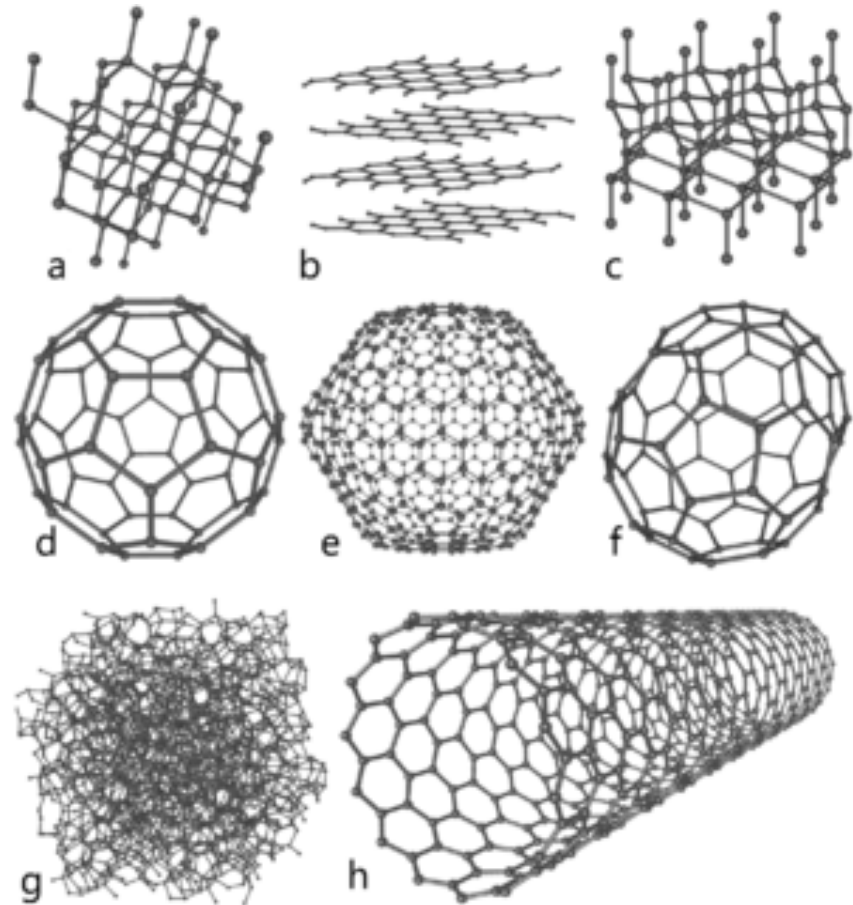


**Carbon Nanotubes**

Applications of Carbon Nanotubes are an exciting area of exploration in that they display a number of performative qualities. Aside from their extreme mechanical strength, the electronic properties of CNTs, which can be either metallic or semiconducting, make this a unique material. High thermal conductivity and chemical resistance are additional qualities. Together, the properties of this material lend itself well to sensory and actuation applications.



## Basic Properties:

**Carbon nanotubes** (CNTs) are allotropes of carbon with a cylindrical nanostructure. These cylindrical carbon molecules have unusual properties, which are valuable for nanotechnology, electronics, optics and other fields of materials science and technology. In particular, owing to their extraordinary thermal conductivity and mechanical and electrical properties, carbon nanotubes may find applications as additives to various structural materials.

**Graphite** (*graphein*, "to draw/write", for its use in pencils) is one of the most common allotropes of carbon. Graphite is an electrical conductor. Thus, it can be used in, for instance, electrical arc lamp electrodes

## basic properties:

“CNTs are light in weight and have the strongest tensile strength of any synthetic fiber. They are expected to produce fibers 100 times stronger than steel and 1/6<sup>th</sup> the weight – almost certainly the strongest fibers that will ever be made out of anything.”

“In addition to their strength, some CNTs can conduct electricity better than copper.”

