Atomic precision advanced manufacturing (APAM) for microelectronics

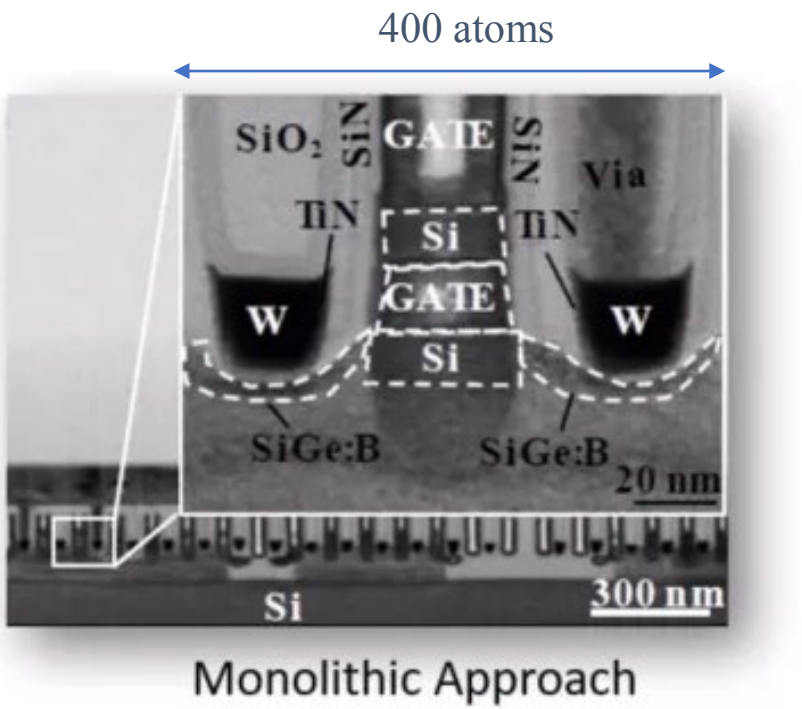
PRESENTED BY

Shashank Misra

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia LLC, a wholly owned subsidiary of Honeywell International Inc. for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

Atomic scale control may open new opportunities

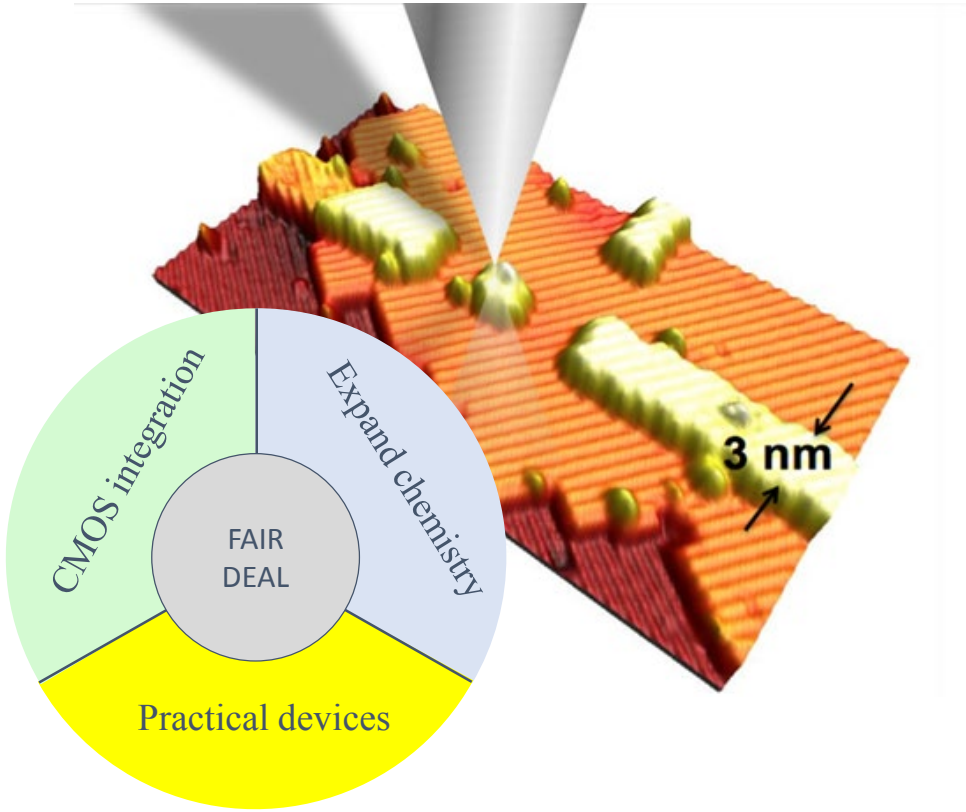
Manufacturing is approaching the atomic scale



