ISSCC 2000 Panel:

"Where will processor performance improvement come from in the next ten years?"

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Year 2000 → 2011

Lg = 0.12 µm → 0.03 µm

 tox = 2.2 nm → 0.7 nm

 Vd = 1.65 V → 0.6 V

 Vth = 0.3 V → ?? V

 xj = 48 nm → 15 nm

Limit in reducing Vth

Limit in thinning tox

SiO2: 2 – 1.3 nm

High K dielectrics
ZrO2-SiO2, HfO2-SiO2

Limit in thinning xj

High R

New doping

New structure

Limit in Interconnects

Some kind of dynamic Vth?
A graph showing the gate length (µm) over the years from 1970 to 2020. The y-axis represents the oxide thickness $t_{ox}$ (nm) on a logarithmic scale, ranging from $10^{-2}$ to $10^2$. The x-axis represents the year from 1970 to 2020.

- **Red**: almost within ITRS spec.
- **Blue**: without ITRS spec.

Key events and companies highlighted on the graph include:
- **IBM’99 (SOI)**
- **Toshiba’94**
- **Toshiba’93**
- **Lucent’99**
- **Intel’99**

The graph illustrates the progress in semiconductor technology over time, with markers indicating the year and company associated with each data point.
Gate Length (µm)

Year

Red: almost within ITRS spec.
Blue: outside of ITRS spec.

Toshiba '93
Tox = 3.0 nm

Intel '99
Tox = 2.0 nm

IBM '99 (SOI)
Tox = 2.5 nm

Toshiba '94
Tox = 1.5 nm

Lucent '99
Tox = 1.3 nm
Red symbols satisfies $I_d @ W = 1 \mu m (mA)$.
**Interconnects**

**Year 2000**
- Cu
- TaN
- SiN
- 0.225 µm
- 8 nm

**Year 2011**
- Cu Diffusion Barrier
- Inter metal layer: $K = 3.5 - 4.0$
- No Cu Diffusion Barrier
- Inter metal layer: $K < 1.5$
- 0.065 µm
Year 2110
Extrapolation of the trend with some saturation
Many important interesting application
Home, Entertainment, Office, Translation, Health care

Year 2120???
More assembly technique: 3D

<table>
<thead>
<tr>
<th>Year 2110</th>
<th>Combination of bio and semiconductor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensor</td>
<td>Brain</td>
</tr>
<tr>
<td>Infrared</td>
<td>Ulta small volume</td>
</tr>
<tr>
<td>Humidity</td>
<td>Small number of neuron cells</td>
</tr>
<tr>
<td>CO₂</td>
<td>Extremely low power</td>
</tr>
<tr>
<td>Real time</td>
<td>Image processing</td>
</tr>
<tr>
<td>(Artificial) Intelligence</td>
<td></td>
</tr>
<tr>
<td>3D flight control</td>
<td></td>
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</tbody>
</table>

Long lifetime by DNA manipulation
Bio-computer

Mosquito