# Basic Advantages and process of producing/using Nanotube Ink on Paper

## Advantages

Paper over plastic can improve film adhesion  
Scaleable, low cost, high performing, flexible

## Process

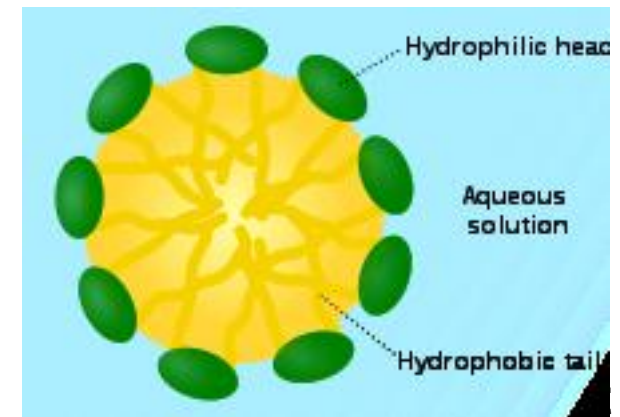
Nano material is capped with Surfactant molecules so that they can be dispersed as separate particles in a solvent to form ink.

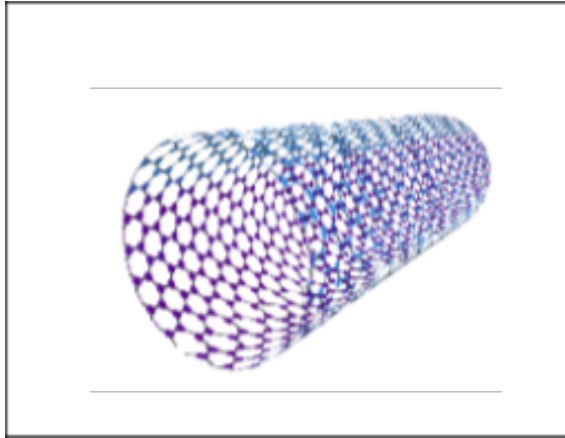
Ink is then deposited onto flat substrates, followed by surfactant removal and solvent evaporation

Surfactant removal is critical because they are insulating and limit the charge transfer between the nano materials.

This step involves extensive washing and chemical displacement, which can cause detachment of the film

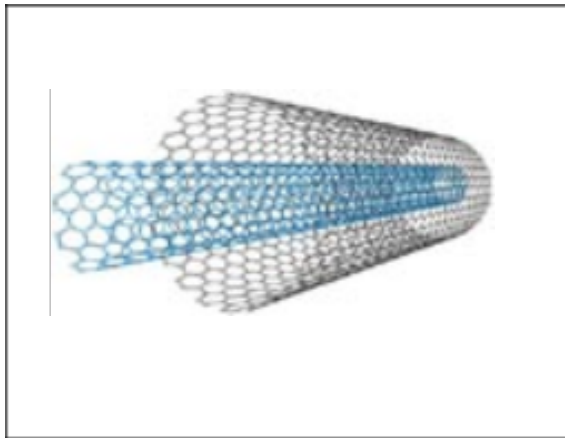
Polymer binders/adhesives are sometimes used to improve binding, but can also decrease conductivity





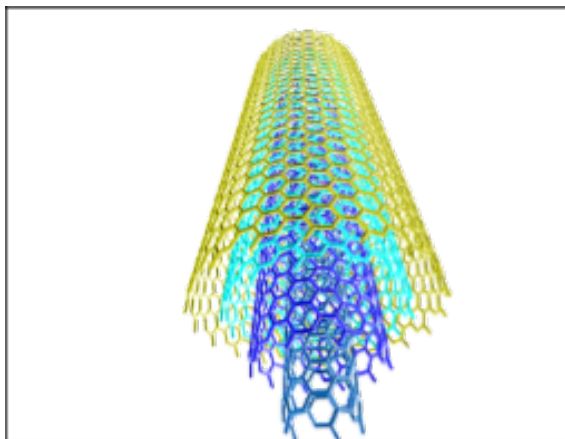
## Single-Wall Carbon Nanotubes (SWCNT)

- a single, atom-thick cylindrical wall called graphene
- very pliable into unusual shapes, but harder to make
- on the leading edge of electronic fabrication and miniaturized electronics



## Double-Wall Carbon Nanotubes (DWCNT)

- synthetic blend of SWCNT and MWCNT
- similar thermal and electrical properties as MWCNT
- similar flexibilities as SWCNT
- more chemical and thermal stability than SWCNT



## Multi-Wall Carbon Nanotubes (MWCNT)

- shaped like a scroll or a coaxial cable
- easier to produce larger quantities than SWCNT
- Less understood because it is more complex
- Structural imperfections diminish material's properties

## Transport Properties of Conductive Materials

Material	Thermal Conductivity (W/m.k)	Electrical Conductivity
Carbon Nanotubes	> 3000	$10^6 - 10^7$
Copper	400	$6 \times 10^7$
Carbon Fiber - Pitch	1000	$2 - 8.5 \times 10^6$
Carbon Fiber - PAN	8 - 105	$6.5 - 14 \times 10^6$

