Report on Hands-on Training Program
"Semiconductor Devices for Quantum Applications"
Organized by: Nanoscale Research Facility (NRF), IIT Delhi
Dates: July 21–25, 2025
Sponsored by: QMD Foundation under the National Quantum Mission (NQM)

1. Introduction

The Nanoscale Research Facility (NRF) at IIT Delhi, a premier hub for nanotechnology and device research in India, hosted an intensive **five-day national-level hands-on training program** on *"Semiconductor Devices for Quantum Applications"*. The workshop, conducted under the aegis of the **National Quantum Mission (NQM)** and sponsored by the **QMD Foundation**, served as a landmark initiative to bridge the knowledge and skill gap in the fabrication and characterization of advanced quantum-enabled semiconductor devices.

With growing momentum in quantum technology worldwide, this training emerged as a **crucial step toward preparing the next generation of quantum device scientists and engineers**, offering access to cutting-edge cleanroom infrastructure and expert mentorship from leading scientists and technocrats.

2. Distinguished Coordination and Participation

The program was meticulously coordinated by:

- **Prof. Rajendra Singh** – Associate Dean (R&D), IIT Delhi
- **Prof. Vamsi K. Komarala** – Coordinator, NRF
- **Prof. Samaresh Das** – Expert in CMOS technology
- **Dr. Uday Dadwal** – Cleanroom safety and device fabrication specialist

Their leadership ensured that the event offered not just lectures but deep, practice-driven engagement with sophisticated tools, materials, and real-world protocols.

3. Day-wise Summary of the Training

Day 1: Setting the Quantum Stage

The training commenced with a vibrant **inaugural session** and **welcome address by Prof. Vamsi K. Komarala**, introducing participants to NRF's vision. The inaugural lecture by **Prof. Rajendra Singh** on the **National Quantum Mission (NQM)** provided critical insight into India's long-term strategic goals in the quantum domain. This was followed by **cleanroom protocol training** by Dr. Uday Dadwal, emphasizing the discipline, precision, and safety essential in quantum semiconductor processing.

A guided **lab tour of the NRF cleanroom facility** offered participants a rare opportunity to interact directly with equipment such as sputter systems, lithography units, and deposition chambers—many of which are at par with international standards.

Day 2: Designing the Quantum World

The day started on an inspiring note with an **online keynote lecture by Dr. Vinod Dham**, fondly known as the 'Father of the Pentium chip'. His thoughts on innovation, self-reliance in semiconductor technology, and India's rising potential electrified the audience.

This was followed by a **deep-dive session on mask design and device layout** by **Dr. Nahid Chaudhary**, empowering participants to conceptualize, draft, and simulate device structures with quantum relevance. Practical sessions on **wafer cleaning** and a foundational lecture on **CMOS technology by Prof. Samaresh Das** capped off a day packed with ideation and process initiation.

Day 3: Material Deposition and Precision Patterning

A crucial day focused on **thin-film engineering and photolithography**. Ragani led the participants through oxide growth and deposition techniques—vital for dielectric layer formation in quantum devices.

This was followed by a highly interactive, hands-on session on **photolithography** by Manjeet, allowing the participants to physically transfer patterns onto semiconductor wafers, an experience seldom available outside high-end R&D facilities.

Day 4: Metallization and Device Finalization

Prof. Rajendra Singh, Associate Dean (R&D), delivered a **deeply insightful and engaging one-hour technical lecture** that set the tone for the rest of the training. Moving beyond a basic introduction to the National Quantum Mission, Prof. Singh gave participants a **masterclass on semiconductor device fabrication**. He meticulously explained the complete process flow—from wafer selection to final device characterization—demystifying each stage with practical examples and visuals.

A **key highlight of his session** was a live demonstration of **various types of semiconductor wafers**, including:

- **Si (100) and Si (111)** wafers
- **SOI (Silicon-on-Insulator)** wafers
- **III–V compound wafers** like GaAs and InP
- **Sapphire substrates**, often used in quantum photonic devices
- **SiC and GaN** wafers for high-power applications

He discussed in detail the **specifications of each wafer**—such as crystal orientation, doping type and level (n-type, p-type), resistivity, thickness, surface finish, and cleanliness standards (prime vs. test grade)—and emphasized **how these parameters critically influence device performance**.

Prof. Singh also explained **how wafer selection varies with application**, such as for CMOS, MEMS, quantum dots, or photonic devices. He shared **insights on global wafer suppliers**, comparing manufacturers like **Siltronic, SUMCO, Soitec, and Wafer World**, and discussed procurement strategies for research labs and industries.

