Chapter 15 Summary and Future Trends

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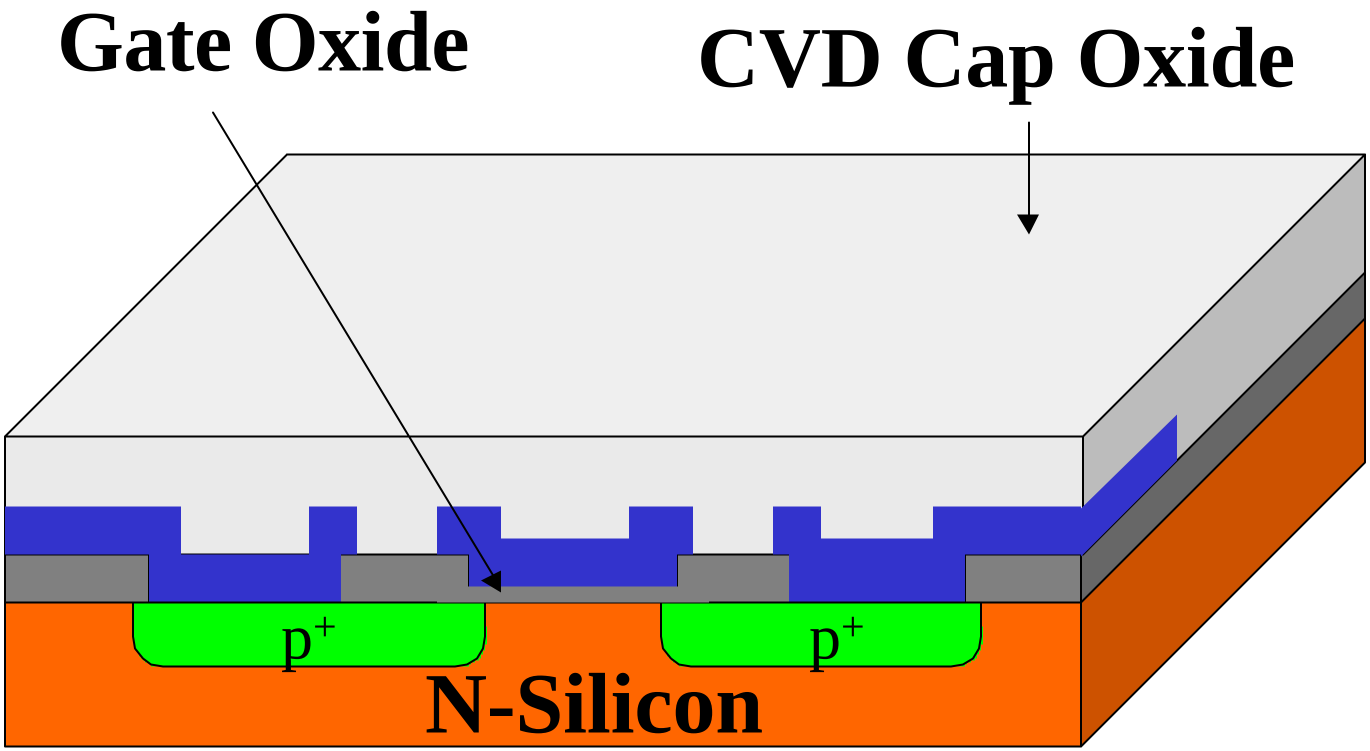
The 1960s

