Nanocomposite Materials for the Electronics Components Industry

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Nanotechnology definitions

- The term “nanotechnology” is used to describe materials, devices, or structures with feature sizes less than 100 nm
- For composite materials, properties can deviate from simple rules of mixing when phase domains are less than 1 micron
- At less than 100 nm, significant interfacial effects are observed
- At less than 10 nm, atomic or quantum effects are observed

The evolution of nanocomposites

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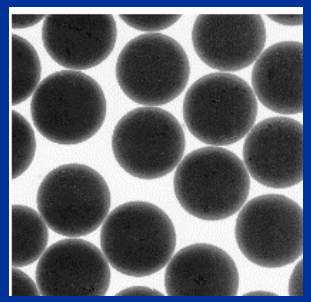

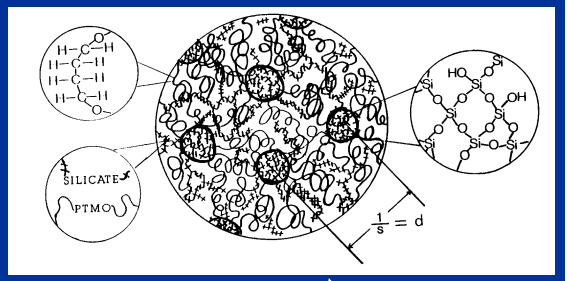

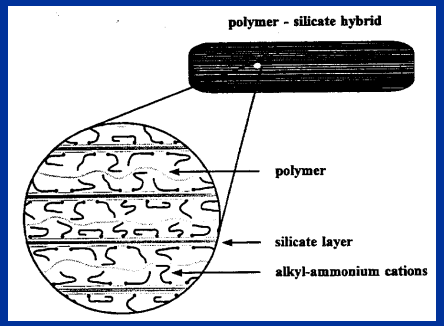

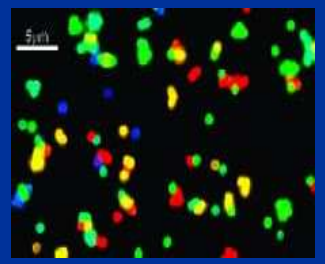

$SiCl_4 + H_2O$

1900
- Silane Hydrolysis
- Carbon black

1950-1960
- Stöber process
- Fumed silica
- Precipitated oxides

1970
- Sol-Gel processing
- Fullerenes

1980
- Highly ordered Nanocomposites
- Nanoparticles

1990
- Quantum dots
- Nanowires
- Nanotubes

2000

Commercial sources of nanomaterials

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- Colloidal solutions
  - WR Grace (from DuPont)
  - PQ Corporation
  - Nissan Chemical
- Fumed oxides, carbons
  - Degussa
  - Cabot
  - Columbian Chemical
- Organoclays
  - Nanocor
  - Rheox
  - Southern Clay Products
- Nanoparticle oxides and metals
  - Nanophase
  - NanoProducts
  - nTech
- POSS and related compounds
  - Hybrid Plastics
- Quantum Dots
  - Quantum Dot Corp
  - Evident Technologies
  - Nanosys

Electronics Market and Technology Trends

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- Electronics market trends
  - Device miniaturization
  - Increased levels of integration
  - Operation in harsh conditions
  - Quality and reliability
  - Environmental concerns
  - Cost reduction
- Technology trends
  - Nanotechnology
  - Environmentally friendly manufacturing
  - New materials
  - Computer assisted design

Device miniaturization

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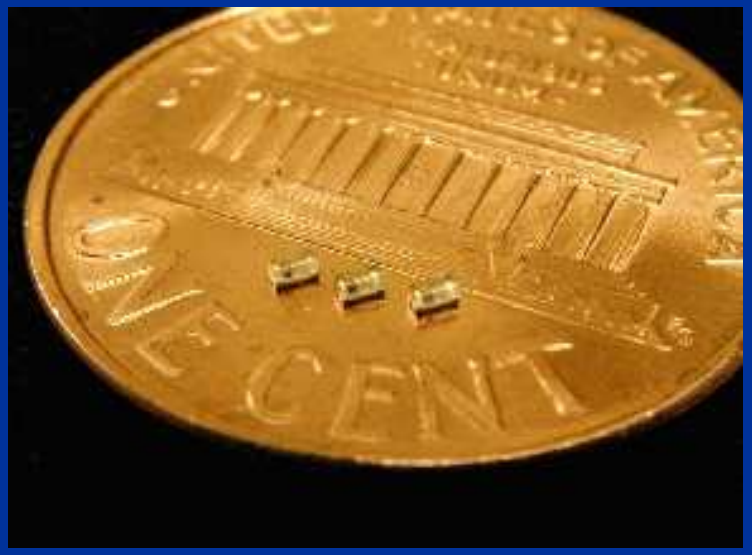
1206	3 mm x 1.5 mm	
0805	2 mm x 1.3 mm	
0603	1.5 mm x 0.8 mm	
0402	1 mm x 0.5 mm	
0201	0.5 mm x 0.3 mm	



Surface Mount Devices
- Resistors
- Inductors
- Capacitors
- LEDs
- Diodes
- Varistors

