

How Small is a Nanometer?

A primer for people who are unfamiliar with the
Semiconductor Industry

Paul Knutrud

Vice President of Marketing

Inspectrology

Sudbury MA

www.Inspectrology.com



Let us start with some large
things for reference

Saigon Square Market Ho Chi Minh City Vietnam



Chiang Kai-shek Memorial Hall Taipei, Taiwan ROC 76 meters high



A wide-angle photograph of the Angkor Wat temple complex in Cambodia. The central focus is a large, multi-tiered stone structure with a prominent, ornate spire (prang) rising from its top. The architecture is made of dark grey sandstone, showing signs of age and weathering. The sky is a mix of blue and white, with scattered clouds. In the foreground, a paved area shows several people walking, providing a sense of scale to the massive structure.

Angkor Wat Cambodia
1,000 square metres of bas reliefs



Marina Bay Sands - Singapore

560000 square meters

3 x 57 Stories

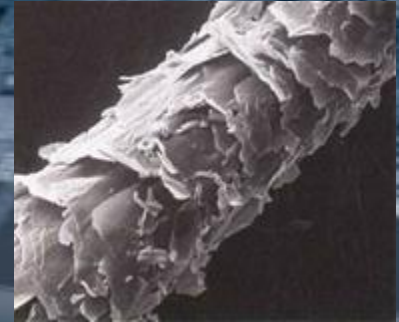
2551 Rooms

What is a nanometer?

- 1 millimeter is $1 / 1000$ of a meter
- 1 micron is $1 / 1000$ of a millimeter
- 1 nanometer is $1 / 1000$ of a micron
- 1,000,000,000,000,000,000 nanometers = 1 meter

How small is a nanometer?

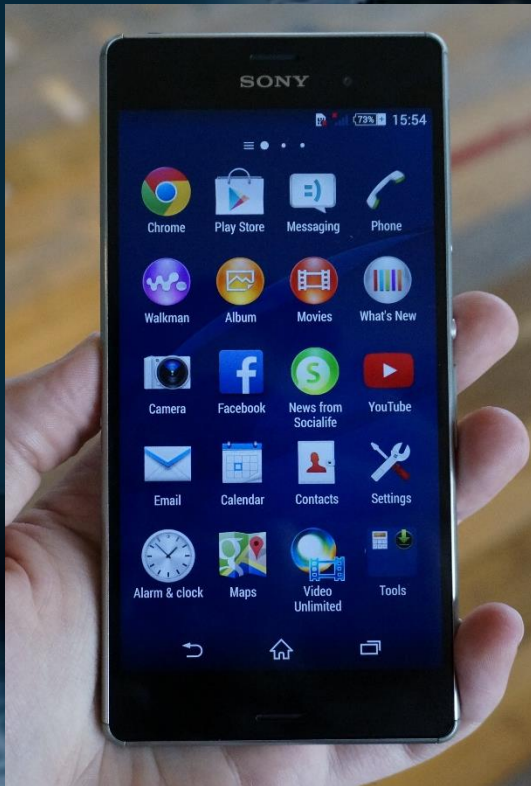
- 90 Microns – Copy paper
- 20 Microns – Thinnest human hair
- 10 Microns – Width of human blood cell
- 1 Micron = 1000 Nanometers



- 1 Nanometer = Diameter of about 4 silicon atoms
- Or 20,000 times thinner than your hair



What is more powerful?



The Saturn V developed
7.6 million pounds of thrust at launch



Computing Power was a bit less

- The **Saturn Launch Vehicle Digital Computer (LVDC)** executed 12,190 instructions per second



The ARM Coretex A57 Smartphone processor runs at about 40 billion Instructions per Second.



The new A72 will be 1.8 times faster

Moore's Law

- In 1965 Gordon E. Moore, cofounder of Intel noted that the number of components in a microprocessor chip had roughly doubled every 2 years from 1958 – 1965. He predicted that this trend would continue for at least another 10 years.
- Moore's Law holds mostly true even today, 50 years later.

