Silicon Nanowire for Sensing

Fabio Rui
Silicon Nanowire

• 1-D nanomaterial, single crystalline
• Introduced 2001
• Sensing of ions, small molecules, nucleic acids or proteins
• Ultra sensitive
Fabrication

• Top-down (a)
  • Expensive
  • Time consuming
  • 20-100nm

• Bottom-up (b)
  • No mass product
  • Alignment
  • <10nm possible
Electrostatically formed Nanowire
Tuning and Scanning

(a)  
0.5 V  p⁺  0.5 V  n⁺  SiO₂  p⁺  JG1  JG2

(b)  
0 V  p⁺  0 V  n⁺  SiO₂  p⁺  JG1  JG2
Controlled Alignment

• Lengmuir-Blodgett
  • Water-air interface
  • 8-10 NW per $\mu m$
• Blown-bubble
  • Gas flow 1 NW per 3 $\mu m$
Surface functionalization

• 1-2 nm native oxide layer
• Silanol groups
Reusable Surface

- Functional group
- Antibody
- Sensing
- Clean and reuse
How it works

• Receptors on SiNW
• Between S and D
• Sensing solution
• Change of conductance
FET

*n-channel Enhancement-mode ( Normally-off)*)

\[ I_D \]

\[ \begin{align*}
    +V_G & : V_G = 0 \\
    -V_G & : V_G = 0
\end{align*} \]

**A**
- Metal gate
- Oxide
- Source (S)
- Drain (D)
- p-Si
- G

\[ V_G < 0 \]

Accumulation of carriers
Conductance increase

**B**
- Surface chemistry
- Molecular binding
- Accumulation of carriers
- Conductance increase

Molecular gate
Summary

• Small
• Low cost
• Label-free
• Real-time
• Sensitive
• Diagnostics of diseases
• Screening
• Environmental monitoring
References

• Silicon nanowire field-effect transistor-based biosensors for biomedical diagnosis and cellular recording investigation; Kuan-I Chen et al 2010

• Silicon nanowires as field-effect transducers for biosensor development: a review; M. Omair Noor et al 2013

• Silicon Nanowire Field-Effect transistors a versatile class of potentiometric nanobiosensors; Luye M U et al 2015

• High Performance Silicon Nanowire Field Effect Transistors; Yi Cui et al 2002

• Tuneable diameter electrostatically formed nanowire for high sensitivity gas sensing; Alex Henning et al 2014