Molecular Monolayers for Conformal doping on vertical transistors

Reshma Krishnan Under the Guidance of Prof. V.R. Rao

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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 ON-current improvement in conformal doping Doping source and drain: Implantation challenge

State-of-the-art transistors



Figure: Planar MOSFET vs FinFETs

source : realworldtech.com

State-of-the-art transistors ON-current improvement in conformal doping Doping source and drain: Implantation challenges

Simulations showing improved ON current



Figure: Top Only source drain extension - Conformal extension

State-of-the-art transistors ON-current improvement in conformal doping Doping source and drain: Implantation challenges

Simulations showing improved ON current



Figure: ON current comparison of the two devices

Source : Bartek J. Pawlak, Doping Strategies for finfets, Materials, Science Forum Vols. 573-574, 2008, pp. 333-338.

State-of-the-art transistors ON-current improvement in conformal doping Doping source and drain: Implantation challenges

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.

State-of-the-art transistors ON-current improvement in conformal doping Doping source and drain: Implantation challenges

Energy of implantation: Recrystallization defects



Figure: Amorphous Silicon: Recrystallization defects for narrow fins

Source : Bartek J. Pawlak, Doping Strategies for finfets, Materials Science Forum Vols. 573-574, 2008, pp. 333-338.

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

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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 method of doping Characterization techniques for doping

The 2 step process



Figure: Various steps involved in doping

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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

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Electrical characterization techniques

Measuring Sheet Resistance after doping



Figure: Sheet resistance measurements on bare wafers a set \mathbb{R}^{2} , \mathbb{R}^{2}

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Electrical characterization techniques

Type Conversion in CVs



Figure: P type to N type conversion

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Material characterization techniques

• SIMS measurement to study the doping profile



Figure: Arsenic doping profile in Silicon

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SAM on fins



Figure: Growth on 3D structures

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EDS spectral analysis on this sample



Figure: EDS analysis on the previous surface

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State-of-the-art fin structures



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AFM characterization



Figure: AFM scans on bulk silicon fins

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Conclusion

- A different approach towards defect free doping is expeimented
- 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

The method of doping Characterization techniques for doping

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Thanks a ton for being patient listeners!!