



Nanotechnology without the Hype
Brown Enterprise Forum

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President

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**Nanotechnology vs.
Molecular Nanotechnology**

Nanotechnology

- Describes anything with characteristic dimensions at the nanometer (one billionth of a meter) scale.

Molecular Nanotechnology (MNT)

- Use of a controlled sequence of nanopositioning to perform mechanochemistry at exactly the reaction sites desired, flexibly manufacturing atomically precise products under software control.



Zyvex is the world's first molecular nanotechnology company.

Our vision is to be the leading worldwide supplier of tools, products, and services that enable adaptable, affordable, and molecularly precise manufacturing.



Corporate Introduction



- Privately held company; Founded in 1997
- Located in Richardson, Texas
- Detailed Five-Year Strategic Business and Marketing plans
- Detailed Technology Roadmap
- Aggressive IP strategy
- Extensive list of scientific and business publications



Resources

- Headcount: 55 and increasing
 - 14 Ph.D.s
 - Engineers, scientists, technical management
- 44,000 sq. ft. facility
- Class 1000 clean room
- Several fully equipped laboratories
- CNC-equipped machine shop
- Equipment: SEM, TEM, AFM, SPM, UHV-STM, numerous lasers, MEMS motion analyzer, electrical testing station





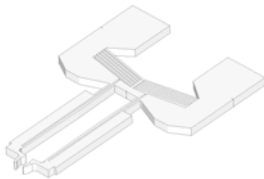
Intellectual Property

Zyvex patents

- 15 patents issued
- 42 patents pending
- 5 notifications of allowance

Categories

- Molecular nanotechnology
- Microassembly technology
- Nanostructure process techniques
- Micro- and nanodevices
- Microconnector technology
- Nanomaterials