Processor Speeds

- Transistor Computer (1955) University of Manchester
 - 200 transistors
- Intel 4004 (1971) .092 MIPS
 - 2,300 transistors
 - 10 micron process technology (.01 mm)
- Intel Core i7 Gen 5
 - About 1.4 billion transistors
 - 14 nanometer process (.000014 mm)
- Oracle Sparc M7
 - 10 billion transistors
 - 28 nm process

What is a Semiconductor?

- a material which has electrical conductivity between that of a metal and that of an insulator. Semiconductors are the foundation of modern solid state electronics, including transistors, solar cells, light-emitting diodes (LEDs), quantum dots and digital and analog integrated circuits.

What is a transistor?



A Transistor is a switch

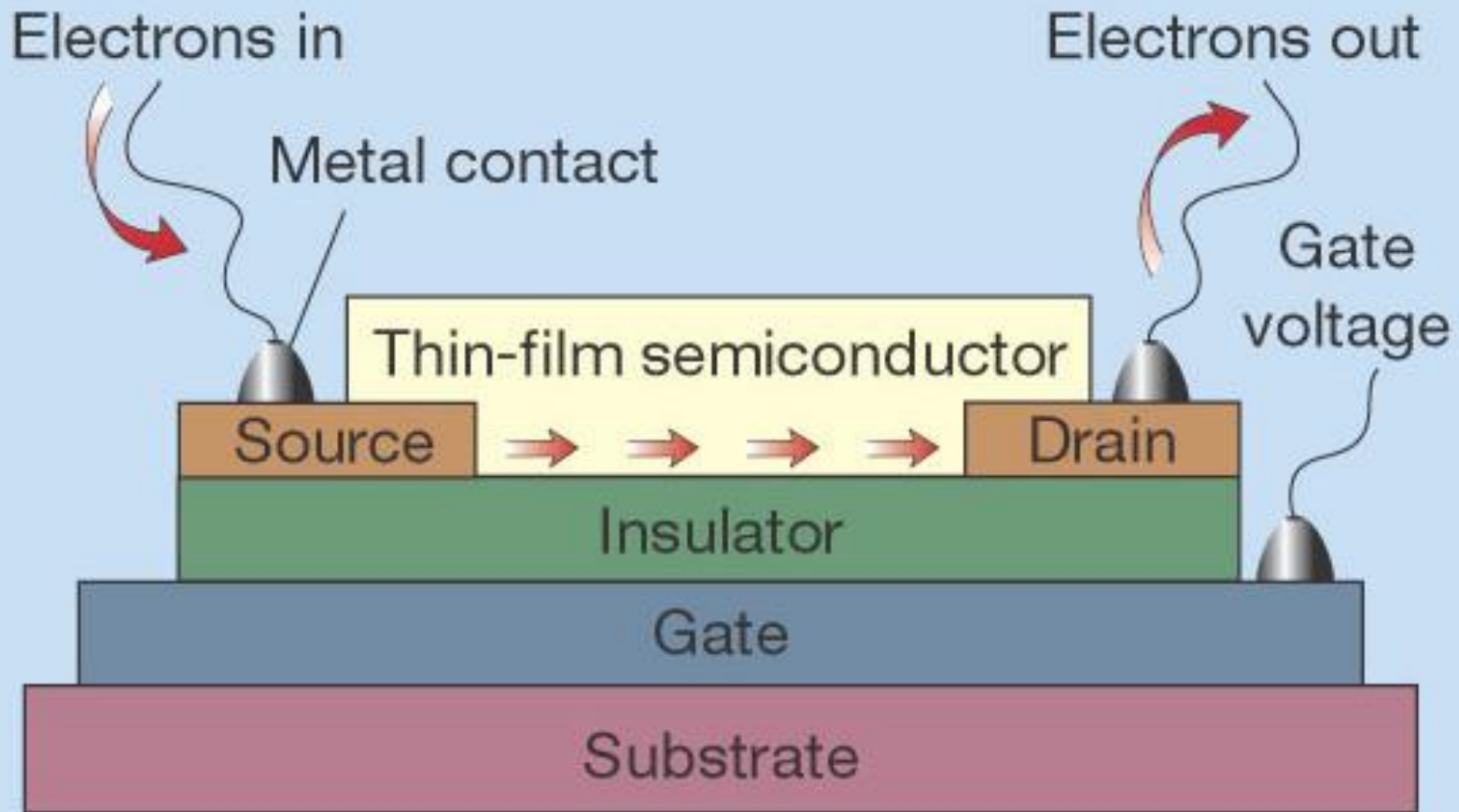


Just like your light switch



except....

