Molecular Monolayers for Conformal doping on vertical transistors

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I will take you through....

- Need for conformal doping on state-of-the-art transistors
- Self Assembled Monolayers (SAM) : a brief introduction
- Characterizing SAM
- Method of doping using SAM
- Characterization of doping : techniques
  - Electrical
  - Material
- Pros and cons of this method
State-of-the-art transistors

**Figure:** Planar MOSFET vs FinFETs

source: realworldtech.com
Simulations showing improved ON current

Figure: Top Only source drain extension - Conformal extension
Simulations showing improved ON current

Figure: ON current comparison of the two devices

Pitch : Shadowing effects

Figure: Tilted ion implantation, improvement in conformal doping

Source : Damien Lenoble et al., The junction challenges in the FinFET device, IEEE IWJT, 2006.
Energy of implantation: Recrystallization defects

**Figure:** Amorphous Silicon: Recrystallization defects for narrow fins

Self-Assembly on any substrate: How is it achieved?

Self assembly is achieved in two steps:
- Functionalizing the surface to aid the covalent bonding
- Growth phase: Exposing the functionalized surface to the organic molecules

**Figure:** One way of achieving hydroxyl functionalization on silicon followed by SAM formation
Examples of prominent self assembly systems

- Gold-thiol self assembly: investigated for work function tuning in OFETs, for sensing applications etc.
- Alumina-phosphonate SAMs used as dielectric in OFETs, better layer for an organic semiconductor growth compared to the alumina surface
Methods of forming a SAM

Two ways of achieving this

- Liquid phase/ Solution phase SAM growth: SAM formed by dipping in a solution
- Vapour phase SAM: A carrier gas takes this compound in vapour phase
Characterization techniques for SAM

- Elemental analysis tools such as XPS
- Bond energy measurement such as FTIR

**Figure:** XPS data for As in PAO
The 2 step process

**Figure:** Various steps involved in doping
Why the method leads to a conformal doping

Since the SAM forms uniformly all over the substrate surface, there would be maximum step coverage on the 3D structures too!

**Figure:** Motivation behind this work for fin like structures
Electrical characterization techniques

Measuring Sheet Resistance after doping

Figure: Sheet resistance measurements on bare wafers
Electrical characterization techniques

Type Conversion in CVs

Figure: P type to N type conversion
Material characterization techniques

- SIMS measurement to study the doping profile

**Figure:** Arsenic doping profile in Silicon
Figure: Growth on 3D structures
EDS spectral analysis on this sample

**Figure:** EDS analysis on the previous surface
State-of-the-art fin structures
AFM characterization

3D AFM image of 150nm wide fins

Another profiling using AFM across a single fin to measure height

**Figure:** AFM scans on bulk silicon fins
Conclusion

- A different approach towards defect free doping is experimented.
- Doping on bare wafers with As dopants are studied.
- The dopant distribution on fin structures are currently being looked at.
- Objective is to demonstrate successful doping on these structures uniformly with minimum defects.
Thanks a ton for being patient listeners!!