STEP-AND-GROW APPROACH FOR PRECISELY POSITIONED NANOWIRE ARRAY STRUCTURE FABRICATION


*Department of Industrial & Manufacturing Engineering  
Center for Nanotechnology Education & Utilization  
The Pennsylvania State University, University Park, PA 16802 USA
Outline

• Technical Overview
• Current Techniques (Synthesis & Assembly)
• Step-and-Grow Approach
• Summary
Technical Overview

- The future success of nanotechnology lies in the ability to manufacture in large volumes in an economical and environmentally sound manner.

- Over the past several years considerable progress has been made in the synthesis of nanoelements (powders, tubes, wires, rods, and fibers, among other geometries). However, post growth assembly techniques are neither practical nor necessarily environmentally safe.


SiGe nanowires grown by VLS technique using a commercially available alumina template*
**Current Techniques (Synthesis)**

* TOP-DOWN Approach Example

**ADVANTAGES:**
- Highly oriented wires
- Good contact with electrical terminals

**DISADVANTAGES:**
- Slow & expensive
Current Techniques (Synthesis)
* BOTTOM-UP Approach Example

- Porous materials as host templates for nanowire growth
- Techniques for filling the templates: pressure injection, electrochemical deposition, vapor deposition

**ADVANTAGES:**
- Cost effective

**DISADVANTAGES:**
- Need to harvest
- Placement needed
Current Techniques (Assembly)

Example 1: Pick and Place

Example 2: Electric Field Induced


Step-and-Grow Approach
- Using the Template

Example: Polyaniline (PANI) Nanowire Synthesis

Process Flow

- electrical pads on substrate
- positioning of template
- separation
- synthesis
Step-and-Grow Approach - Template Plate Fabrication

- e-beam resist spin-coat
- e-beam exposure/development
- hard mask deposit
- lift-off
- dry-etching
- hard mask etching
- template plate casting on master mold
- template plate separation from master mold
Synthesized PANI Nanowires

PANI nanowires

electrode

silicon oxide

electrode

200nm PANI nanowires
Synthesized PANI Nanowires

- Demonstration of 40 Sequential Synthesis Events Using a Single Template Plate
Synthesized Sn Nanowires
I-V Characteristics

• 200nm Single Nanowire

I-V characteristics of single PANI nanowire (200nm wide, 200nm high)
Manufacturing Perspective

- Reduce Cost
- Reuseable “tooling”
- Establishing process parameters
- Process time, throughput
- Dimensional Specs
- In process Inspection
- Yield, Quality, Process Repeatability
Fabrication of Electrodes
Process time is 8hrs
(Multiple Wafers)

New SiO₂ Substrates
Lithography
Development
Dry Etching
Metal Deposition
Lift Off
Cut Wafer with Electrodes

Fabrication of Templates
Process time is 3hrs
(Multiple Templates)

Clean Master Mold
Apply h-PDMS
Cure h-PDMS
Apply s-PDMS
Cure s-PDMS
PDMS Template Separation

New SiO₂ Substrates
E-beam
Development
Metal Deposition
Lift Off
Dry Etching
Wet Etching
Cut Wafer
Apply TFOS Layer

Fabrication of Master Mold
Process time is 1day
(Only 1 Wafer!)

Place Template on Wafer
Apply Precursor Solution
Apply Voltage on Electrodes
Check for Electrical Conductivity
Separate Template from Wafer
Check for Electrical Conductivity

Step-Place-Grow Process Time is 6mins per Substrate
Summary

• We have demonstrated an integrated synthesis/assembly approach that is economic and environmentally safe.

• This approach solves major manufacturing problems associated with nanowire devices since it results in a multiplicity of precisely positioned, oriented, and electrically contacted nanowires without the need for any “pick-and-place”.

• The “grow-in-place” architecture and methodology remove the need for template dissolution, post-synthesis nanowire manipulation, and post-synthesis electrical contacting.

• In addition, the “grow-in-place” manufacturing approach is environmentally friendly. The nanowires have little possibility of escaping into the environment.

• Still need to address more manufacturing concerns