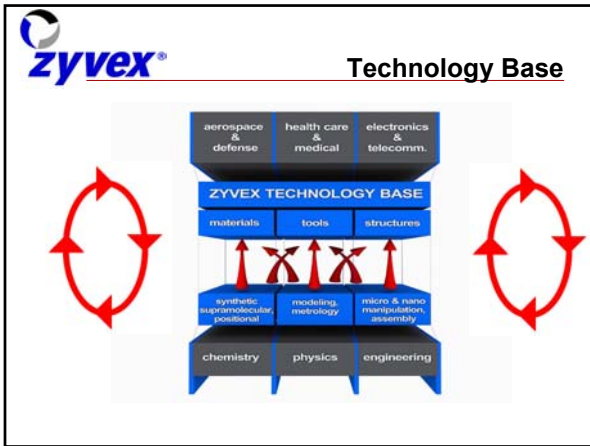


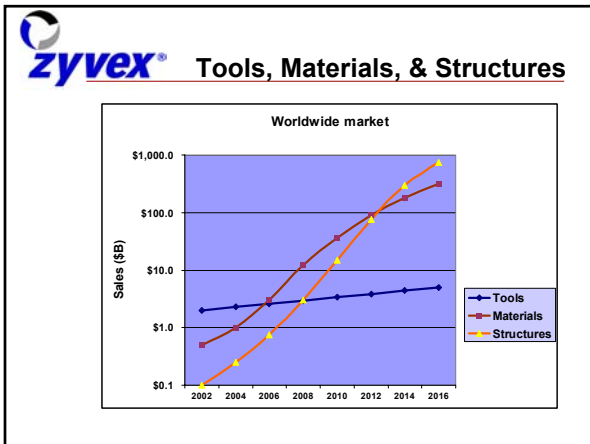
zyvex **Customers**
Partial List

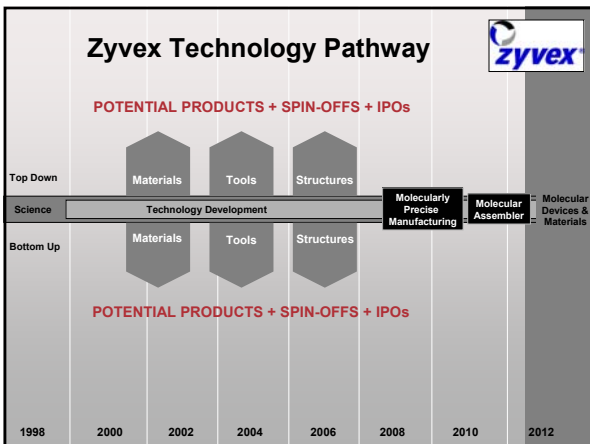
zyvex **Alliances**
Partial List

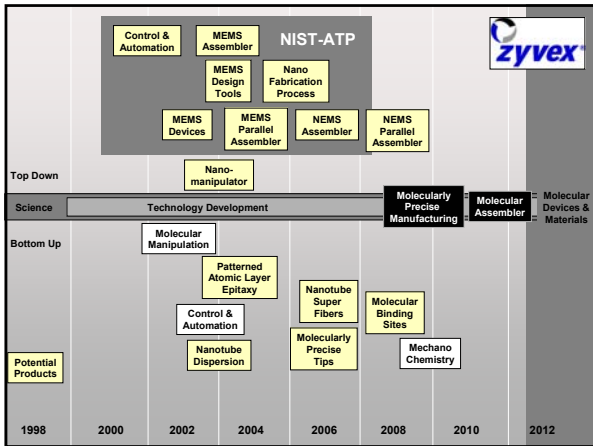
FROST & SULLIVAN


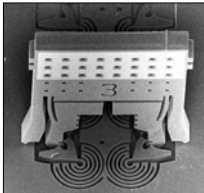
zyvex **Press**
Partial List














**The ZyveX Approach:
MicroAssembly Program**



Assembled Microsystems

- **Integrated Miniature Systems for:**
 - Miniature Analytical Instrumentation
 - Optical Systems
 - Other Applications

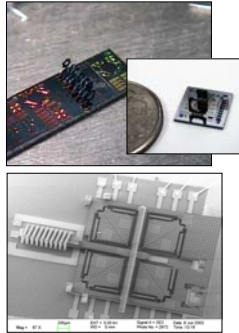




Assembled Systems

Examples:

- Miniature SEM column
- Variable optical attenuator
- Variable inductor
- Linear micromotor
- Mechtiles



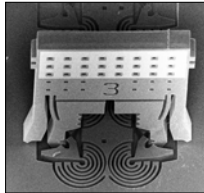


Connector Details

Self centering mechanical connectors allow higher precision than assembly robot.

- **Connector types**

- Powered gripper, zero insertion force
- Jammer gripper
- Electrical connector
- Bistable





Assembly Software

- **MEMulator assembly modeling**

- Three-dimensional modeling of MEMS-based components
- Assembled system design
- Assembly process and sequence auto-generated
- Assembly process visualized





Assembly Processes 1

- Automated, serial 5 DOF assembly
- Serial hybrid 3DOF assembly
- Parallel two-by-one powered gripper assembly
- Parallel four-by-one unpowered gripper assembly

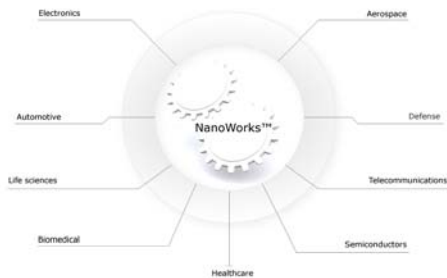




The Zyvex Approach: NanoWorks™ Tools



NanoWorks Tools Market





Zyvex NanoWorks™ Tools

- **Technology Platform with several configurations**
 - S100 Nanomanipulator System
 - F100 Nanomanipulator System
 - L100 Nanomanipulator System
 - A100 Assembly System
 - KZ100 Assembly System
 - NanoEffector™ Probes
 - NanoEffector™ Microgrippers
 - mDriver™ 1000 MEMS Driving System
 - tDriver™ 1600 MEMS Driving Station



Nanomanipulator Systems



- 3-Dimensional control
- Illuminated keypad
- Control software runs on Windows





Nanomanipulator Systems



Install in an Scanning Electron Microscope, Focused Ion Beam System, or Optical Microscope

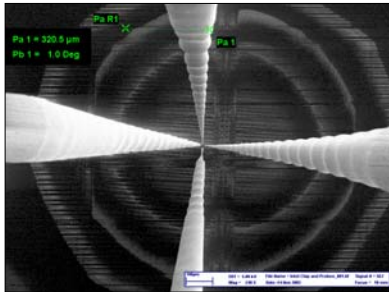


In an FIB System





Probing an IC





IC Probing

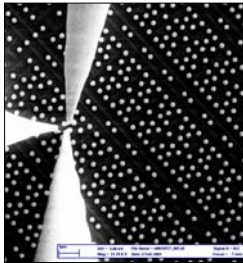
Advantages

- Compatible with SEM and FIB platform
- 5 nanometer movement control
- "Hard contact" probing
- Easy to learn, easy to use
- Low noise – 1pA measurement capability
- Proprietary NanoSharp™ Probes

zyvex® S100 IC Tungsten Via Probing

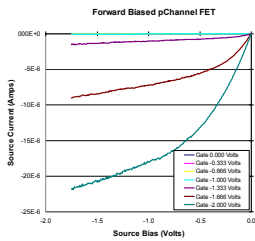
- Used Zyvex KZ100 Nanomanipulator to make electrical contact and IV data acquisition.
- Measurements were taken within seconds.
- The following data sets show the electrical response of a n-type FET with forward and reverse bias across the source and drain.

