A NOVEL ENABLING SEMICONDUCTOR TECHNOLOGY FOR NEXTGEN OPTOELECTRONIC INTEGRATED CIRCUITS (OIC)

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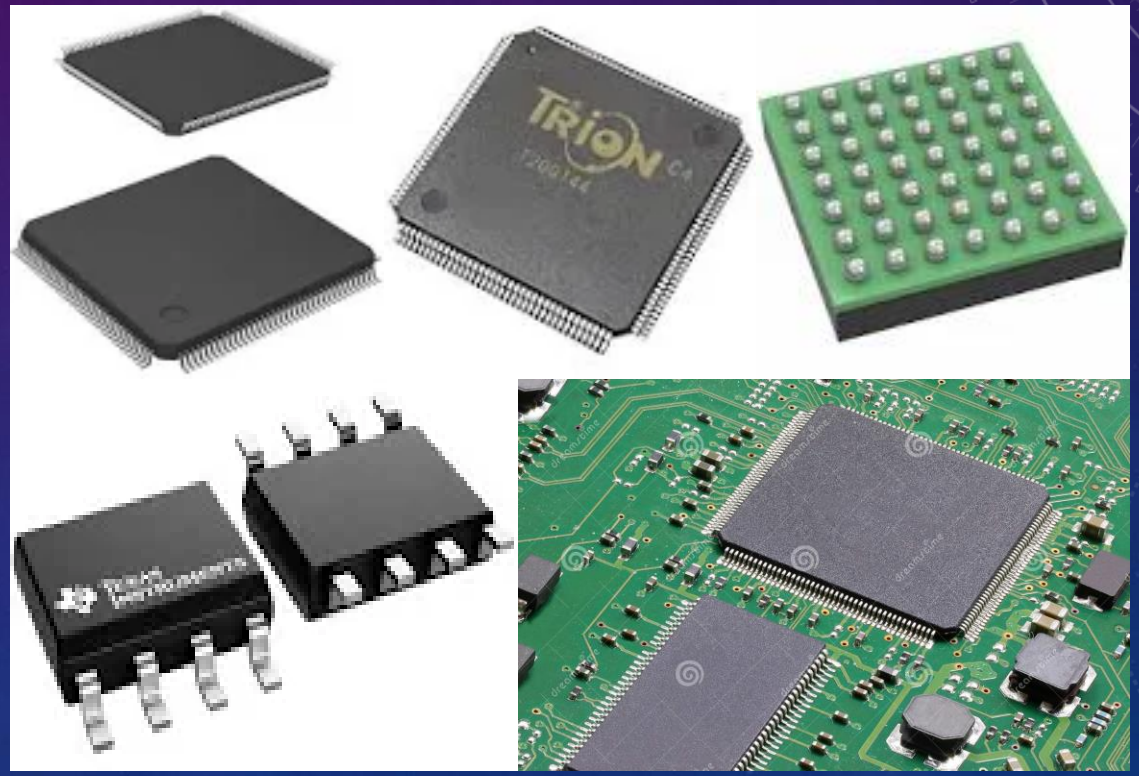
PRESENTATION LAYOUT

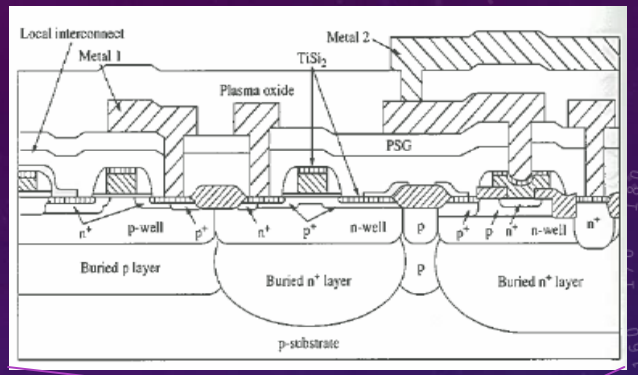
- INTRODUCTION
- SEMICONDUCTOR TECHNOLOGY– THE SILICON AGE
- OPTOELECTRONIC INTEGRATED CIRCUITS (OIC)
- SILICON GERMANIUM TIN (SiGeSn) NEXTGEN SEMICINDUCTOR TECHNOLOGY
- ULTRA-HIGH VACUUM PLASMA ENHANCED CHEMICAL VAPOR EPITAXY
- SOME REPORTED RESULTs

Electronic board with transistor microchip integrated circuits and miniaturized diodes