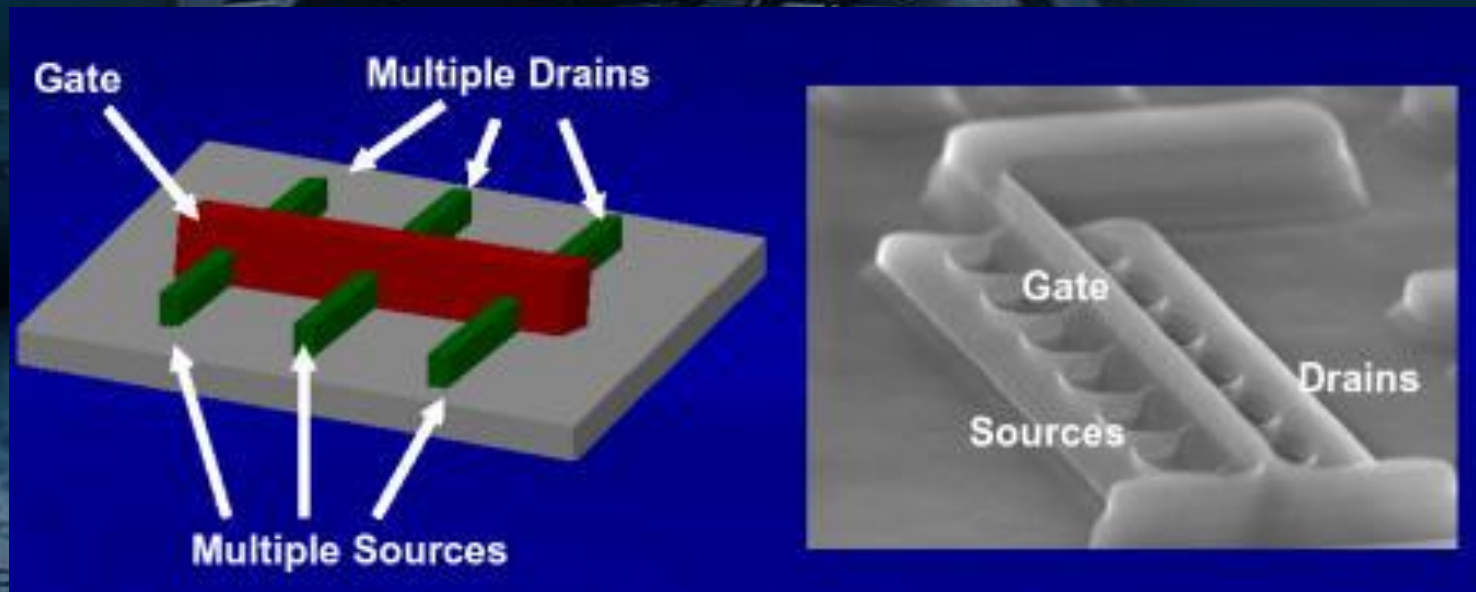
A transistor is an electronically controlled switch