His lecture was **enlightening for beginners and advanced researchers alike**, as it connected the dots between theory, fabrication, and real-world device applications. The session also provided valuable practical context for the subsequent hands-on modules.

The focus shifted to **contact engineering and metallization**. Shivansh conducted a detailed walkthrough of **metal deposition processes**, followed by a critical session on **contact formation and lift-off techniques**, led by **Mr. Manish Kumar Rautela**. This step was pivotal as it marked the transition from mere structures to working device components.

Each participant got a rare chance to operate or observe **real-time fabrication steps**, allowing them to understand the nuances of cleanroom workflow, alignment accuracy, and material compatibility in multilayered device architectures.

Day 5: Electrical Characterization and Grand Conclusion

The final day of the training program marked the **culmination of an immersive journey** through the processes of semiconductor device fabrication for quantum applications. The day's activities revolved around **electrical characterization—the moment of truth for any fabricated device.**

Led by **Shivansh**, participants were guided through intricate techniques such as **I–V (current-voltage) measurements, probe station handling, and device parameter extraction.** These real-time evaluations helped participants interpret performance indicators such as threshold voltage, contact resistance, leakage current, and rectification behavior, providing a tangible understanding of how theoretical parameters manifest in actual devices.

The **post-lunch session took a reflective and celebratory turn** with an engaging quiz—designed not as an exam, but as a lively and enjoyable recap of the entire week's learnings. It stimulated collaborative discussion among participants and gave them a chance to reinforce key concepts through a more informal and fun format.

Valedictory Session: Reflections, Recognitions, and Renewed Vision

The final session, held at the **NRF Committee Room**, was both emotional and uplifting. Each participant received a **certificate of successful completion**, acknowledging their active engagement and hands-on performance during the week-long program. The **technical team and lab assistants were specially recognized** for their unwavering support and precision in managing sophisticated equipment and ensuring smooth operations throughout.

The session featured **remarks and reflections from participants**, many of whom described the training as a **transformative learning experience**:

Closing Remarks by the Coordinators

Prof. Rajendra Singh, Associate Dean (R&D), addressed the participants with heartfelt words, acknowledging their discipline and enthusiasm. His concluding remarks emphasized the strategic importance of such training programs in the context of the **National Quantum Mission (NQM)**.

"This program was not just a training- it was a capacity-building exercise to accelerate India's leadership in quantum technologies. The real test begins now- as you take this knowledge forward into your labs, your research, and your innovations."

He also encouraged participants to stay connected with NRF and leverage the growing ecosystem of collaboration made possible through national missions like NQM.

Dr. Uday Dadwal, who led many of the cleanroom practical sessions, emphasized the value of hands-on rigour:

"You've seen the challenges of precision work in a cleanroom. It's not about speed; it's about consistency, care, and a scientific mindset. Every nanometer matter when you're building quantum technologies."

The valedictory concluded with a group photo, informal networking among participants and coordinators, and a strong sense of community and shared vision for advancing semiconductor research in India.

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4. Impact and Outlook

This hands-on training program was far more than a short-term academic workshop—it emerged as a **strategic, capacity-building initiative aligned with India's long-term goals** in quantum and semiconductor technology development.

Participants walked away not only with **theoretical clarity and experimental skills** but also with **rare access to India's most advanced cleanroom infrastructure**, bridging the gap between curriculum and cutting-edge R&D. The program **empowered a new generation of technologists**—young researchers, industry professionals, and postdoctoral scholars—to become **active contributors to national missions and global innovation efforts**.

Several participants expressed their interest in continuing collaboration with NRF and IIT Delhi, highlighting the possibility of joint research, facility access, and proposal development under the NQM umbrella.

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5. Acknowledgment

This program would not have been possible without the **visionary leadership and coordination** of Prof. Rajendra Singh, Prof. Vamsi K. Komarala, Prof. Samaresh Das, and Dr. Uday Dadwal, whose commitment to research excellence and knowledge dissemination shaped the entire event.

Heartfelt thanks go to the **dedicated technical staff, speakers, trainers, and the administrative team** at NRF for ensuring seamless execution. Special appreciation is extended to the **QMD Foundation and the National Quantum Mission (NQM)** for their generous support and alignment with the nation's research priorities.

The seamless integration of **lectures, live demonstrations, cleanroom practice, and one-on-one interaction** reflected the collaborative and high-impact ethos of NRF and IIT Delhi.