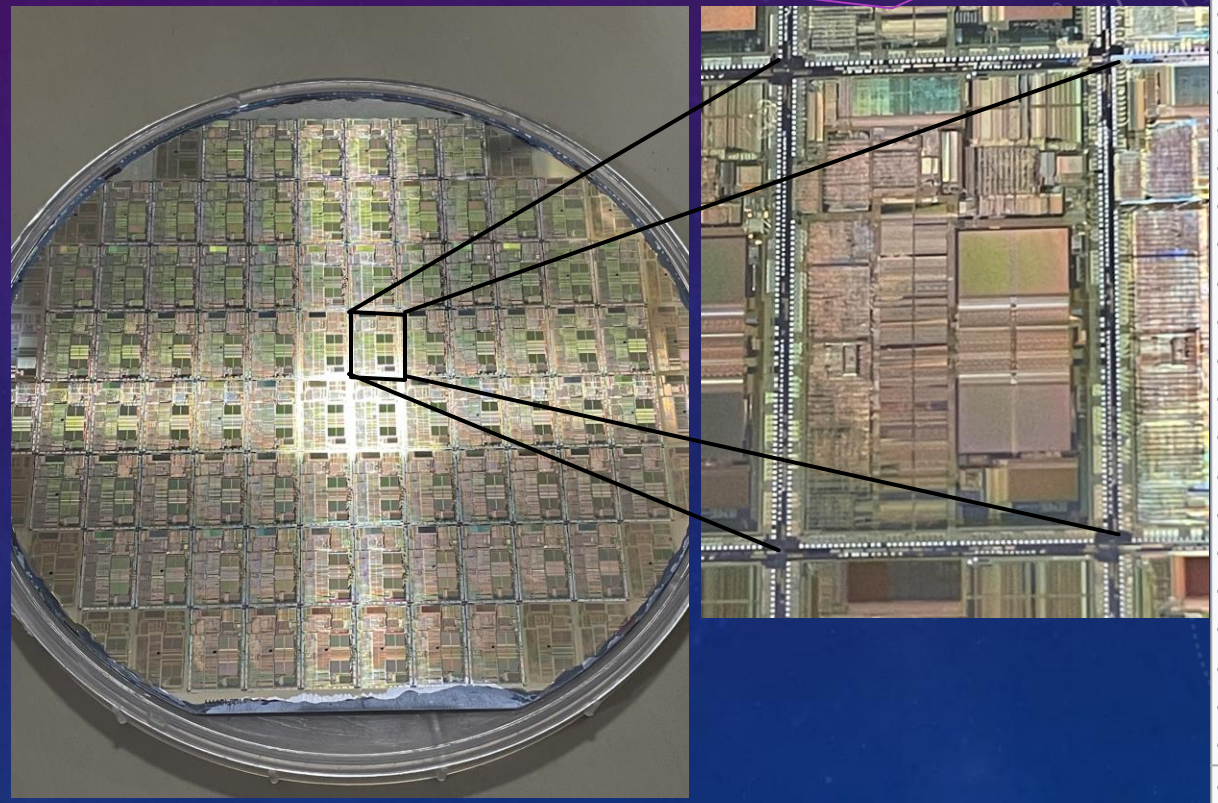
INTEGRATED CIRCUITS (IC)—THE DIGITAL REVOLUTION



IC TECHNOLOGY—SILICON AGE



- IC Technology has progressed rapidly over the years
- Minimum line widths and therefore device sizes have shrunk
- Minuimum linewidth of 30 nm in 2010 has given way to 3 nm now
- Processor speeds have not gone up due to interconnect delays
- Interconnects are made from copper and is limited by electron
- Optical interconnects could bump up speed by several orders
- We need to replace 10 levels of copper with one optical level
- Optical devices (lasers and detectors) are made in III-V not Si
- III-V semiconductors are incompatible with Si which is Group IV
- We have developed a novel enabling technology based on G IV
- GeSn and SiGeSn lasers and detectors demonstrated by us
- Even the IC could be built in SiGeSn with improved electronics
- Future technology calls for Optoelectronic Integrated Circuits