Monolithic Approach

S. Subramanian, VLSI 2020

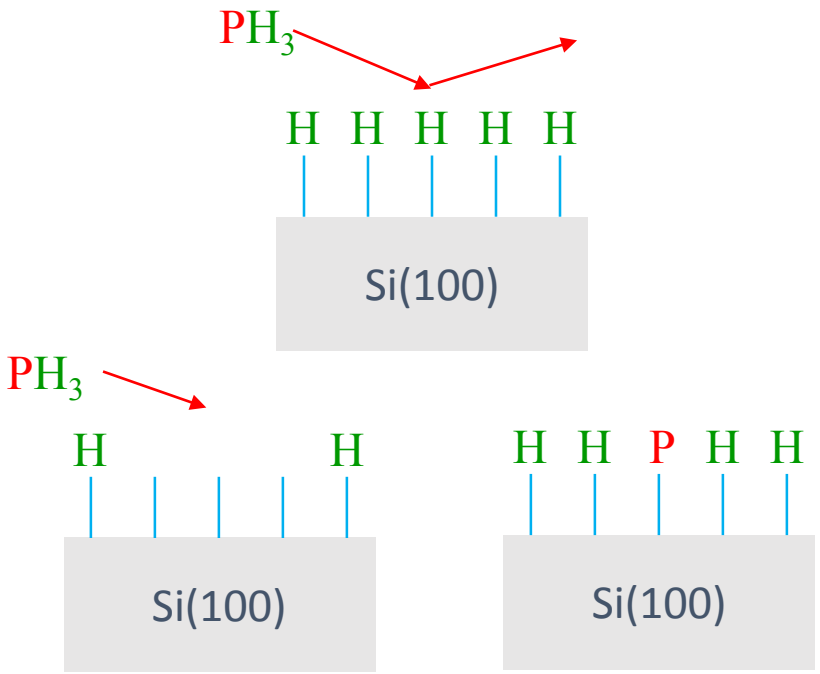
Atomic precision advanced manufacturing (APAM)

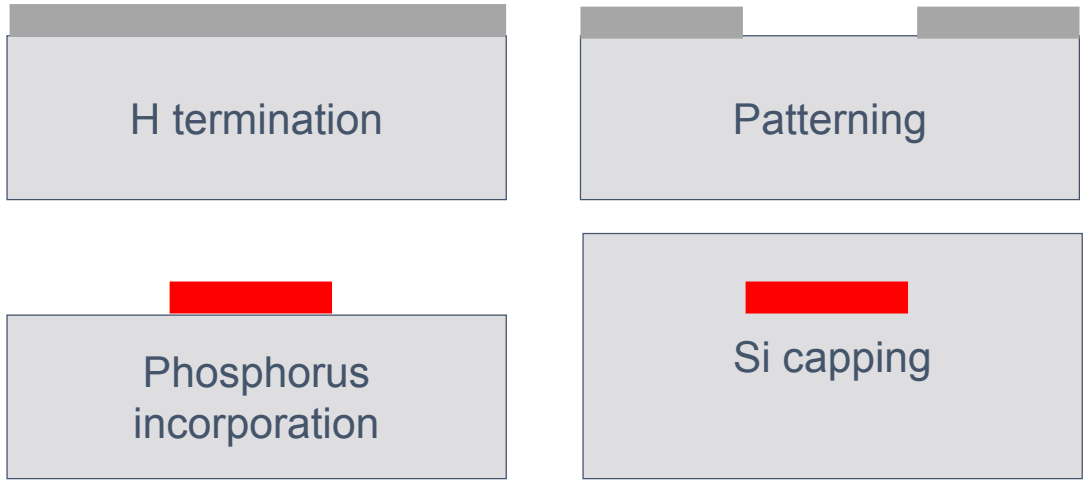


Far-reaching Applications, Implications, and Realization of Digital Electronics at the Atomic Limit

APAM lets us explore the device physics & processing limits of the future

How does APAM work?