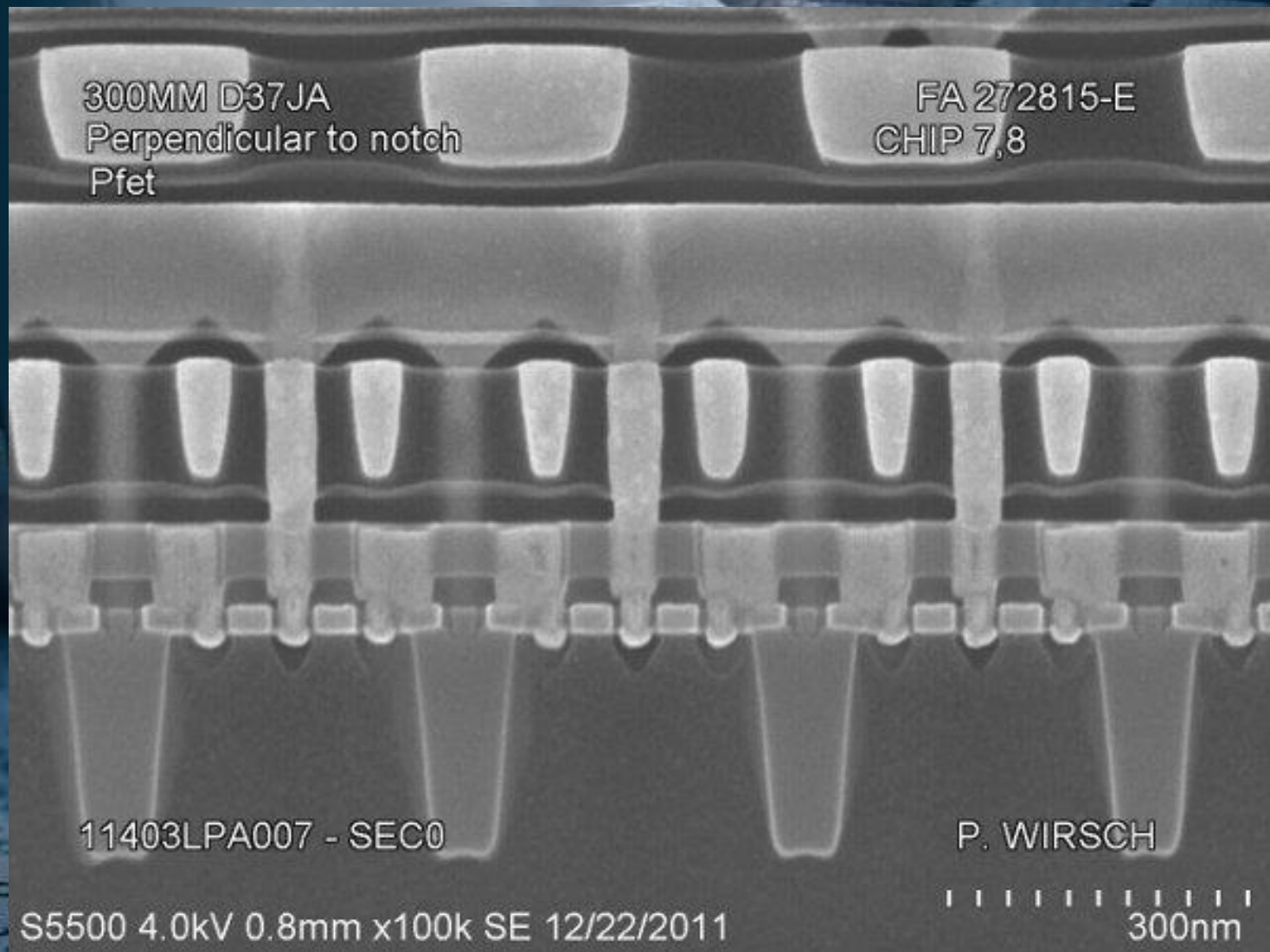
The CMOS Transistor has become the industry standard

- CMOS – Complimentary Metal Oxide Semiconductor
- MOSFET - (metal-oxide-semiconductor field-effect transistor)