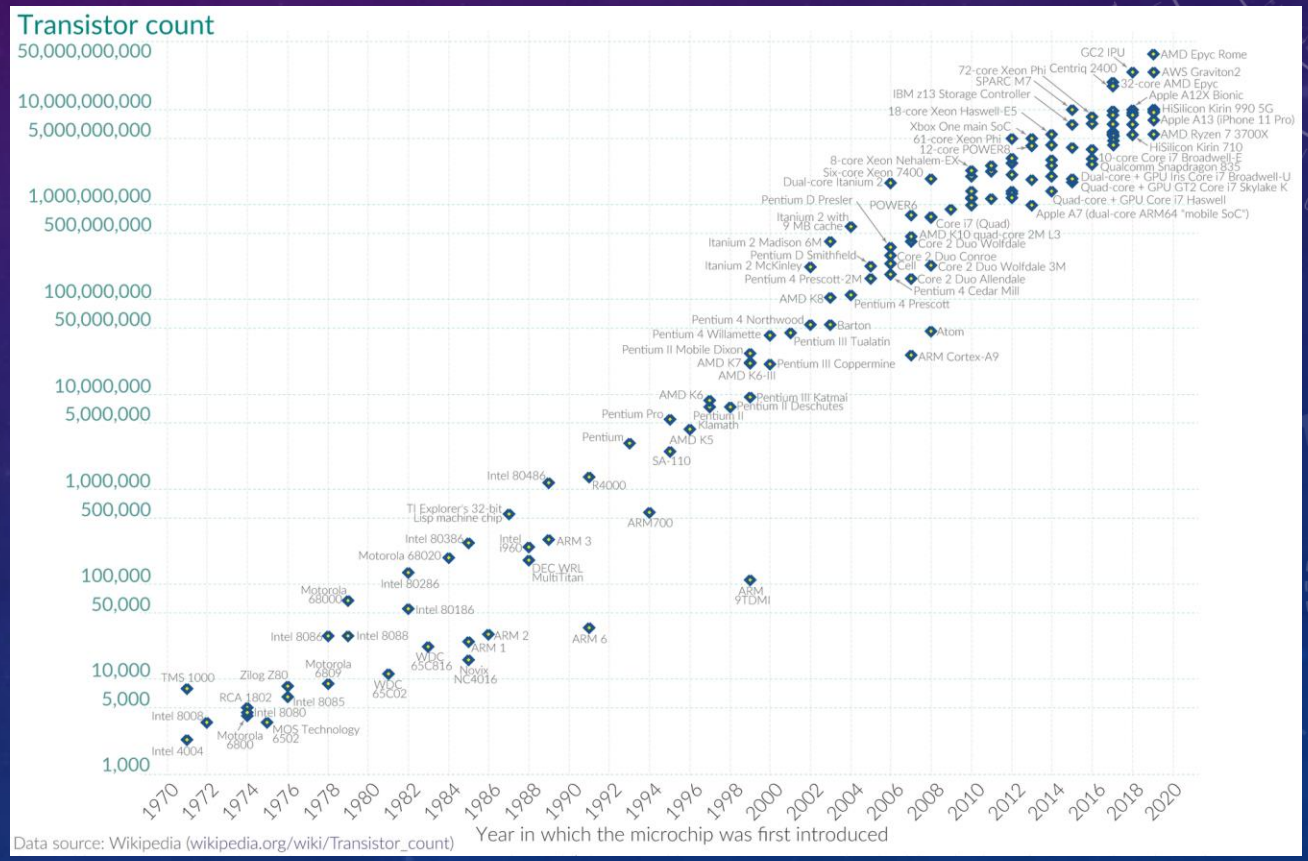


- 10 µm – 1971
- 6 µm – 1974
- 3 µm – 1977
- 1.5 µm – 1981
- 1 µm – 1984
- 800 nm – 1987
- 600 nm – 1990
- 350 nm – 1993
- 250 nm – 1996
- 180 nm – 1999
- 130 nm – 2001
- 90 nm – 2003
- 65 nm – 2005
- 45 nm – 2007
- 32 nm – 2009
- 22 nm – 2012
- 14 nm – 2014
- 10 nm – 2016
- 7 nm – 2018
- **5 nm** – 2020
- 3 nm – 2022