## health hazards:

- Currently, CNTs are considered a “green” industrial process, but ...
- ... studies have shown a correlation between fine particles in the air and mortality rates
- there is a possibility that carbon nanotubes in the air could cause a respiration risk
- studies have been inconclusive, although large quantities injected into mice have caused death
- usage in industrial mechanics such as cars and other products could eventually cause wear and tear, releasing particles into the air





## **Structural**

textiles(waterproof, tear-resistant), sports equipment(lighter, stronger), artificial muscle, structural cable(high strength/weight ratio), fire protection(heat reflection)

## **Electromagnetic**

buckypaper(heat sink, backlight for LCD screens), conductive films(transparent and electrically conductive), displays, magnets, solar cells, transistor

## **Electroacoustic**

loudspeakers

## **Chemical**

desalination, air filter, hydrogen storage

## **Mechanical**

oscillator, slick surface, waterproof, infrared detector

## **Electrical circuits**

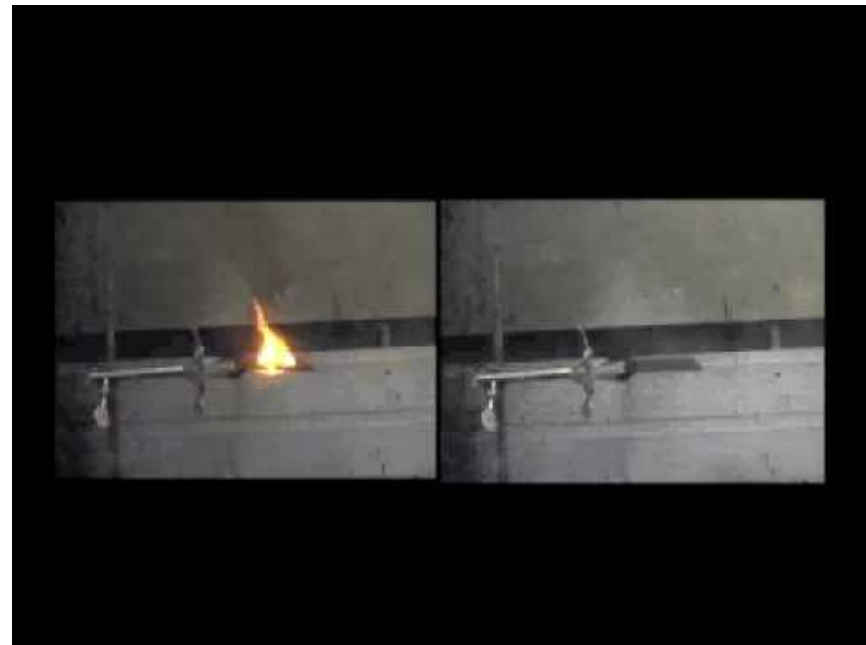
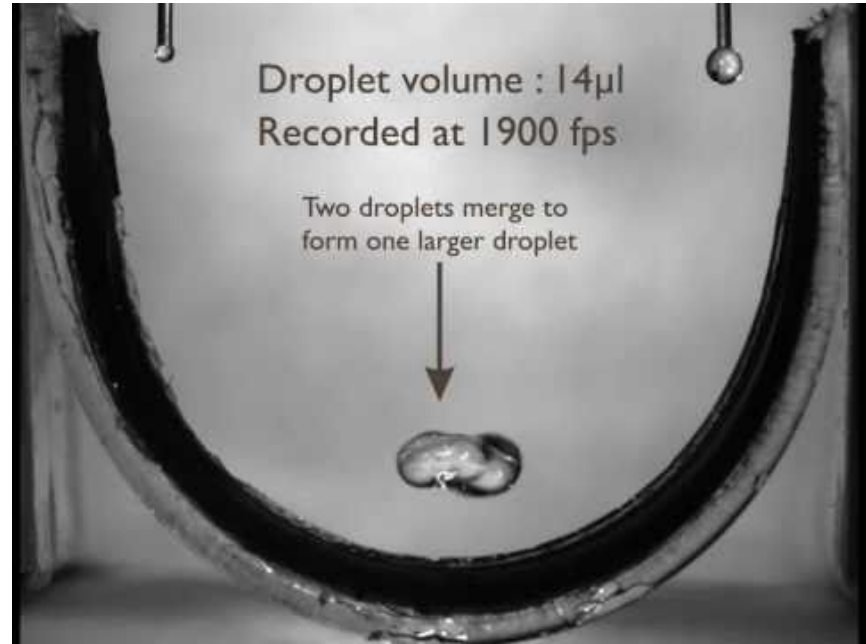
interconnects, transistors