- First IC product
- Bipolar dominant
- PMOS
- Diffusion for doping
- Metal gate

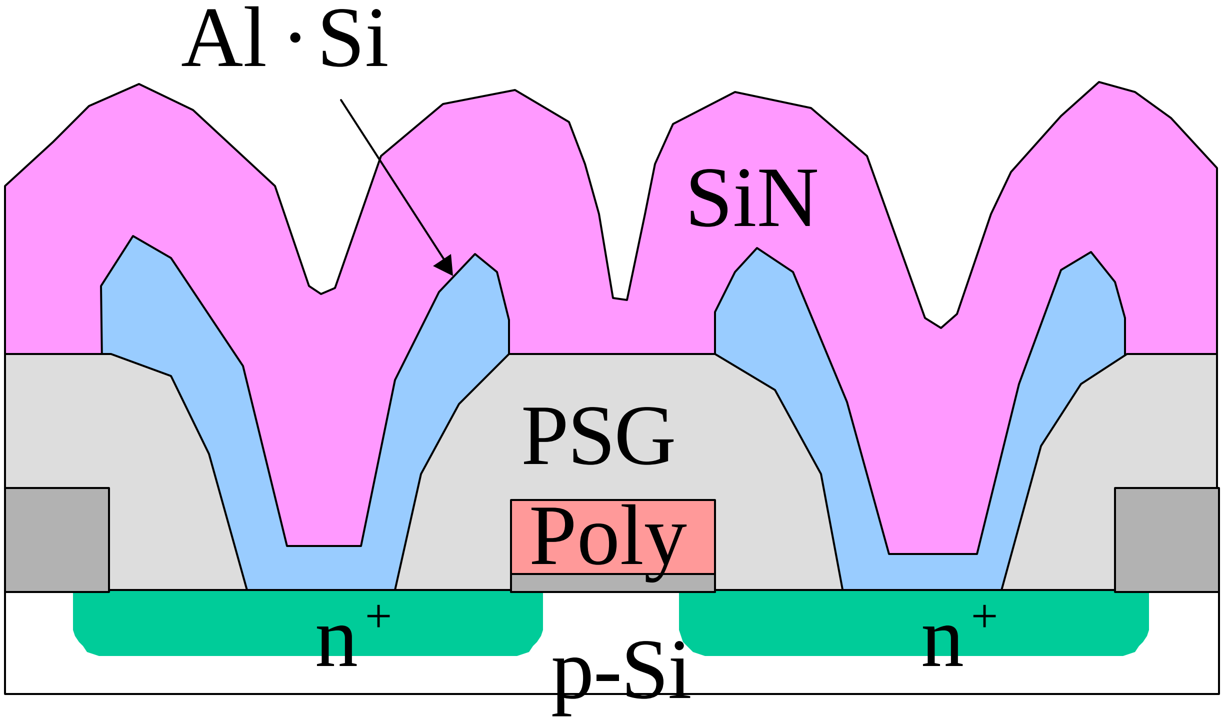
PMOS in the 1960s



The 1970s

- Bipolar dominant
- NMOS
- Ion implantation for doping after mid-1970s
- Self-aligned source/drain
- Polysilicon gate
- Main driving force: electronic watches and calculators