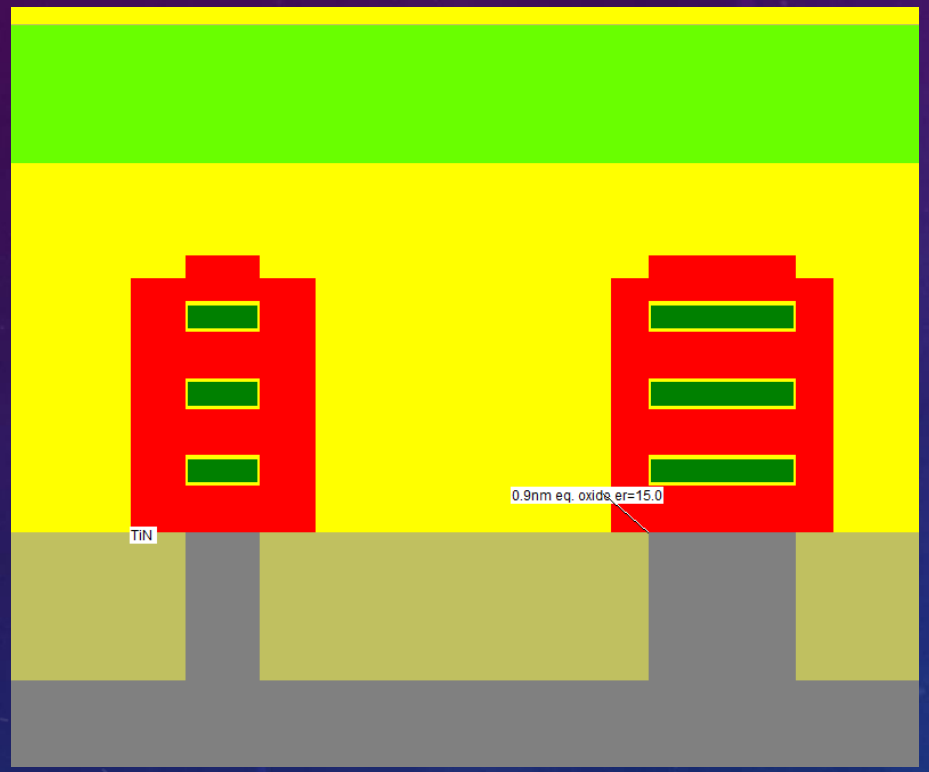
- Future 2 nm ~ 2024

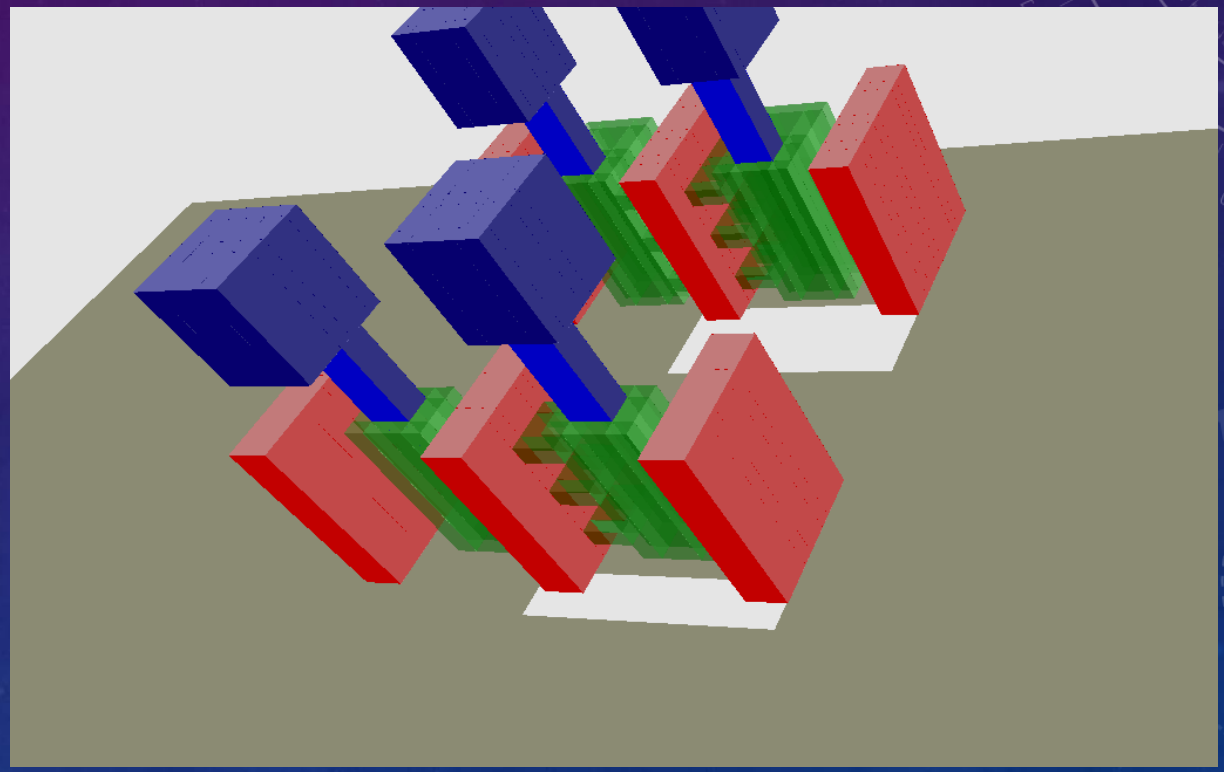
MOORE'S LAW OF DOUBLING

- SINCE EARLY 70'S THE NUMBER OF TRANSISTORS ON A CHIP HAVE DOUBLED EVERY 18 MONTHS
- MINIMUM SIZE (TECHNOLOGY NODE) ON A COMPUTER CHIP HAS REACHED 3 NM
- PROCESSING SPEED IS LIMITED BY INTERCONNECT DELAY