Interconnect Technology Focus

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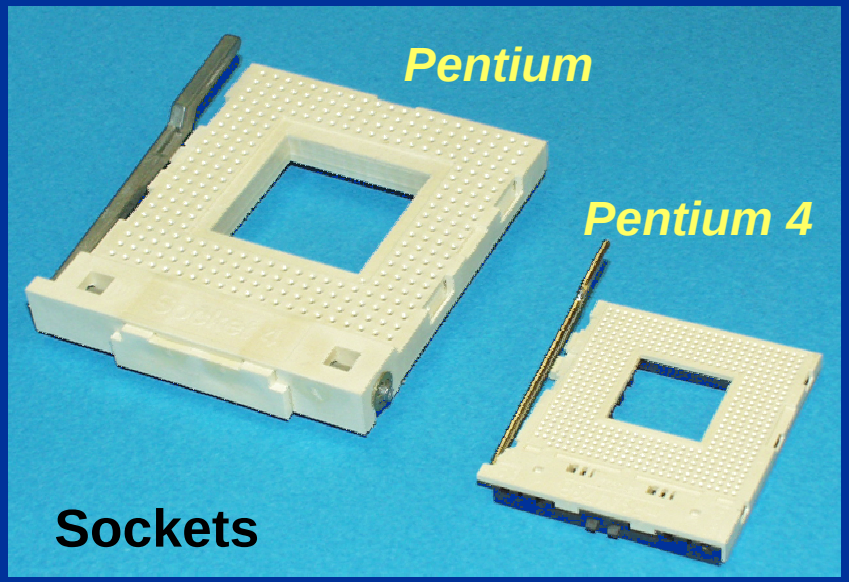
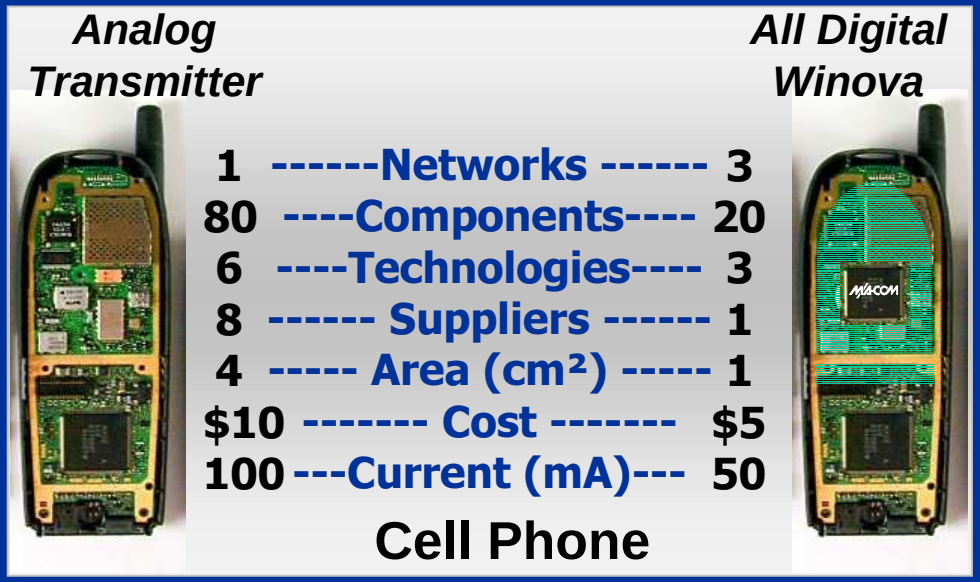
Reduce: Cost / Size / Distortion

Increase: Density / Function / Customer Satisfaction





Interconnect must have minimal impact on the end product

Nanocomposite materials in electronics

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- **Current Products:** Nanomaterials in resettable fuses
  - Carbon-polymer nanocomposite
  - Sold under the trade name Polyswitch™
  - 2 billion devices per year
- **Current Research:** Organoclay-polymer composites
  - Highly oriented nanocomposites
  - Unique barrier properties
  - Potential applications in wire insulation, tubing, connectors, and packaging
- **Future Directions:** Nanomaterials development areas
  - Micro- and Nanocircuitry
  - Embedded identification

Carbon-polymer nanocomposites

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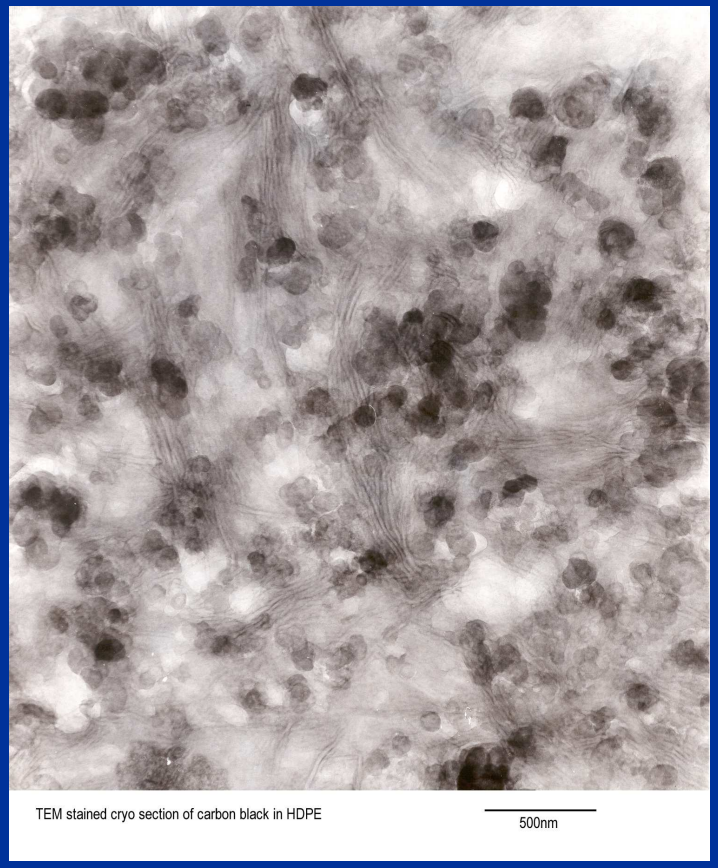