## **Medicine**

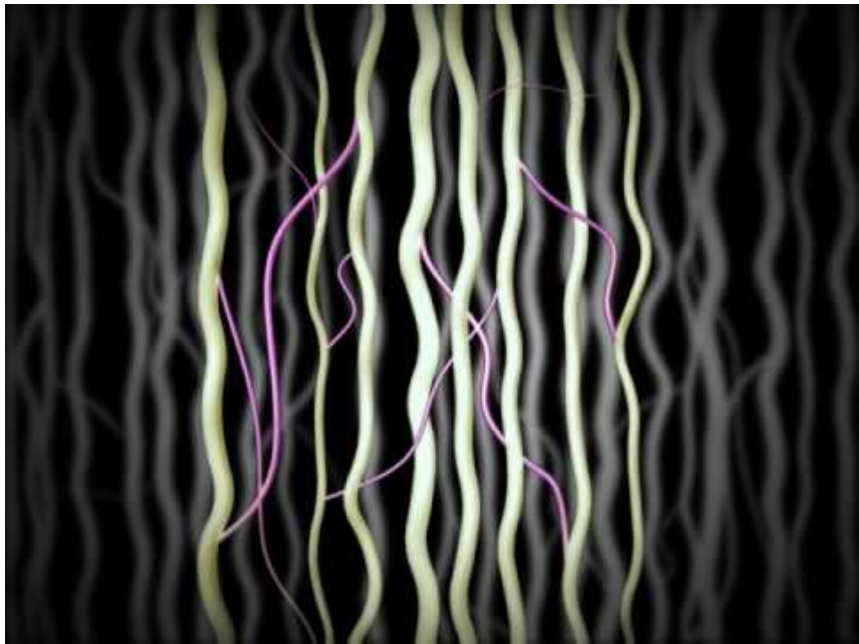
scaffold material for osteoblast proliferation and bone formation

Source: [http://en.wikipedia.org/wiki/Potential\\_applications\\_of\\_carbon\\_nanotubes](http://en.wikipedia.org/wiki/Potential_applications_of_carbon_nanotubes)

# Applications



# Applications



# Applications



Neri Oxman, John Hart;  
Construction In Vivo:

Prototype material architecture of a partially transparent envelope, created from nanotubes (CNTs) and polymers, which behave like a membrane

<http://www.nanobliss.com/constructioninvivo/>



**Nanotube textiles:** Cotton thread dipped in a mixture of carbon nanotubes and conductive polymers carries enough electrical current to light up a light-emitting diode.

Credit: Bong Sup Shim

# Resources

Supplier	Product	Application	Cost	Contact	
SWeNT, Norman, OK	Carbon Nanotubes, Carbon Nanotube Ink Relationship with nanotube extruders for conductive filament.	Screen Printing,	100ml /\$500.	<a href="http://swentnano.com">http://swentnano.com</a> Rick Jansen 860.428.9482	
NanoLab, Waltham, MA	Carbon Nanotube Ink, Nanotube paper, Carbon fiber veil composites	printing of nanotube electronics and sensors, composites	42ml singlewall carbon nanotube ink cartridge \$250;	<a href="http://www.nano-lab.com">http://www.nano-lab.com</a> 781.609.2722	

## Description

### SWeNT (Southwest Nano Technologies)

- § SWeNT's V Series CNT Inks, have been designed specifically for use in conventional printing processes, without the need for any secondary operations beyond conventional oven drying
- § The CNT ink flows and levels well on surfaces such as polyester and glass and line resolution of 0.3 mm has been demonstrated.
- § The V Series Inks are delivered premixed and ready to use.
- § Contains up to 40% Surfactants. Considered hazardous.
- § Stir to reduce viscosity (or thickness) and resistance.

### NanoLab

- § NanoLab offers a wide variety of nanomaterials, including carbon nanotube powders, aligned nanotube arrays, nanoparticles, products made from carbon nanotubes & nanotube processing aids.
- § Working to develop products in fields of composites, optical devices and field emission.





**No complicated drying equipment is required.**