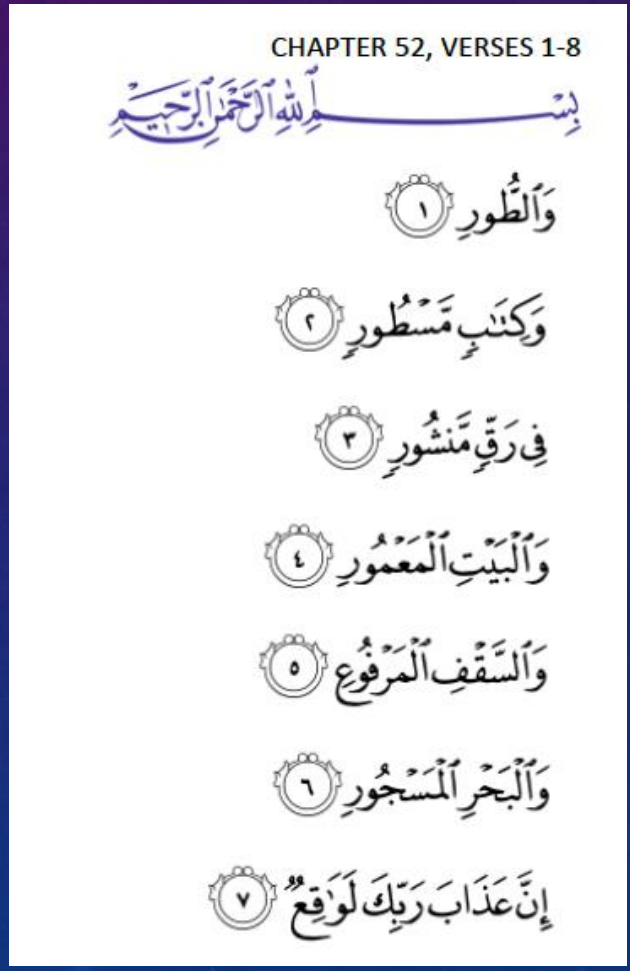
3NM NANO-SHEET FET TECHNOLOGY





THE HOLY QUR'AN MENTIONS THE DIGITAL AGE

- In the name of Allah, the gracious, ever merciful
- By the Mount Tur
- By a register, serially transmitted
- In a thin film, spread
- By the house, bustling with people
- By the building, rising high
- By the sea, flowing over
- The punishment from your Lord shall certainly come to pass



INTRA-CHIP OPTICAL SUPER-HIGHWAY

- The metallization layer count may exceed 15
- We can displace top 10 lines of copper with one optical interconnect layer
- We may have 4 to 16 optical hubs on each IC chip consisting of laser/detector pair to transfer electrical signals back and forth from optical signal
- These optical devices must be made on Si substrate using compatible SiGeSn alloy technology
- GaAs and GaN based technologies cannot provide integrated processing

