Growth and Characterization of Aluminum Nitride (AlN) Nanowires

Alicia Herro
Senior, Physics, College of Arts and Sciences, University of North Texas
Nanotechnology

• Scale of up to 100 nanometers (nm)
  – 0-D: no dimension over 100 nm (quantum dots)
  – 1-D: only one dimension over 100 nm, one degree of ‘freedom’ (nanowires)
  – 2-D: two dimensions over 100 nm (thin films)
  – 3-D: all dimensions larger than nanoscale (bulk)

• Effects of quantum mechanics can be seen
Benefits of AlN

- High Thermal Conductivity [285 W/(m·K)]
- High Resistivity
- Resists Corrosion
- Large Piezoelectric Coefficient (5.1 pm V⁻¹)
- Good Mechanical Strength
- Low Dielectric Loss
- Chemically Stable
- Wide-Band Gap Semiconductor (6.3 eV)
Prior Work

• Summer Research Experience for Undergraduates (REU)
  – National Nanotechnology Infrastructure Network (NNIN)
  – Howard University
REU Project Goals

• Manufacture AlN nanowires both with and ultimately without a catalyst
• Test the effects of the growth conditions on the production of AlN nanowires
• Test and characterize some of the simple mechanical and electrical properties
Difficulties

• **Gibbs free energy of formation:**
  – Determines what products a reaction forms
  – The lower the free energy the more favored that product is

• **At the same temperature (773 K) the Gibbs free energy of formation for:**
  – Aluminum oxide \((\text{Al}_2\text{O}_3)\) is -1432.6
  – AI N is -219.2*

• **Any oxygen in our system would therefore bond to the aluminum instead of allowing it to bond with the nitrogen**

Growth Procedures

• Used NH$_3$ (Ammonia) as the source of the nitrogen

• Used AlCl$_3$ (Aluminum Chloride) powder as the source of aluminum
  – Used .2 grams
  – Held in a BN (Boron Nitride) boat

• Put substrates 30 cm downstream of the sources
CVD Setup

- Quartz Tube
- Quartz Liner
- NH$_3$
- BN boat with 0.2 g of AlCl$_3$
- Substrates

Quartz Tube to Quartz Liner = 30 cm
REU Results

• Many samples had a powder deposited on them, composed of either Al and O or of Al and N
  – AlN larger than nano
  – Al$_2$O$_3$ formations varied
    • Different compositions
    • Different growth parameters
Varied Formations of $\text{Al}_2\text{O}_3$
Inferences

• The presence of Al and N
  – Shows that AlN is being formed
  – May hint that the flow of NH$_3$ is not correct

• Presence of oxygen
  – Al is getting oxidized
  – Environment is not perfect
  – The reaction is running in its favored direction
Current Growth Methods

• Vapor-Liquid-Solid (V-L-S) growth – with catalyst
Experimental Method

• Sapphire substrate
  – Closer to the lattice spacing of AlN than silicon
  – No catalyst
    • Thin tips
    • No bead at the end

• Low temperature
  – 875°C
  – Fewer defects
Current CVD Setup

Argon + NH₃

Quartz Tube

= 3 cm

Alumina boat with Al powder

Sapphire
Expected Results

• Nanowires
  – Dense growth pack
  – Nearly vertical arrangement
  – Equal spacing
Acknowledgements for the Summer Research:

- Dr. Gary Harris
- Mr. Crawford Taylor
- Mr. James Griffin
- Ms. Karina Moore
- HNF faculty
- NNIN and the NSF for funding the project
Acknowledgements

• The UNT Honors College
  • Dr. Usha Philipose
• UNT Department of Physics