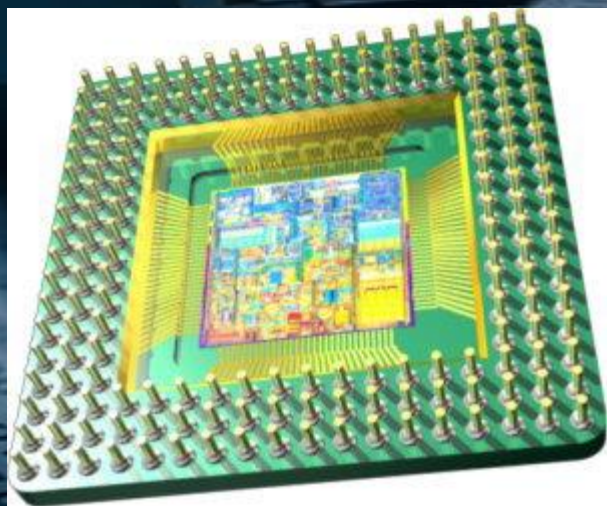
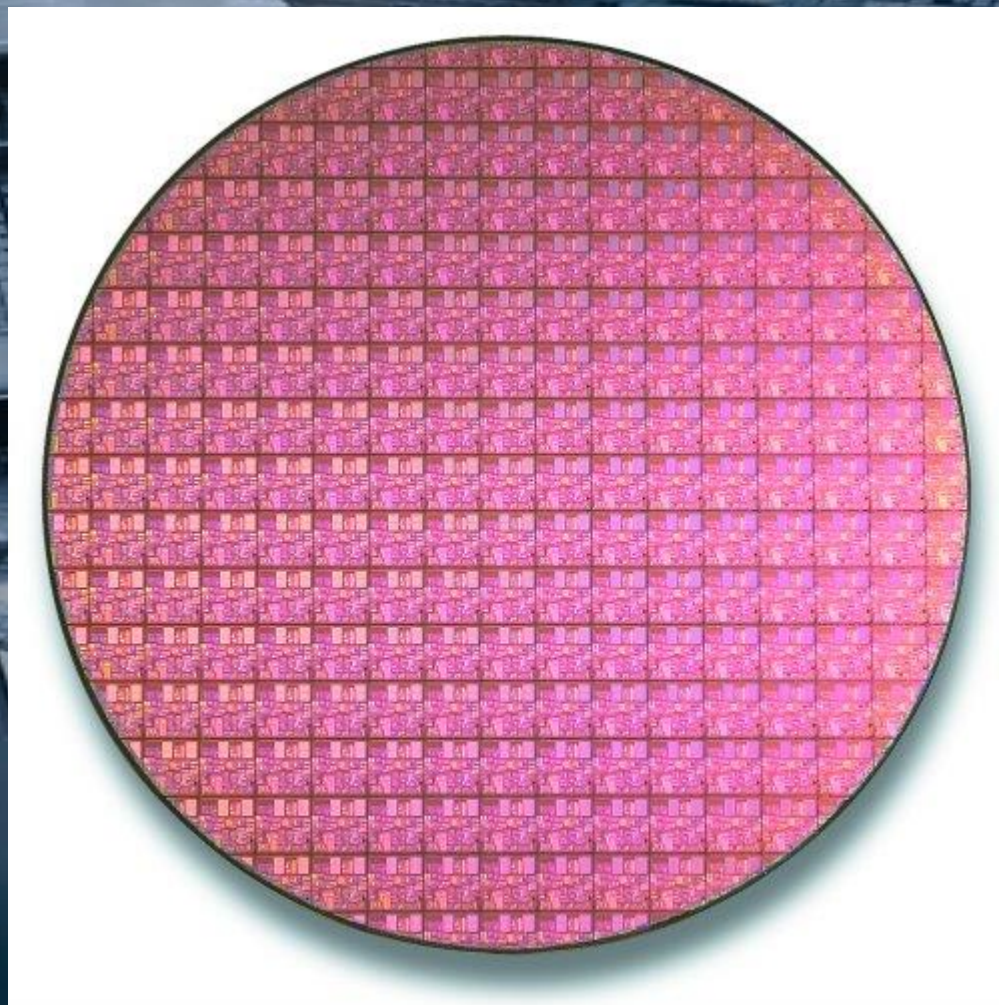
Intel Trigate 3-D transistor



This is a cross section Electron Microscope image of transistors



How are Microprocessors Made?