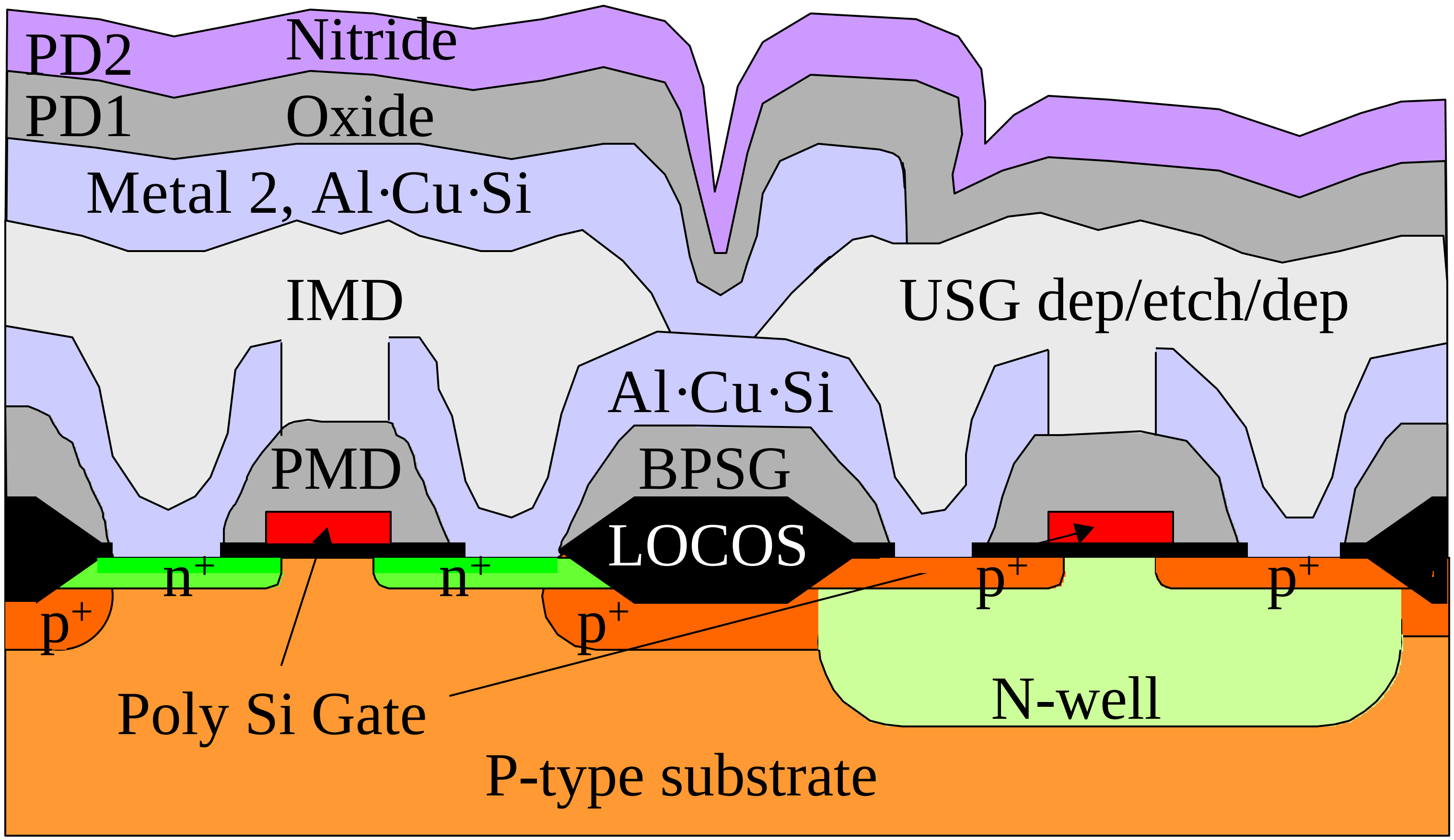
NMOS in the 1970s



The 1980s

- MOSFET surpassed bipolar
- CMOS
- Multi-level interconnections
- Main driving force: personal computer

