The New Steel?
Enabling the Carbon Nanomaterials Revolution: Markets, Metrology, Safety, Scale-Up
NIST Workshop
Gaithersburg, MD
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“Perspective of a Start-up that has moved thru Scale-up into Commercialization”

David J. Arthur, CEO
SouthWest NanoTechnologies, Inc.
http://swentnano.com
Carbon Nanotubes (CNT)

Single-wall

Multi-wall

Specialty Materials

Printed Electronics

Single-wall

Multi-wall

1-2 nm

7 nm

10-20 nm
Start-up:

Founded by Prof. Daniel Resasco in 2001

1 g/day scale

CNT Pilot Plant circa 2005
CoMoCAT® process

Fluidized Bed (Inherently Scalable)

Uniform Heat and Mass Transfer

Proprietary Catalyst (Selective Synthesis)

SWCNT

Catalyst

20 nm

30 patents issued

gas
Scale-up:

New CNT Production Plant, Fall 2008

100 ~ 10,000 g/day scale

Norman, OK

Fluidized Bed Reactors
Scale-up (cont’d):

Industrial Scale Purification

nanoEHS

Metrology
Single-wall CNTs
Conductive & Semiconducting Grades

SWeNT® SG65+
Met. tubes ~ 5%

SWeNT® SG76
Met. tubes ~ 35%
Quality:

Process Improvements in Synthesis & Purification

8 wt% residue

1 wt% residue
Quality (cont’d):

…Without evidence of tube damage.
Where is the market going?

- Thinner, Lighter.
- Large display area.
- Flexible, Rugged.
- Touch interface.
- Lower cost.
- Short cycle time.

Glass $\rightarrow$ Plastic

ITO, Si $\rightarrow$ Organic

Printed Electronics
Why print electronics?

Subtractive Process (Photolithography)

- Deposit film
- Expose
- Develop
- Etch / strip

Additive Process (Printing)

- Less steps.
- Less waste.
- Lower cost.
- Short cycle time.
Big incentive to switch to CNT for Touch sensors:
Cost can be reduced by at least 10%. Cycle time can be reduced from 1 week to 1 day.
Performance:

- Larger Tubes: > 1 µm
- Metallic Enriched: > 70%
- Small Diameter: ~ 0.8 nm
- High Purity: > 99%
- Enriched SC: > 99%

- TCF: < 100 Ω/sq, > 90% VLT
- TFT: Mobility > 10 cm² V⁻¹ s⁻¹, On/Off > 10⁵
Commercialization

The Chasm

Relative % of customers

Innovators, technology enthusiasts
Early adopters, visionaries
Early majority pragmatists
Late majority conservatives
Laggards, skeptics

Time

Customers want technology and performance

Customers want solutions and convenience
CNTs can be printed using Standard Industrial Printing Equipment

* Patents pending
Screen Printing Demo
(using V2V™ ink)
Apps Dev is Key!

Applications Development Center

Canton, MA
What are the Barriers?

• Performance
  – Metrology
  – Quality Improvement
• Easy & Safe to Use
  – Inks
  – nanoEHS
• Supply Chain
  – Apps Dev
  – Strategic Alliances (Global)