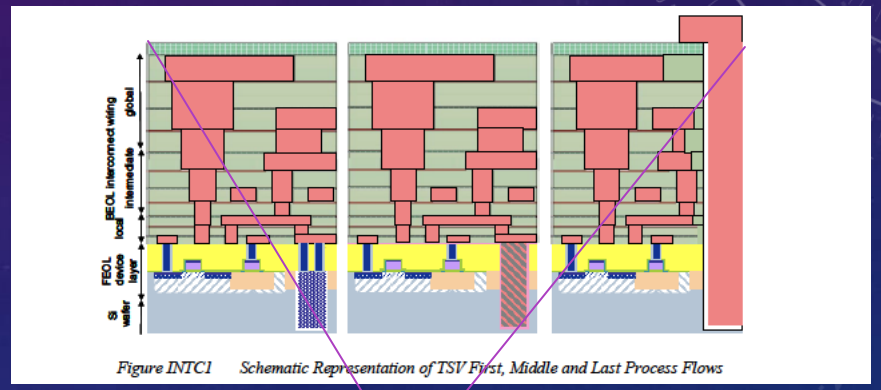
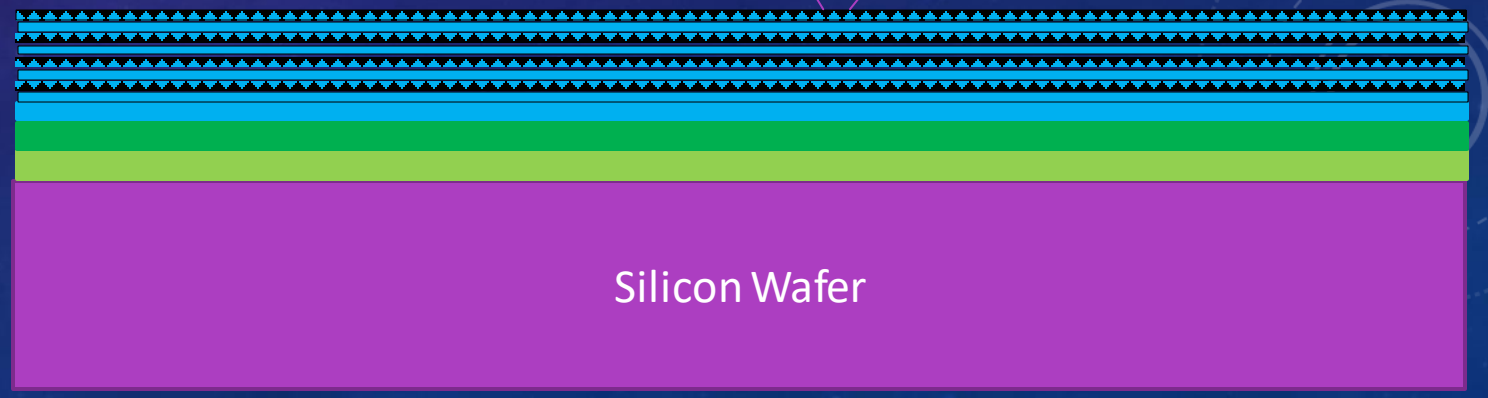
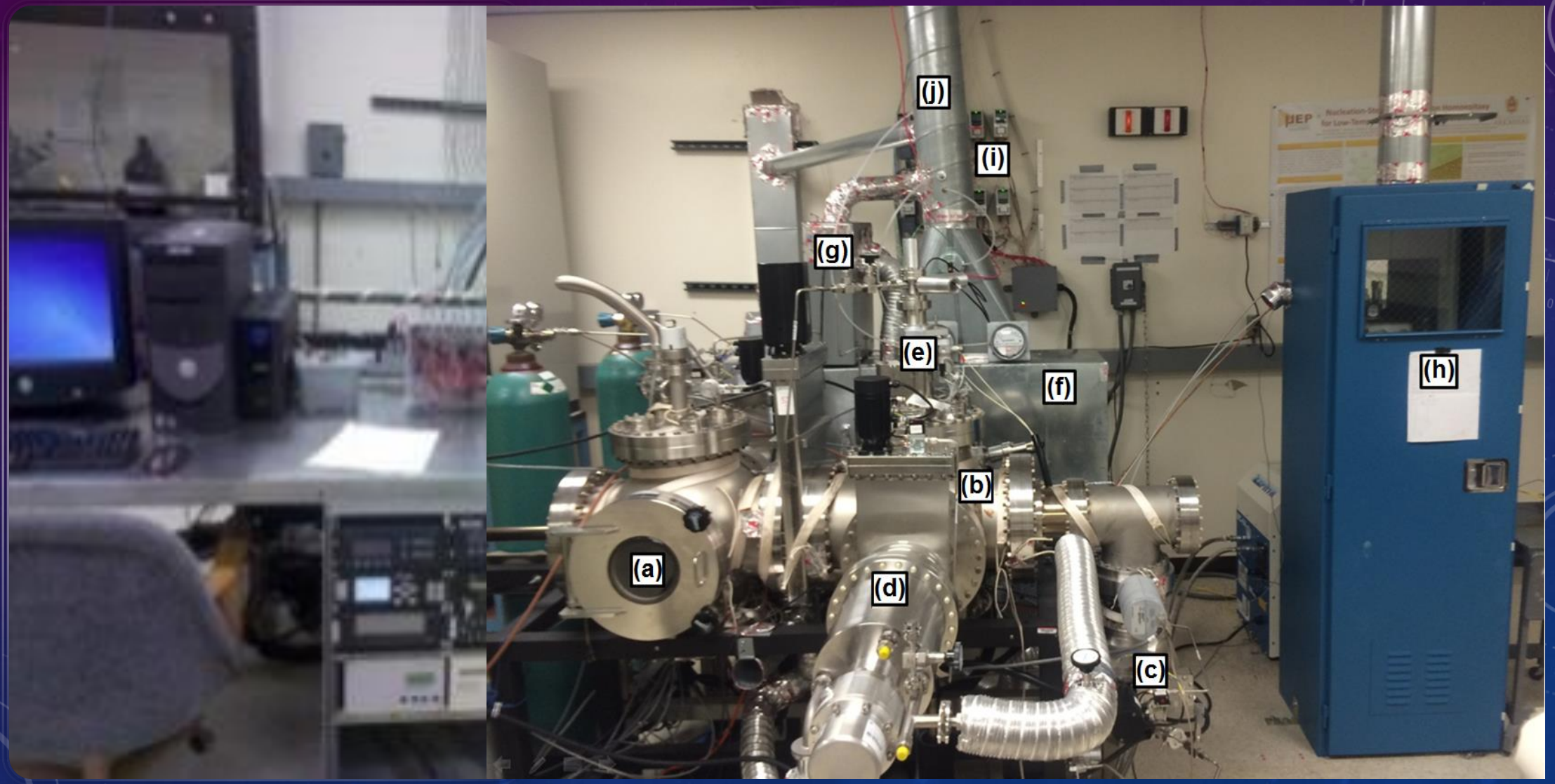