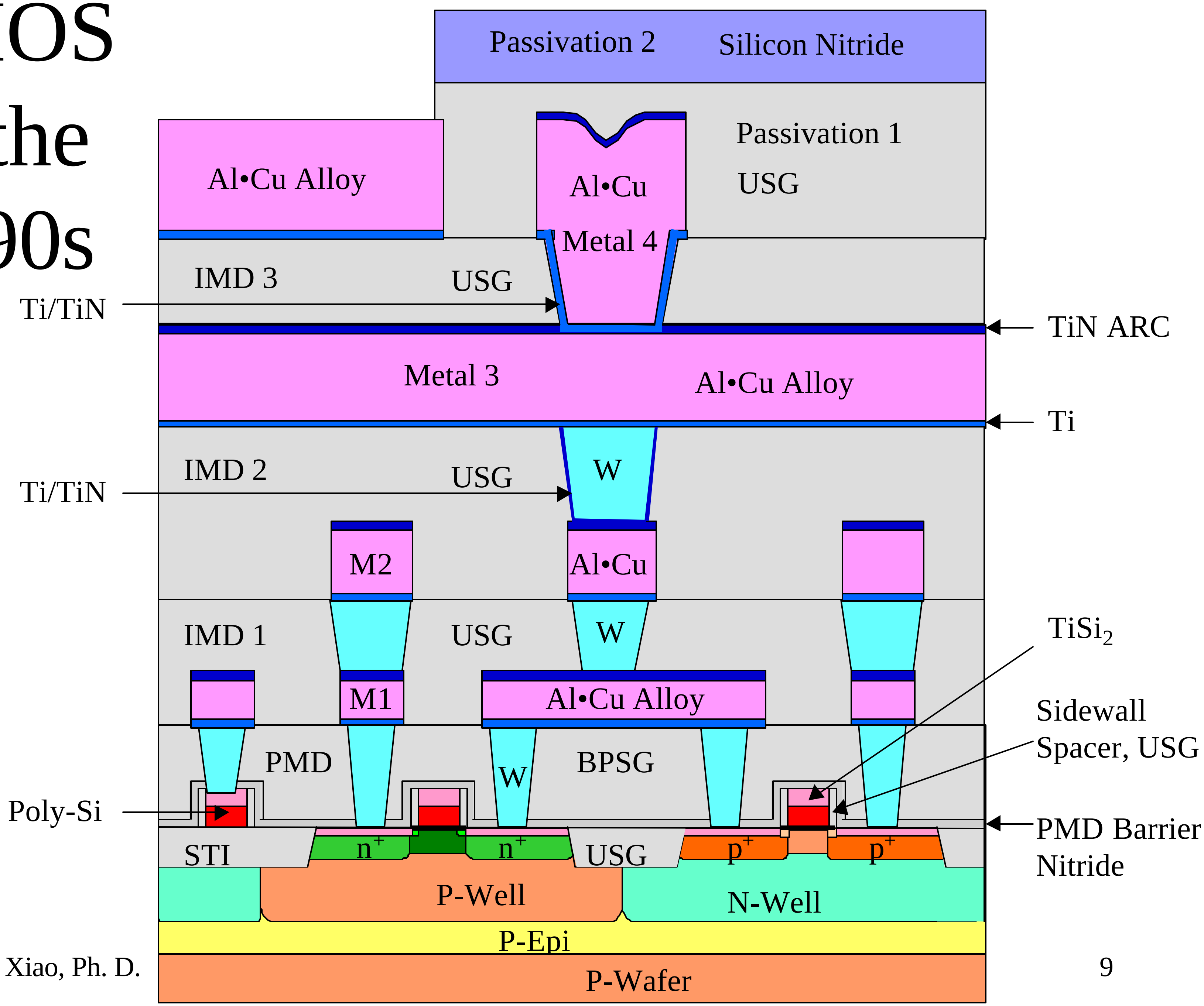
CMOS in the 1980s



The 1990s

- MOSFET dominant
- CMOS
- Multi-level interconnections
  - Tungsten
  - Silicide
  - CMP
- Main driving force: PC, network, internet

