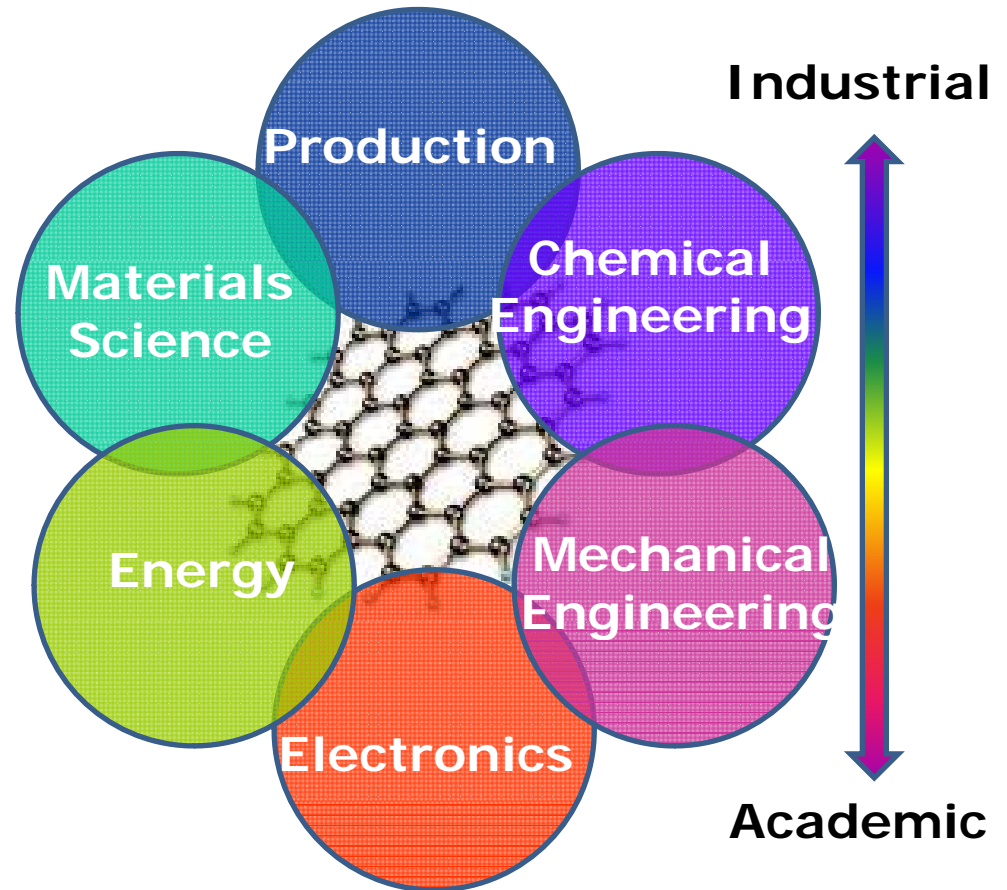


Integration

Integrates research on electronics (ICT), nanomaterials and production (NMP), energy, transport and health.

Connects to Flagship proposals *ICT Beyond Limits* (emerging hardware, phonons & fluctuations) and *Towards Augmented Humanity: Tuning Bionic Man* (bioelectrodes, implants).

In applications IPR landscape is still quite open: *potential for true academy-industry collaboration and European advantage.*



Support

Currently a large, fragmented research effort in Europe:
> 23 EU projects, partners from > 12 EU member states

Academic partners

U. Vienna
Tartu U.
Aalto U.
U. Erlangen
TU Delft
U. Groningen
U. Nijmegen
Chalmers
U. Linköping
U. Cambridge
U. Lancaster
U. Manchester
U. Oxford
...

Institute partners

IMEC
CEA-LETI
CEA-Grenoble
Leibniz Institute
Max Planck Institute
FORTH
Tyndall
IUNET
ICN
NPL
...

Industrial partners

Nokia
Diarc
AMO
Jenoptik
Sentech Instruments
Pirelli Labs
Eldor Corporation
Plasmachem
Sensotran
Intel
...

No formal support solicited at this point