

## Homework set #1

1. Handling the huge information content of nanometer-length-scale patterns presents a major engineering challenge. We want to do a crude, order-of-magnitude, calculation of the rate at which information is processed by a state-of-the-art semiconductor IC fabrication tool and compare this to the state-of-the-art of optical fiber communications.
  - a. What is the information content (measured in “bits”) of a 300-mm-diameter wafer whose surface has been divided into 100-nm-square pixels, each of which can be in one of two states (“part of the pattern” or “not part of the pattern”). (Note: this question equivalently asks, “How many digits would a binary number have to have in order to represent any given state of the wafer?”).
  - b. Suppose the tool is producing 100 of these wafers per hour, each with a new pattern. What is the information throughput, in bits per second, of the tool. Compare this to the capacity of a typical office LAN connection (100 Mbit/sec). What about compared to a state-of-the-art wavelength-division-multiplexed optical fiber capable of data rates of 1 Terabit/sec?
  - c. Given that such a tool costs \$25M to buy, what is the cost in \$/(bit/sec)?
  - d. Assume a wafer will go through  $\sim 10$  patterning steps (in real fabrication processes, the number is more like 20) as it is manufactured. At the end of these steps, assume on average it will have 10 defects per wafer (this is considered mediocre performance). Calculate what this defect rate represents in terms of a “bit-error rate” (i.e. calculate the fraction of the bits that contain errors). Compare this to the typical bit-error rate of a good fiber-optic communication channel ( $\sim 10^{-12}$ ).
  - e. In reality, all the pixels on a wafer are not independent, in fact the same pattern is repeated many times across the wafer in a square-grid array of chips. If each chip is 30 mm on a side, how many 100-nm-square pixels are in a chip?
  - f. Compare the result of **d** to the memory of a state-of-art memory chip. From this comparison, calculate how much area a single bit of memory on the memory chip occupies.
  - g. To make a comparison to a more familiar item: assume you use a desktop inkjet printer to print an image consisting of random, uncorrelated pixels that cover an entire 8.5” x 11” page at the printer’s maximum resolution, what is the resulting information throughput of the printer, in bits/sec?
  - h. If the printer cost \$100, what is the cost in \$/(bits/sec). Compare this to your result for **c**.

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2. Read the two papers in your handout for lecture #1: "There's plenty of room at the bottom" by Feynman, and "An approach to microminiature printed systems" by Buck and Shoulders. Comment on the differences in vision of these two papers.

## References

### *Problem 2*

Feynman, Richard P. "There's Plenty of Room at the Bottom." *Journal of Microelectromechanical Systems* 1 (1992): 60-66.

Buck, D. A., and K. R. Shoulders. "An Approach to Microminiature Printed Systems." *Eastern Joint Computer Conference* (July 1959): 55-59.