Figure INTC1 Schematic Representation of TSV First, Middle and Last Process Flows

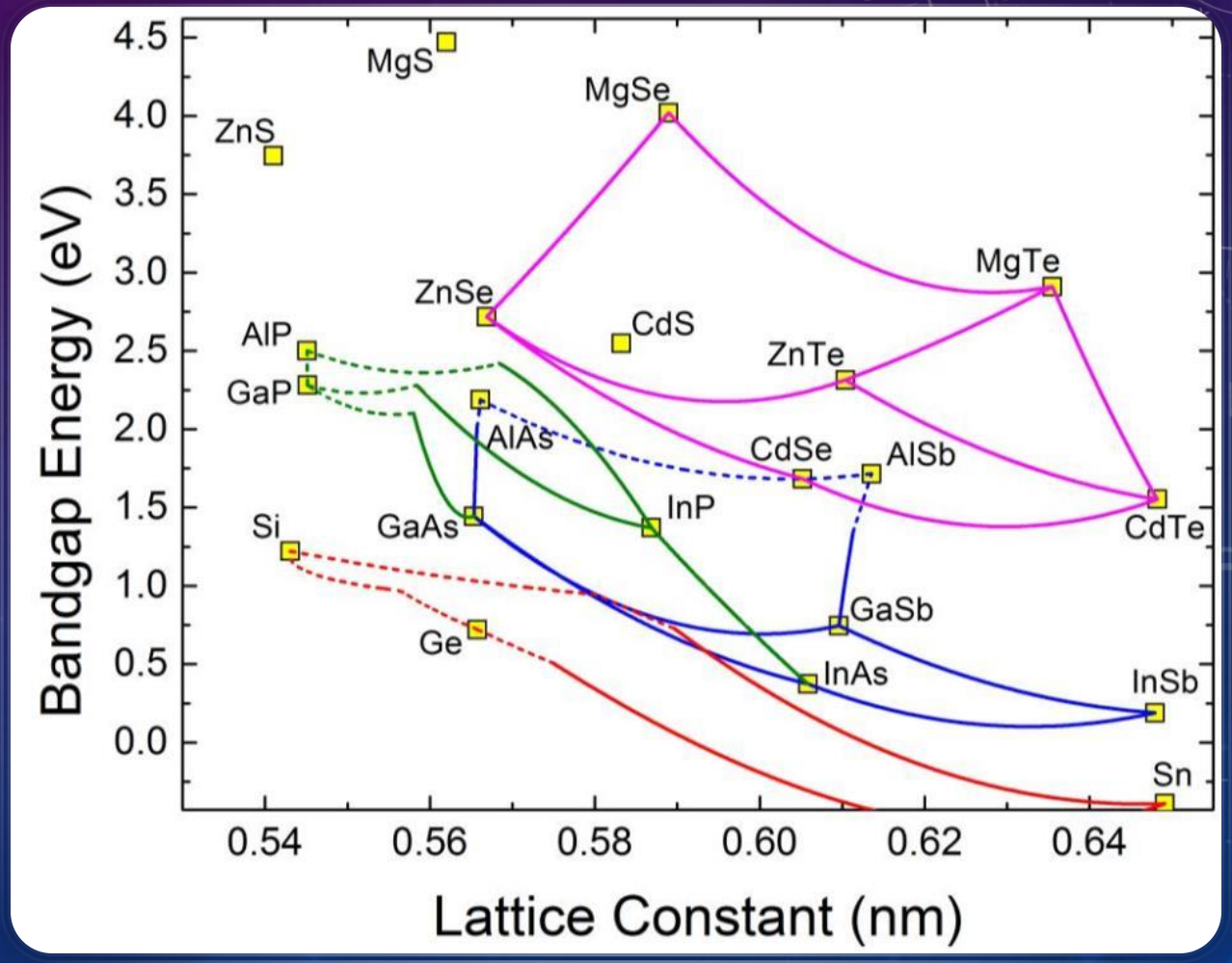


ULTRA-HIGH VACUUM CHEMICAL VAPOR C-SI-GE-SN EPITAXY

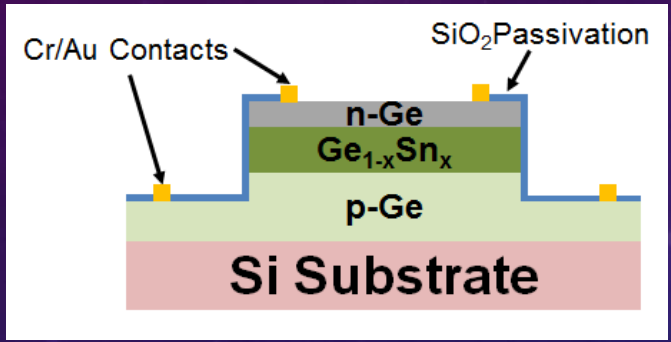


GROUP IV, III-V, AND II-VI ALLOY SEMICONDUCTOR SYSTEMS FOR BANDGAP ENGINEERING FOR OPTICAL DEVICES

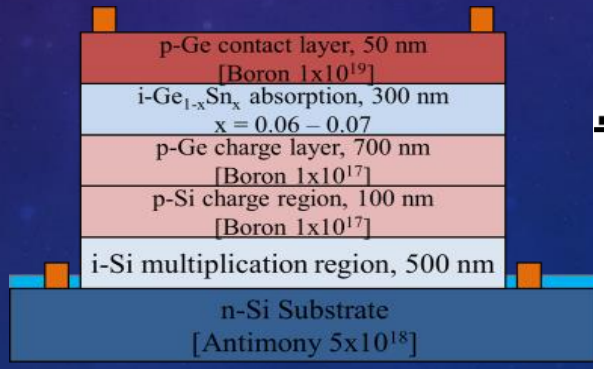
- III-V semiconductors including GaN system could range from Blue light (3.5 eV) to long wavelength (InSb) infrared radiation
- II-VI semiconductor alloy system could range from UV light (MgS) to long IR (HgTe) wavelengths
- Both these systems are incompatible with Group IV Silicon integrated circuits for integrated optical interconnects.
- Group IV alloys of SiGeSn provides a full range of wavelengths and direct/indirect bandgaps to provide long lifetimes for device application and high absorption coefficients for better thin film photodetectors.