zyvex® Probing Solution



Capability demonstrated for many major U.S. semiconductor manufacturers

zyvex® Integrated Circuit Probing

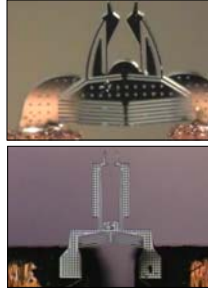


The IV curve of an integrated n-type MOS-FET was generated by the Zyvex KZ100 Nanomanipulator.



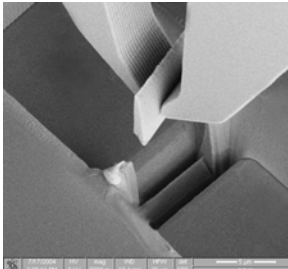
Silicon Microgrippers

- Actuation ~ 14 μm
- In-Plane per Arm:
- Gripper Stiffness ~ 400 $\mu\text{N}/\mu\text{m}$
- Gripping Force ~ 5.6 mN
- Mechanical Potential~3.9e-8 J
- Allowable Deflection ~ 20 μm
- Out-of-Plane per Arm:
- Gripper Stiffness ~ 450 $\mu\text{N}/\mu\text{m}$
- Allowable Deflection ~ 15 μm





TEM Coupon Lift-Out





NanoWorks Tools Applications





NanoWorks Tools – Applications (continued)

Application	Overall Market Category	S100	F100	L100	KZ100	A100	Probes	Grippers
MEMS assembly	Aerospace and Defense, Healthcare and Medical, Electronics and Telecom	√	√			√	√	√
Part separation & cutting	Healthcare and Medical	√	√		√	√	√	√
Nano Welding/Deposition	Aerospace and Defense, Electronics and Telecom	√	√		√		√	√
Part separation & cutting	Healthcare and Medical	√	√		√	√	√	√
Nano Welding/Deposition	Aerospace and Defense, Electronics and Telecom	√	√		√		√	√



NanoWorks Tools – Applications (continued)

Application	Overall Market Category	S100	F100	L100	KZ100	A100	Probes	Grippers
Nanoscale materials characterization	Aerospace and Defense, Healthcare and Medical	√	√		√		√	√
Nanoparticle characterization	Aerospace and Defense, Healthcare and Medical	√	√		√		√	√
Nanomanipulation	Aerospace and Defense, Healthcare and Medical	√	√	√	√		√	√
Spintronics research	Electronics and Telecom	√	√		√		√	
Field emission electron sources	Aerospace and Defense, Electronics and Telecom	√	√		√		√	
In situ experiments	Aerospace and Defense, Healthcare and Medical, Electronics and Telecom	√	√	√	√	√	√	√
Scanning tunneling microscopy	Aerospace and Defense						√	



The Zyvex Approach:
NanoSolve™ Materials

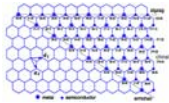


Materials Market

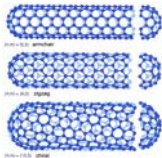




CNT Background



Graphite



Single-Walled Carbon Nanotubes



Multi-Walled Carbon Nanotubes



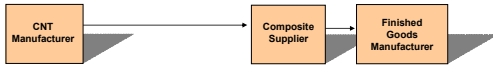
NanoSolve™ Value Chain



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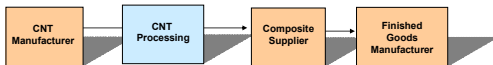
Perceived Supply Chain



If CNTs were simple materials coming from an established manufacturer, then they could be drop-in components into an existing formulation.



Actual Supply Chain



Raw nanotubes aggregate and cannot be dispersed in a host polymer.

Zyvex's Kentera™ technology fixes this problem.