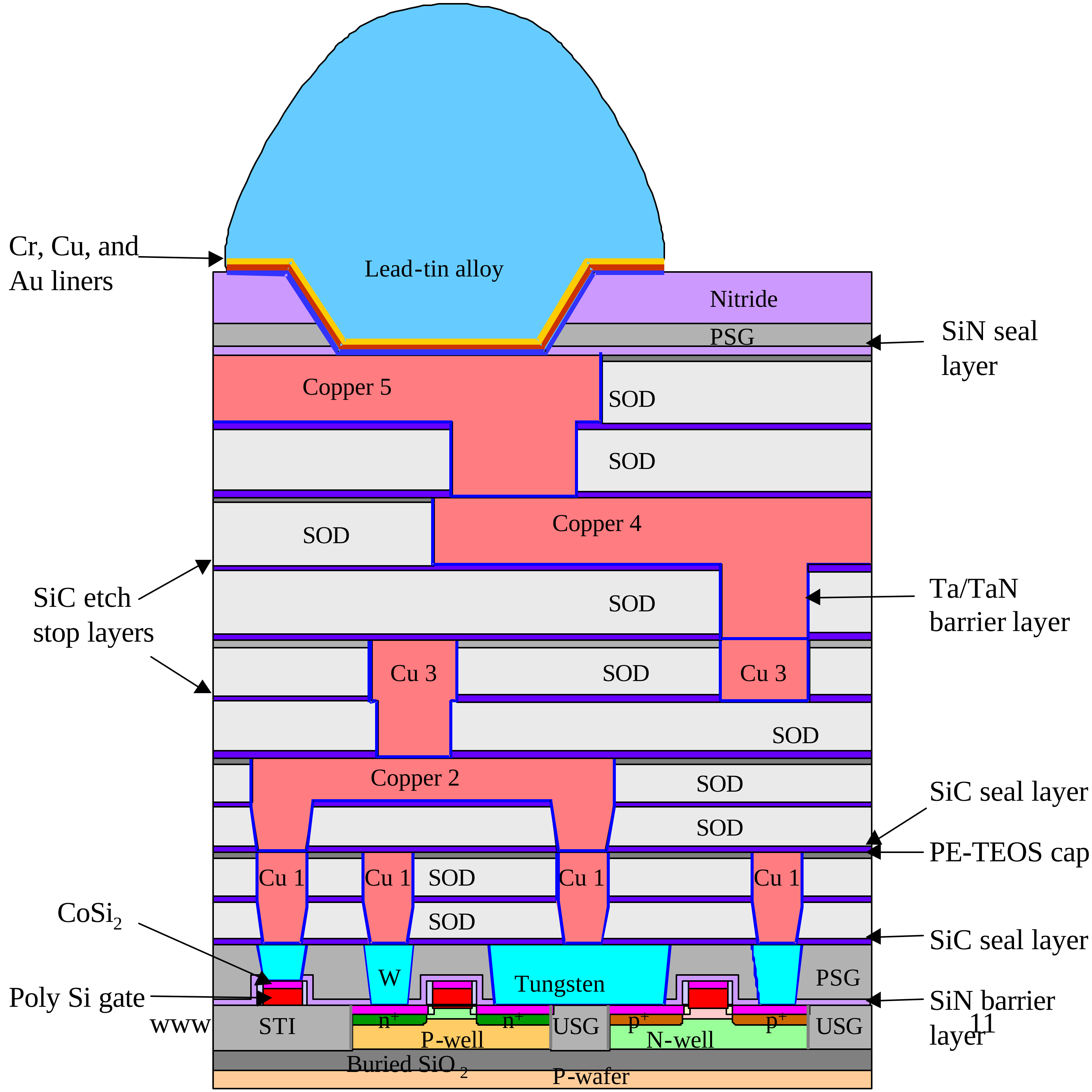
CMOS in the 1990s



The 2000s

- MOSFET dominant
- CMOS
- SOI substrate
- Copper and low-κ interconnection
- Main driving force: telecommunication, network, internet, PC

CMOS in the 2000s



New Materials: Copper

- Metal interconnection: Cu replace Al and W
  - Lower resistivity
  - Improve device speed
  - Higher electromigration resistance
  - Higher current
    - Reduce metal layers that reduce processing steps
  - Lower the production cost
  - Improves overall yield

New Materials: Low-κ

- Low-κ dielectrics replace silicate glass for the interconnection applications
- CVD: CSG and α-FC
- SOD: HSQ and porous silica.
- Combination of copper and low-κ to improves IC chip speed

New Materials: High-κ

- Capacitance of MOS gate capacitor has to be large enough to hold enough charges
- Feature size reducing, gate capacitance reduces
- High-κ, thicker gate dielectric to prevent the leakage and breakdown
- Candidates: TiO_2 (κ ~ 60), Ta_2O_5 (κ ~ 25), and possibly HfO_2

New Materials: High-κ

- BST ($Ba_{½}Sr_{½}TiO_3$, κ up to 600
- DRAM capacitor dielectric

Next Generation Lithography

- Photolithography limit: ~ 50 - 35 nm, after 2010
- Next generation lithography (NGL) technology
  - EUV lithography
  - Projection electron beam lithography
- Still in R&D

Developing Industry

- After more than 50 years, semiconductor industry is still a developing industry, not a matured industry as automobile industry
- New technology is introduced almost daily
- Technology less than ten years could become obsolete

300 mm and Beyond

- Larger wafer size, more chip can be made
- Currently 300 mm (12 inch) transition
- Will become mainstream
- Cost more than 2 billion dollar to build
- 400 mm wafer fabs may start by 2010

World Chip Demands

- Lower chip price, cheaper consumer electronics
  - TVs, VCRs, telephones, and PCs.
- Steady economy development of developing country, especially China and India
- Dramatically increase the demands
- Need more chips!

Auto-chip

- Global location system and voice activated internet access may become standard feature in the future automobiles
- In the near future, General Motors (GM) will consume more IC chips than International Business Machines (better known as IBM) every year

Bio-chip

- Miniaturize test probes and analysis circuits
- Medical IC chips for DNA test
- Fast, accurate diagnosis of DNA related diseases.
- Lab-on-chip

Telecommunication, Internet

- The worldwide development of the telecommunication and internet will still be the main driving force of the continuing rapid development of the IC industry in the near future

Future is Bright

- Boom-bust cycle of the IC industry
- Demands for IC chips will steadily grow
- So will the demands for skillful and knowledgeable workers

Life After the Final Limit

- Physical limit may be reached by ~2030
- Feature size 10 to 5 nm
- IC feature size can no longer shrink
  - IC industry will finally become matured
  - Less frequent technology change
- Still need large number of workers, just like auto industry