Chemical contrast

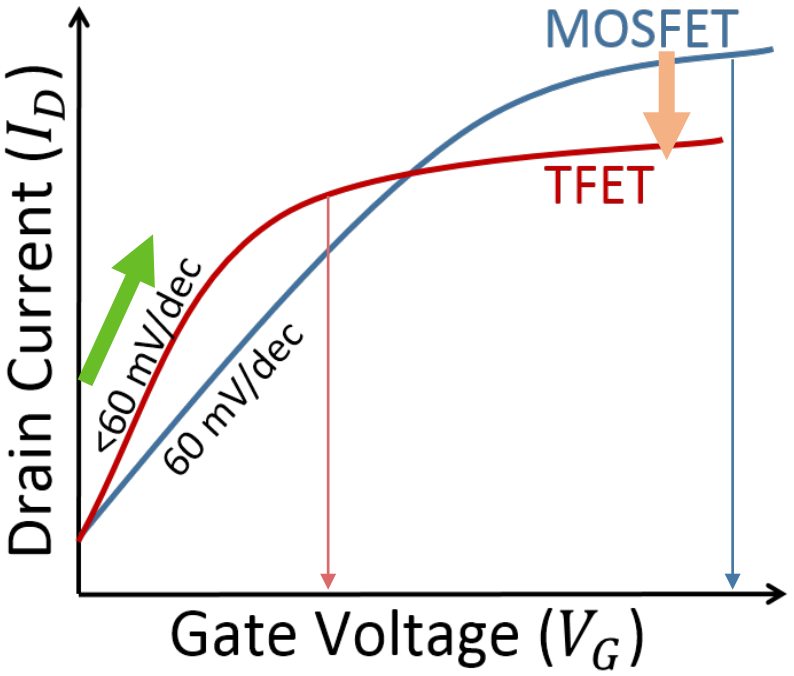
Area-selective chemical reaction
Single-dopant to atomically abrupt
Applied to ALD processes too

Non-equilibrium material

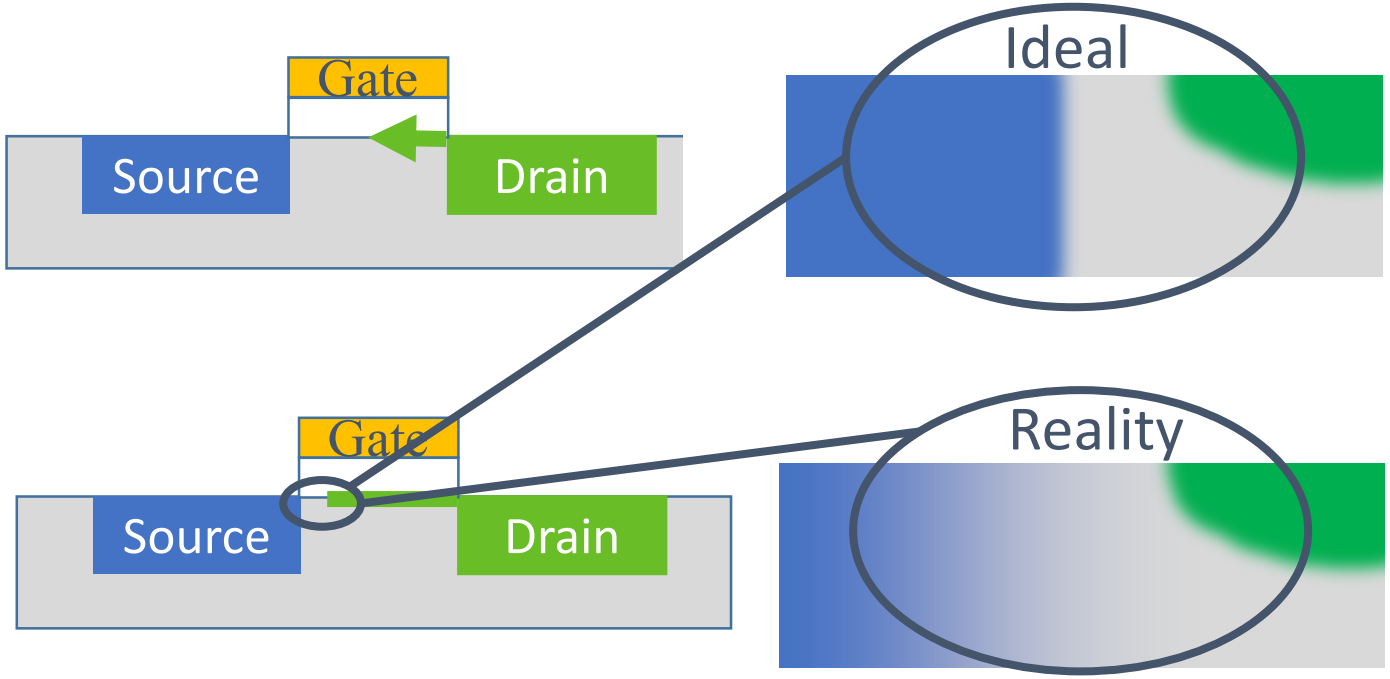
Density >> solid solubility limit
Changes Si electronic structure
Confines electrons