Actual Supply Chain

New or Emerging Processes



- Operationally Unclear**
- Processes not in control
 - QA/QC not established
 - Production capacity unknown
 - Scale-up not guaranteed
 - Capital investment concerns
 - Possible delivery bottlenecks

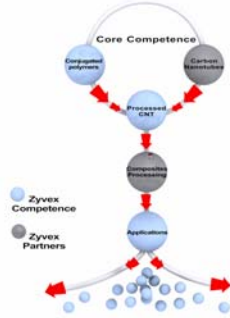
Existing Processes



- Operationally Clear**
- SOPs
 - QA/QC
 - Prices stable
 - Delivery/inventories established



Core Competence





Materials Applications





NanoSolve Materials

Applications

NanoSolve Products	Raw Nano-material	Solvent/ Solvent-free	Feature	Benefits	Host Polymers	Markets
<ul style="list-style-type: none"> Functionalized for a variety of solvents Concentrate Additive for Epoxy Resins Concentrate Additive for Polyurethane/ urea Pre-Polymers 	<ul style="list-style-type: none"> MWNTs SWNTs CNTs 	<ul style="list-style-type: none"> Water Alcohols THF Toluene Xylene Chloroform Chlorobenzene Dichloromethane Ethyl Acetate MEK Non-Solvent Formulations Available 	<ul style="list-style-type: none"> High Concentrations Stable for longer than 30 days Enhanced Properties (i.e. Electrical, Mechanical, Thermal) 	<ul style="list-style-type: none"> Easy to use Cost effective High Volume 	<ul style="list-style-type: none"> Thermoplastics Polyesters Liquid Crystals Epoxyes Acrylate Esters Polyethylene Polypropylene Adhesives Silicones Nylon PMMA 	<ul style="list-style-type: none"> Sporting Goods Aerospace Defense Semiconductor Telecommunications Biomedical Life Sciences Automotive Electronics Rapid Prototyping Mechanical Thermal Materials Safety Attrs and Equipment Textiles

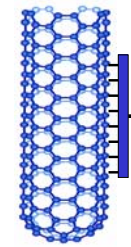


Applications

- **High strength and high stiffness composites – “world’s highest specific strength engineering material” - funded by NASA SBIR Phase II**
 - Aerospace, armor, etc.
- **High toughness composites**
 - Armor, sporting goods, aerospace
- **High thermal conductivity composites**
 - Thermal Interface Materials, Electronics packaging
- **Electrically conductive common plastics**
 - ESD, EMI shielding, conductive cockpit windows



Core Competence: Functionalizing



Functionalization technology

- Two distinct functions:
 - Non-damaging binding
 - Customizable
- Binding applicable to CNTs (SWNTs, DWNTs, MWNTs)
- Functionality may be customized for different applications:
 - Dispersion in solvents
 - Adhesion to composites
 - Other chemical functionality



Products

Additives (Processed CNTs)

- MWNT, SWNT, DWNT
- Soluble in organic solvents and water
- Customized for specific Applications
- For: Epoxies, Polyurethanes, pDCPD

Enhanced Materials

- Polyurethane

Processing Recipes

- Injection molding, Extruding, Casting



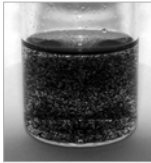
Finished Goods

- Thermal Interface Material (TIM)

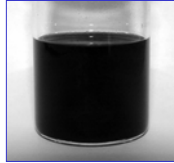


Processed Nanotubes

Product Comparison



Unprocessed nanotubes in liquid



Zyvex processed nanotubes in liquid

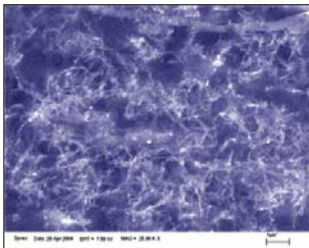


Thermal Interface Applications

- CNTs have extremely high thermal conductivities
—> 2000 W/m- degree K for some SWNTs
- CNTs in polymers could outperform existing products
- Raw CNTs in polymers do not work well
—Fail to disperse/interface with matrix
—Aggregation causes mechanical problems
—Host matrix becomes brittle or stiff
- Dispersion problem solved by Zyvex's Kentera™ technology



Dispersion of NanoSolve™

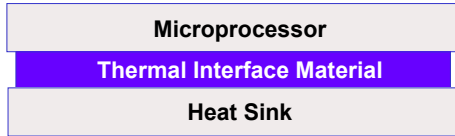


SEM of polyurethane thin film composite loaded at 2.5 wt% with a Zyvex NanoSolve™ SWNT additive. The additive appears as white fibers retained in the matrix.



Electronic Packaging Applications

Removing heat from electronic packages





For more information:

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