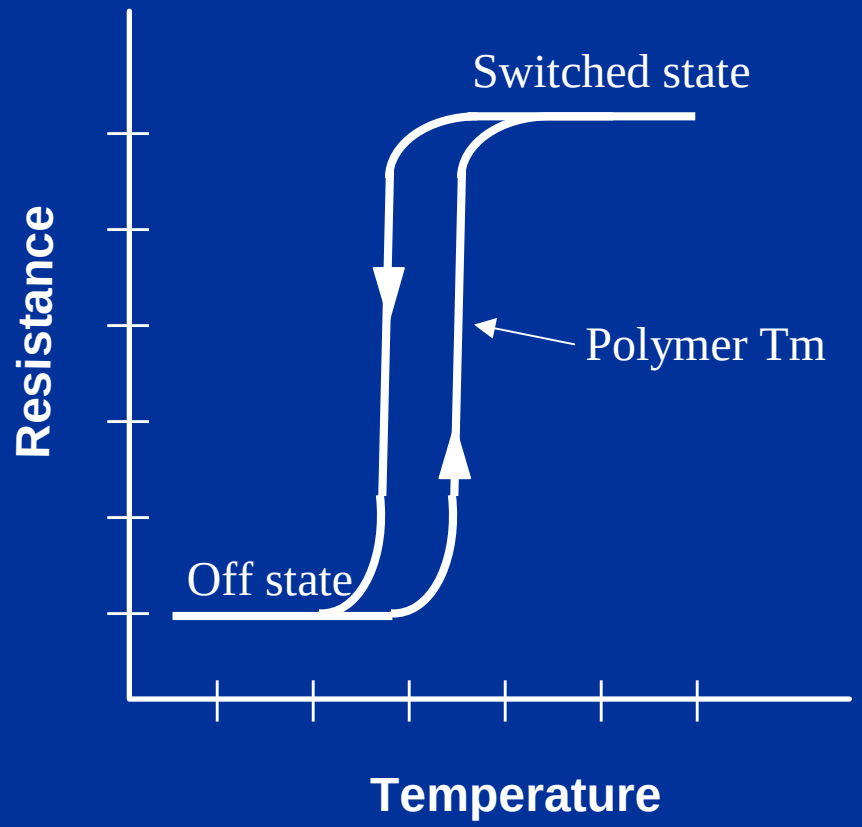

Resettable fuse technology

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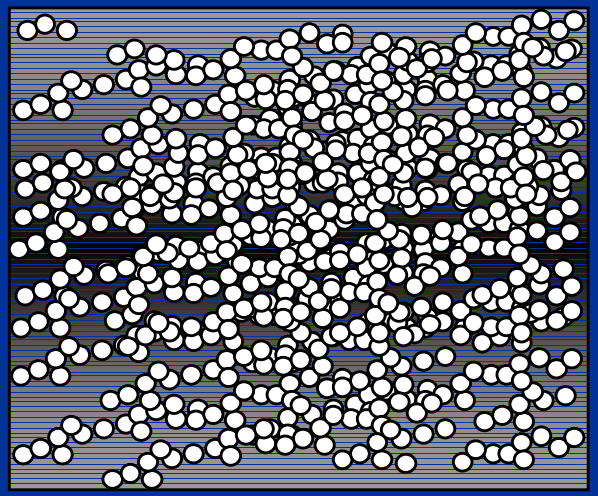
UNDER NORMAL OPERATION

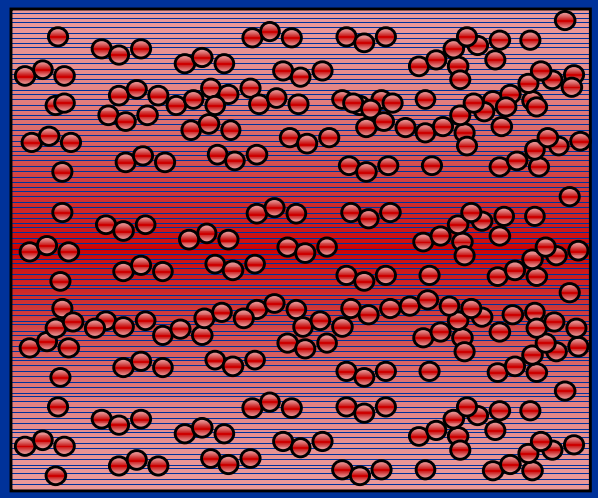


- At the operating current
- Many conductive paths
- Very low resistance

heats up

cools down

UNDER A FAULT CONDITION



- Excessive current causes device to heat
- Fewer conductive paths
- High resistance
- Cools down and resets when fault removed

