

## Industry Observation

### Down the Silicon Information Highway

Does the rapid pace of change in our business have you feeling lost? Confused? In need of technical direction? Fear not, the Semiconductor Industry Association can rescue you with its roadmap to the future. I am, of course, referring to the second iteration of the National Technology Roadmap for Semiconductors published last December by SIA. The roadmap begins with the premise that Moore's Law will always hold true: The number of transistors per chip doubles every 18 months. This and several other historical trends are charted over the next 15 years to provide a picture of the future technological landscape for semiconductor manufacturing — a straight and (increasingly) narrow path to continued industry growth.

And just what will the future hold? Although the roadmap provides the expected extrapolation of current trends (down to the 0.07  $\mu\text{m}$  feature size generation of devices in the year 2010), it does not go far enough to my liking. I need to know more. What will our industry be like in 30 years? Not coincidentally, I will reach retirement age in exactly 30 years and thus have more than an idle interest in this extended outlook.

Since I've done some research into current trends in our industry, I believe I am as qualified to extrapolate as anyone. So follow me, if you dare, to where the SIA feared to tread: The semiconductor industry in the year 2025.

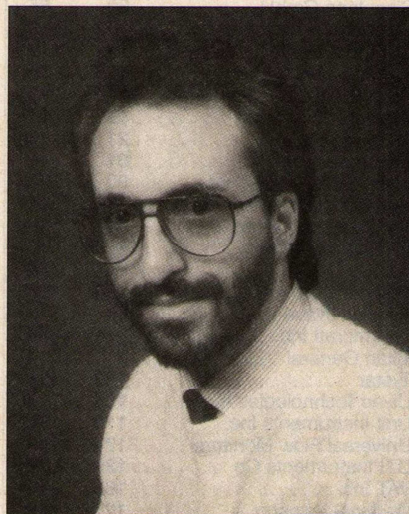
First, let's begin with a statement of assumptions. The following includes those trends used in the SIA roadmap, but also several other important trends too frightening to mention in polite conversation:

- Transistors per chip quadruple every three years.
- Minimum feature size (CD) is cut in half every six years.
- Overlay requirements remain about one-third of the minimum CD.
- DRAM chip area increased  $2.3\times$  every six years.
- Manufacturing costs per  $\text{cm}^2$  of silicon

#### Mack's Roadmap for Semiconductor Production in the Year 2025

- DRAM Chip: 64Tb (that's terabits, folks!)
- Minimum CD: 100Å (that's about 5 photoresist molecules)
- CD Control Spec:  $\pm 10 \text{ \AA}$  (that's  $\pm$ one-half of a photoresist molecule)
- Overlay Spec: 30Å
- Chip Size: 3 x 6 in. (120  $\text{cm}^2$ )
- Wafer Size: 32 in.
- Fab Cost: \$1 Trillion
- Chip Price: \$1,000

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learned here  
is simple:  
Moore's Law is not  
forever.'**



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- Selling prices for DRAM per  $\text{cm}^2$  remain about constant.
- Wafer size doubles every 15 years.
- Fab costs double every three years.

Extending these trends over the next 15 years essentially gives the SIA roadmap for the future. Extending these trends for the next 30 years gives the Mack roadmap for the *far out* future. The results are quite disturbing (see Table).

As you might suspect, neither the laws of physics nor the laws of economics have entered into this prediction of future semiconductor manufacturing. Although the physical barriers to 100Å production on 32 inch wafers are probably insurmountable, the economic barriers worry me even more. Assuming it is possible to create the required technology, who will build a \$1 trillion fab? Even if it is possible to manufacture these chips economically, is there a market for millions and millions of \$1,000 DRAM chips per month? Since fab costs are rising much faster than chip prices, profitability requires significantly increasing DRAM consumption. When will the memory demands saturate?

The lesson to be learned here is simple: Moore's law is not forever. And unfortunately, the Moore's Law slope will change before I retire. Is this a bad thing? The SIA Roadmap describes a "significant danger" that the semiconductor industry will not sustain its current growth if we don't continue to follow Moore's Law. Given the above scenario for the year 2025, I would say that forcing ourselves to adhere to our current path without economic justification is even more dangerous.

We in the semiconductor industry have become addicted to unprecedented growth just as consumers have been addicted to increasingly sophisticated electronic products at ever decreasing prices. However, the semiconductor industry's maturing is inevitable. Although we may not look forward to it, we should be prepared for it. Until then, let's enjoy the ride! □