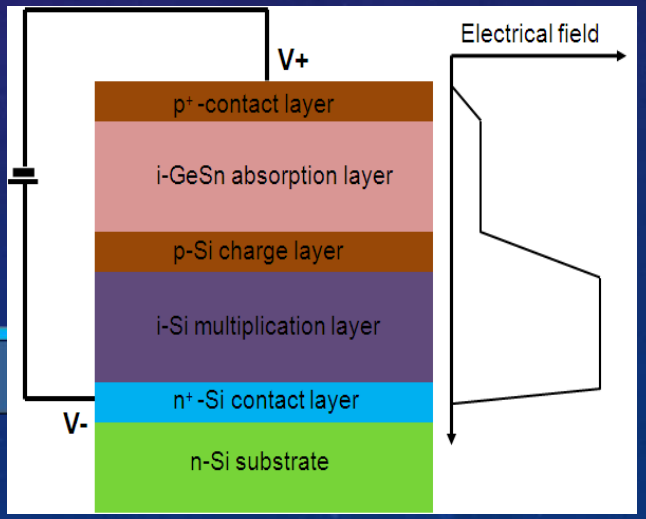
GERMANIUM TIN PHOTODETECTORS



- GeSn Photodiode Detector
- GeSn Avalanche Photo-Diode Detector



Schematic of APD device



SUMMARY AND CONCLUSION

- We reported the first ever direct bandgap GeSn thin films for laser applications
- We reported the first ever laser build with GeSn material
- We reported high quality Ge plasma-deposited films directly on Si at CMOS compatible processing conditions
- We demonstrated high quality GeSn films deposited on Ge/Si substrate
- We reported photodiode infrared detectors on these substrates
- We have a process to deposit defect-free SiGeSn films for various laser structures
- We have funding from Air Force and Navy to continue to develop this trechnology