Applications for resettable fuses

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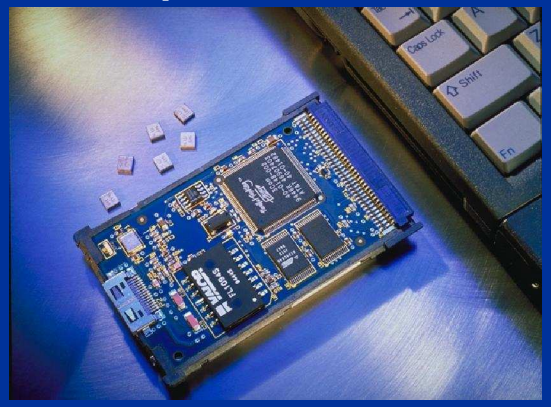
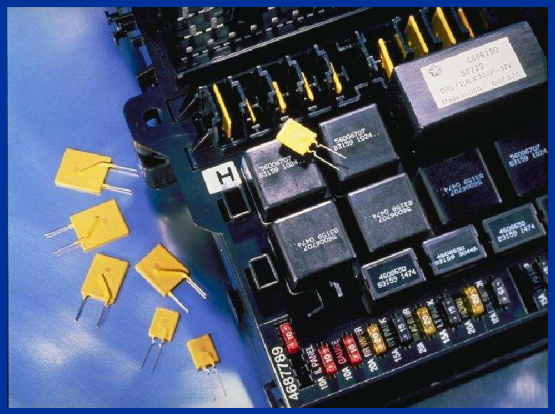
Lithium Cells & Battery Packs