Tunnel field effect transistors (TFET)

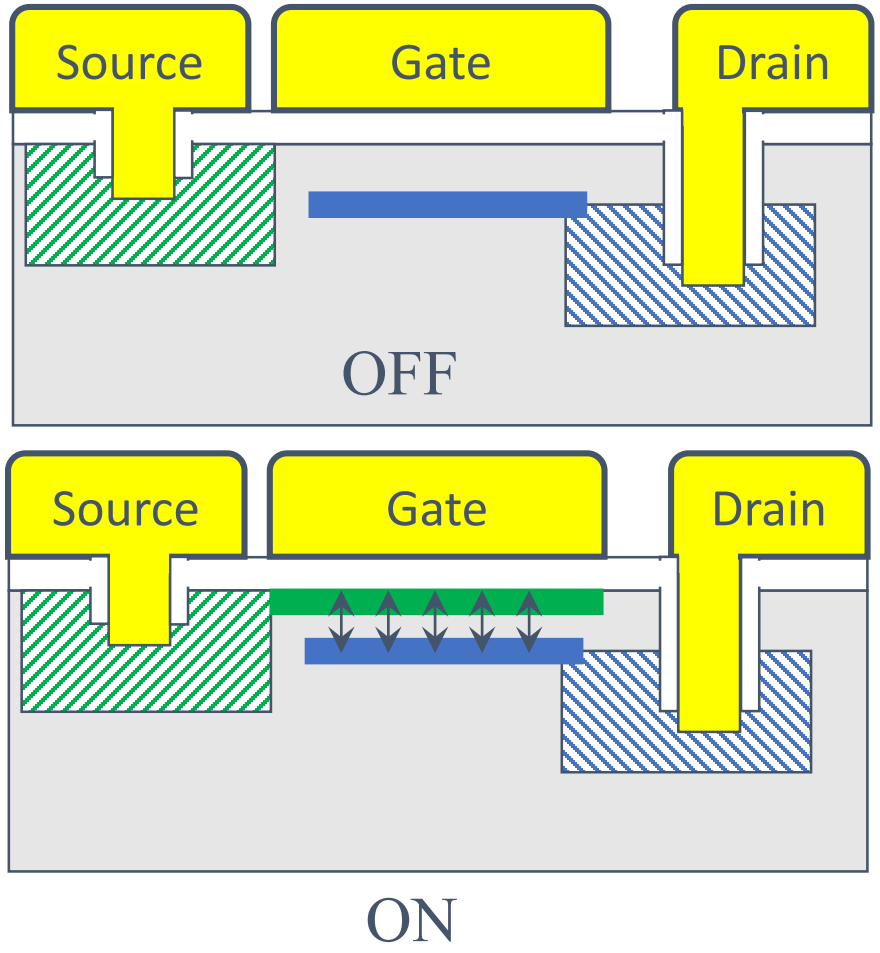
10x improvement in energy efficiency predicted…