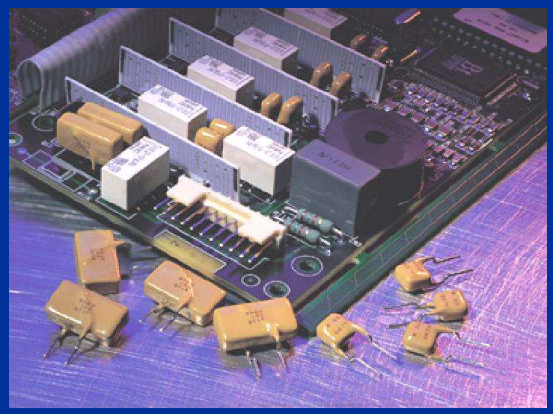
Computer PC Cards



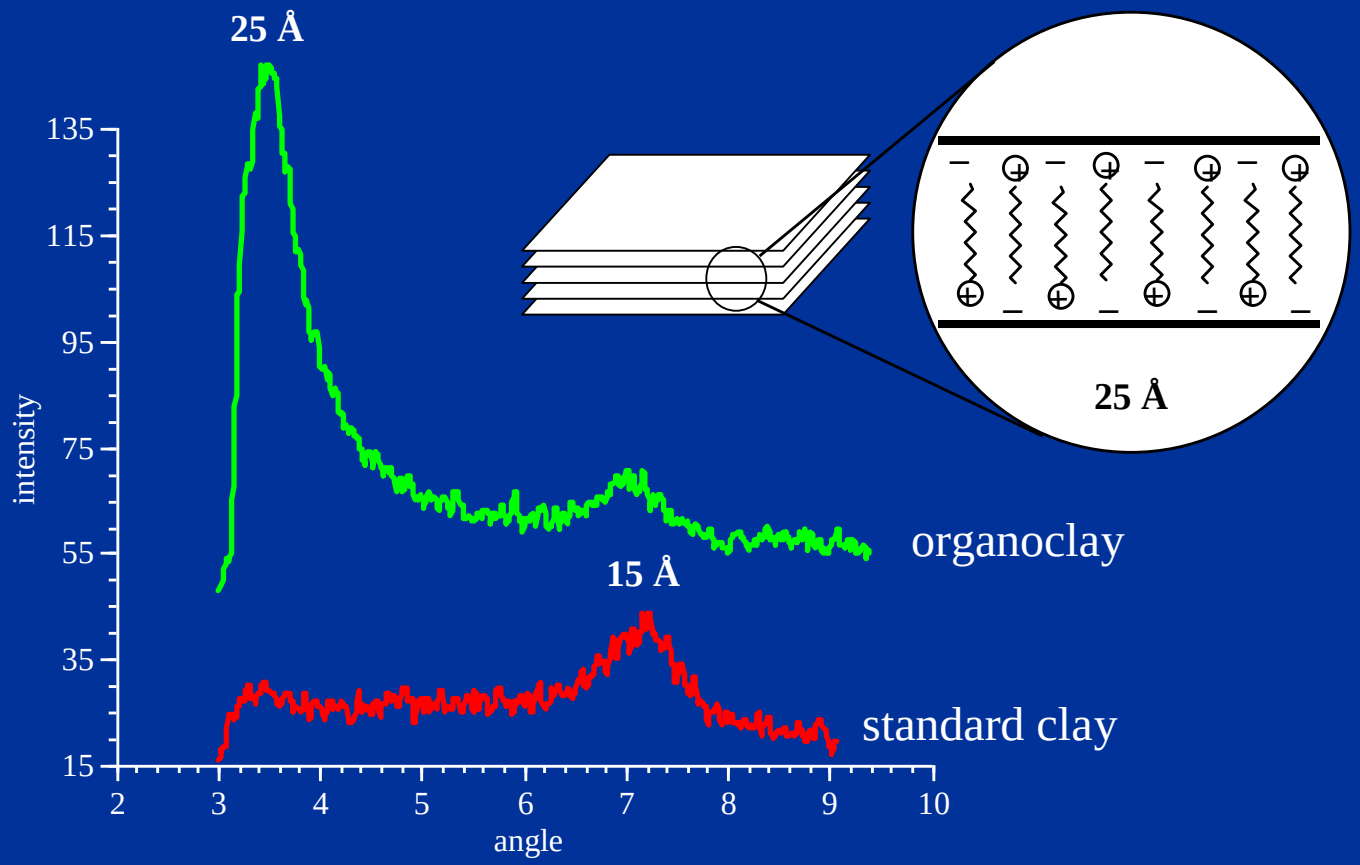
Automotive Wire Harnesses



Network Equipment

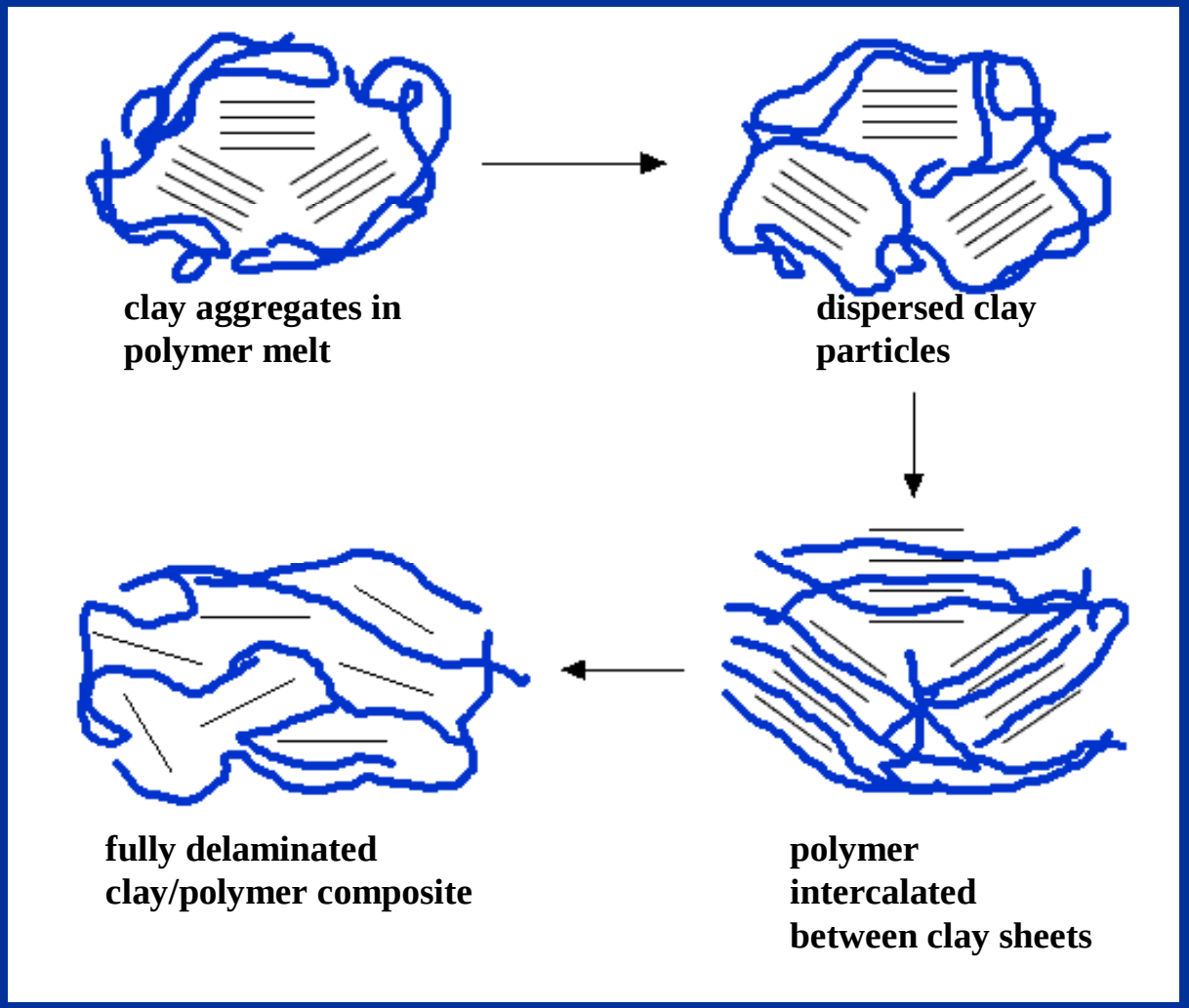


Organoclay-polymer nanocomposites

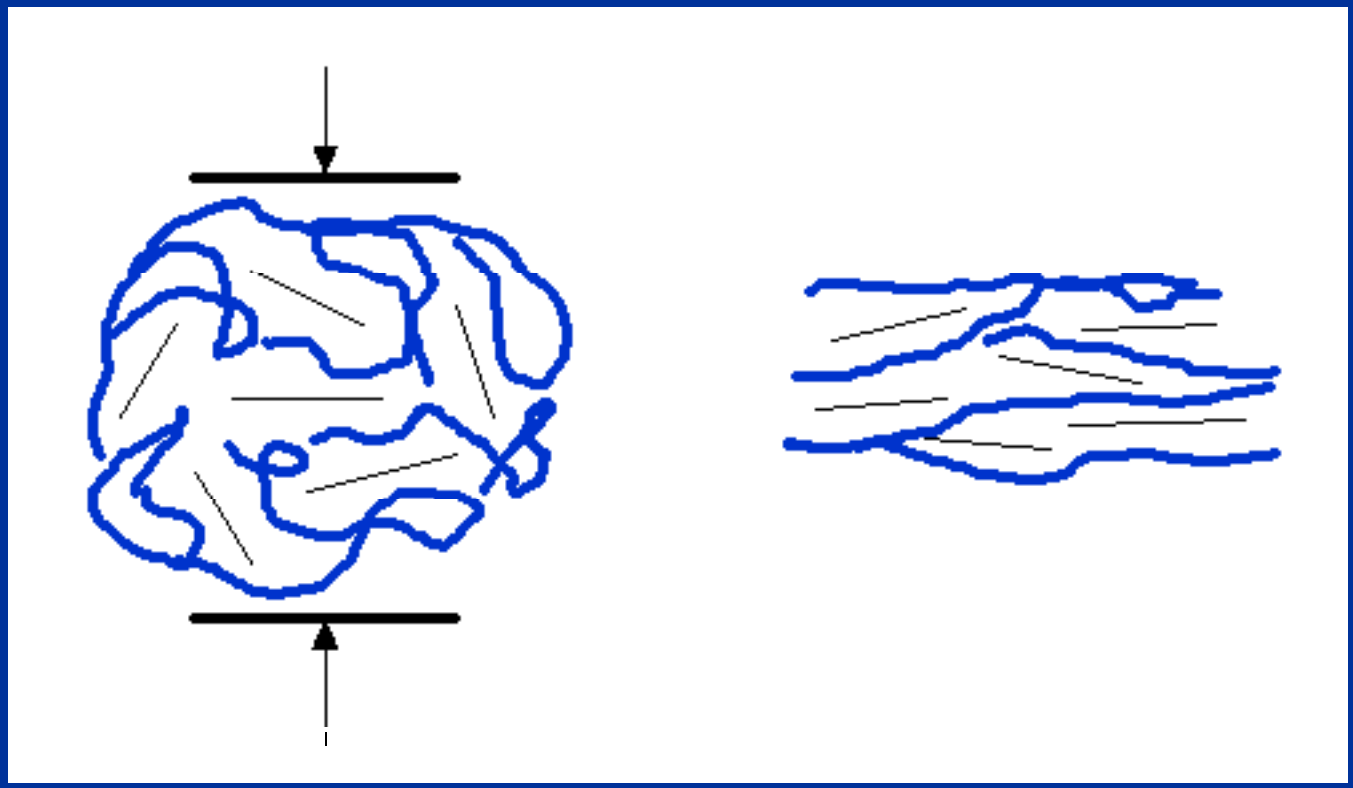


Primary particle size = 10 nm thick x 1000 nm wide

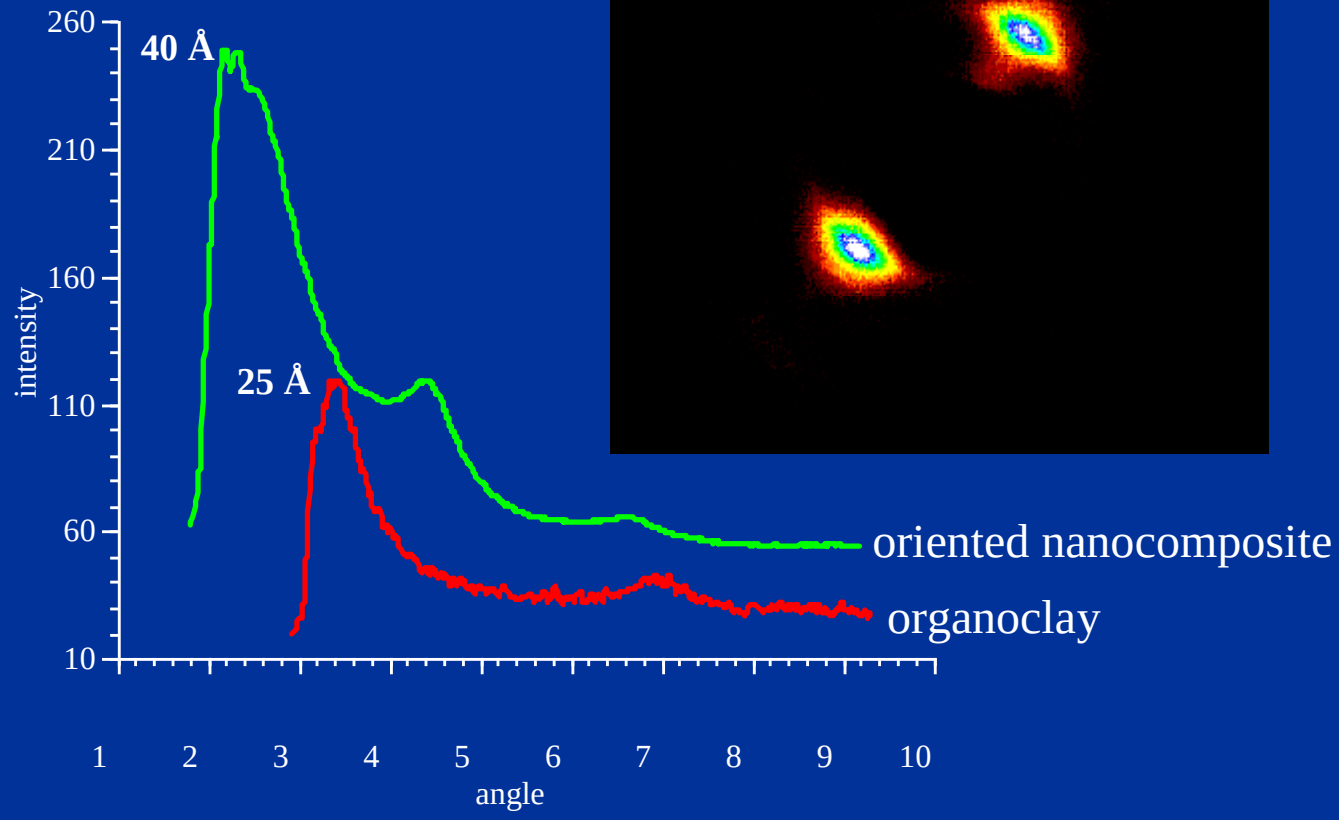
Processing of organoclay nanocomposites



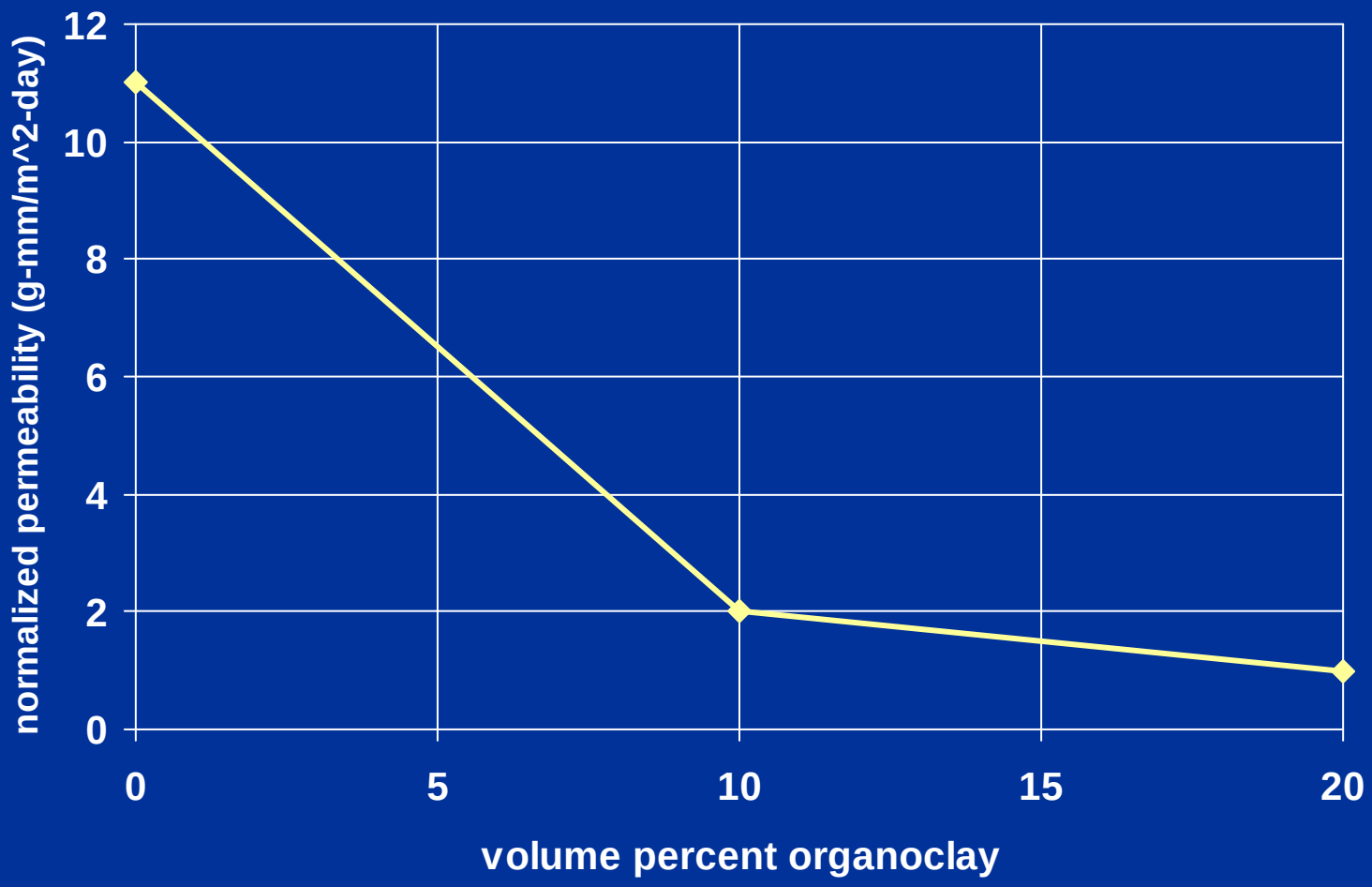
Highly oriented nanocomposites



Evidence of orientation



Reduced water vapor permeability



Organoclay-polymer nanocomposites

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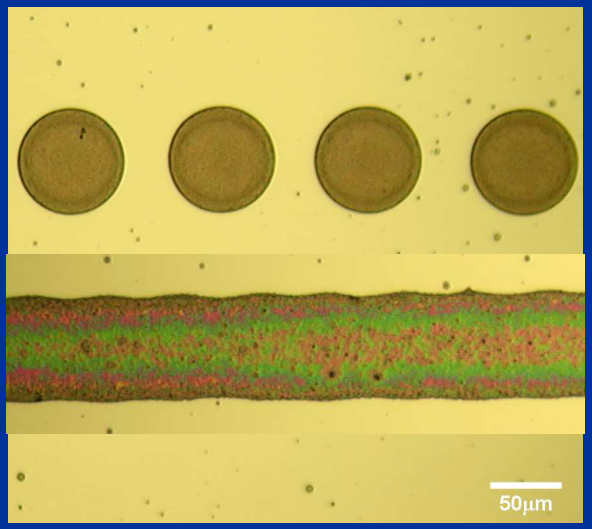
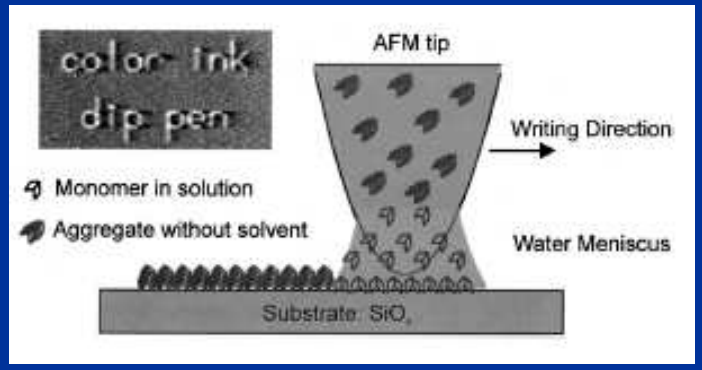
- Property improvements
  - Higher stiffness
  - High elongation
  - Increased heat deflection temperature
  - Reduced vapor permeability
  - Improved flammability resistance
- Applications
  - Plastic housings for automotive and mass transit
  - Heat shrinkable tubing
  - Wire and cable insulation

Micro- and Nanocircuitry





- **Microcircuitry**
  - Inkjet printing
  - Microdispensing
  - Nanomaterials needed to support fine feature size
- **Nanocircuitry**