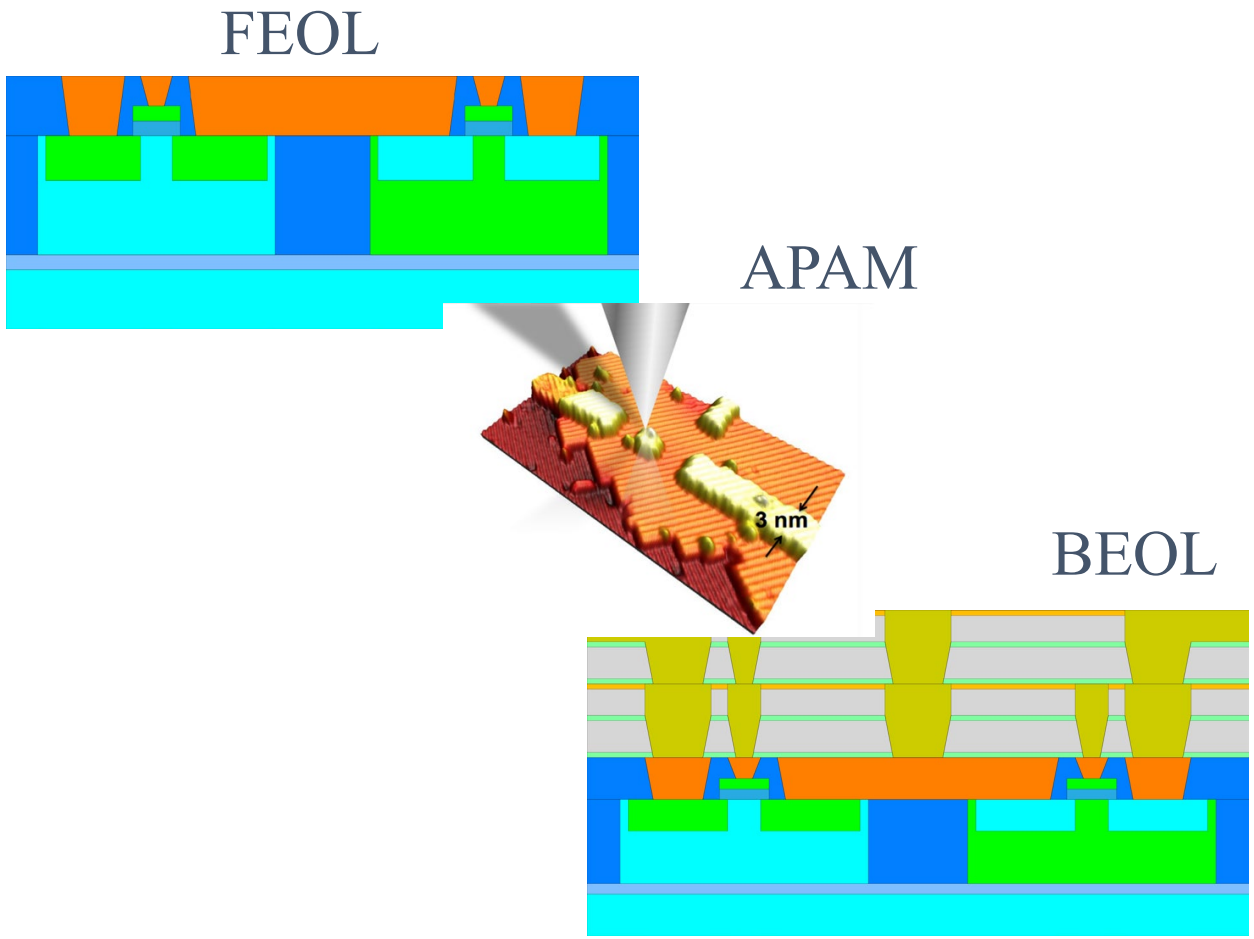


… but never achieved due to manufacturing limitations



DOE/AMO project: APAM-enabled vertical TFET



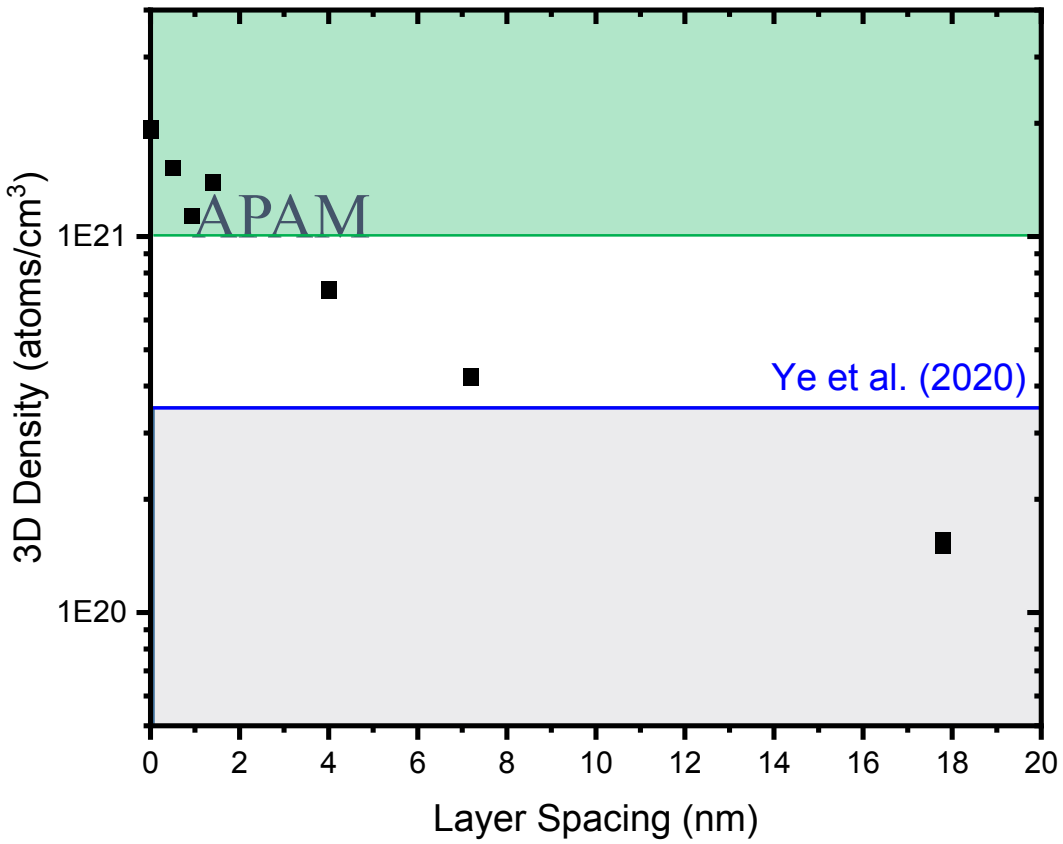


Sharp doping profile: efficient
Vertical geometry: large on & small off current