  - Dip-pen nanolithography
  - Nanotubes and nanowires
- **Applications**
  - Portable electronics
  - Active matrix displays
  - Sensors

Nanoparticles for embedded identification

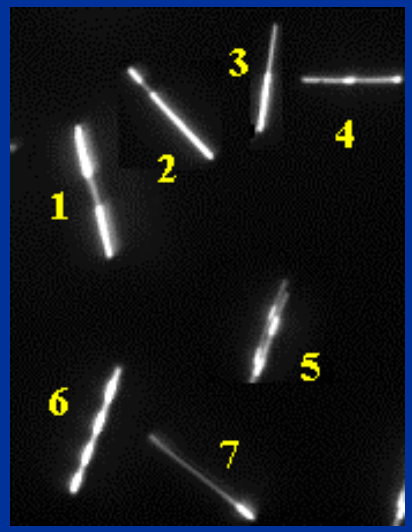


Image of Nanobarcodes™ from Nanoplex Technologies

- Nanoscale luminescent materials such as nanobarcodes or quantum dots can be incorporated into plastics or inks
- Applications
  - Lot traceability
  - Secondary identification
  - Product tracking
  - IP and counterfeit protection

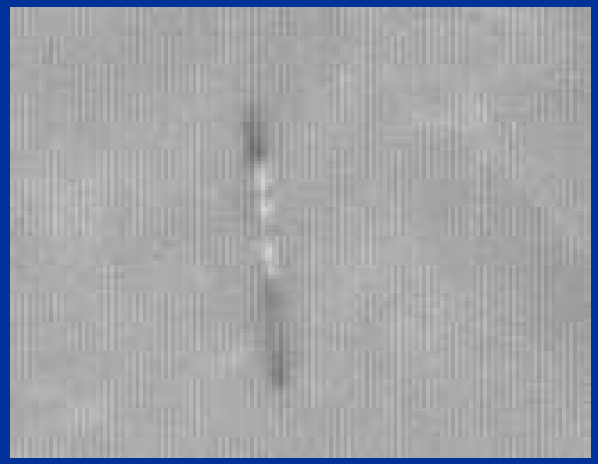


Image of a Nanobarcode™ embedded in silicone

Nanomaterials in Electronics Components

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- Nanomaterials have been used for many centuries in a wide variety of applications
- The electronics components industry currently employs nanomaterials in many products
- Nanomaterials are ideally suited to provide solutions for the continuing demands for smaller, more robust, and cost effective solutions
- Combining nanomaterials with advanced processing and fabrication techniques will open doors to new smaller, smarter, higher performing products

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