Only requires process integration (done by Sandia), not atomic precision

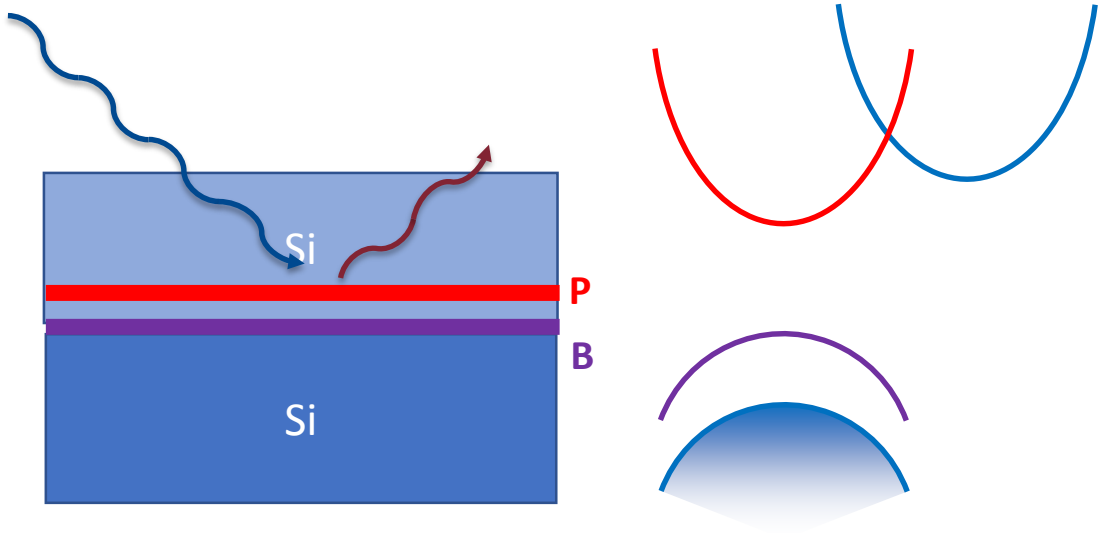
Broader impact

Manufacturing



Extremely high dopant density for contacts
(with U Florida and Applied Materials)

Optically active silicon



P-B bilayer may exhibit direct bandgap
New knobs to change electronic structure