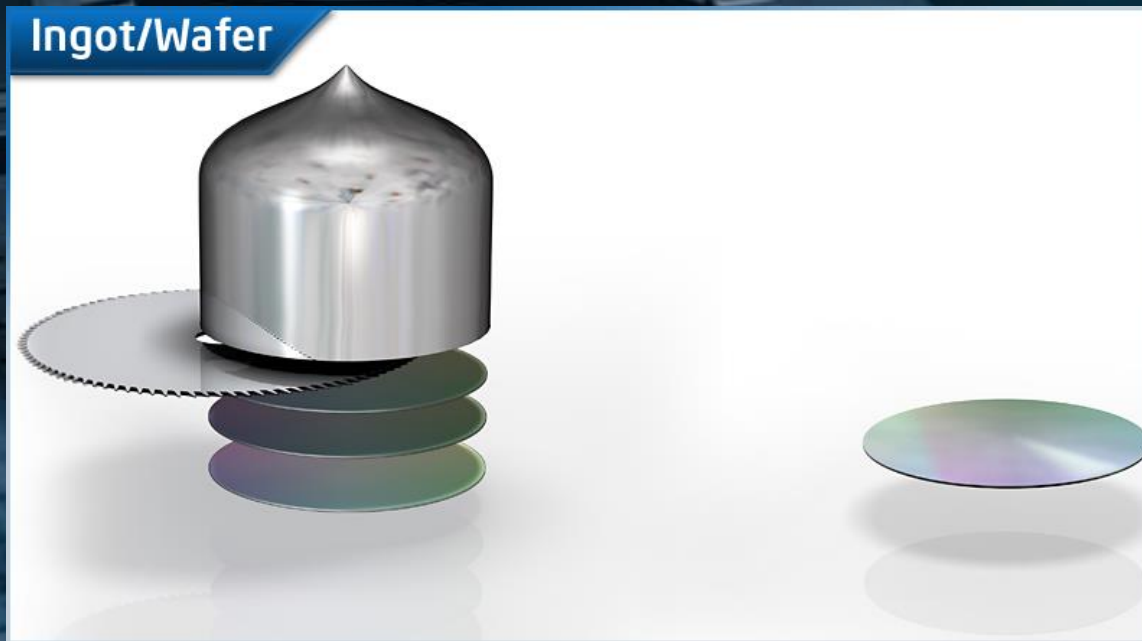
How are Microprocessors Made?

- An ingot of silicon crystal is grown in a lab.



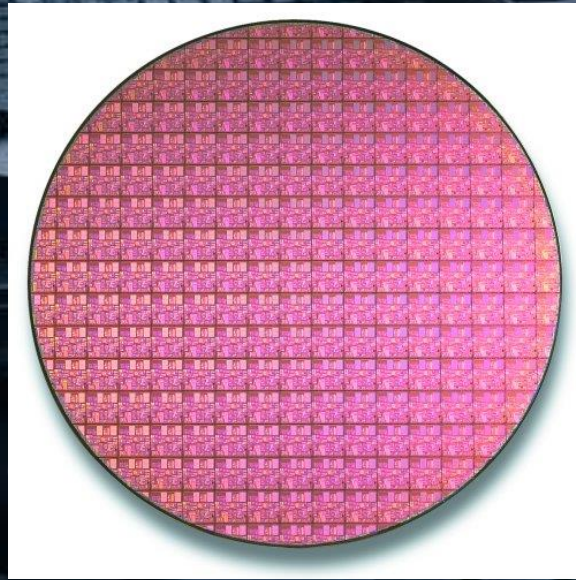
How are Microprocessors Made?

- This is then cut into 1mm thin (or less) slices called wafers.



How are Microprocessors Made?

Wafers are processed to make circuits.



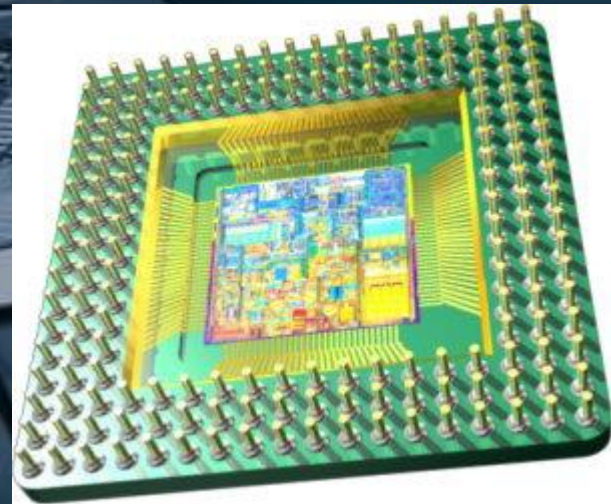
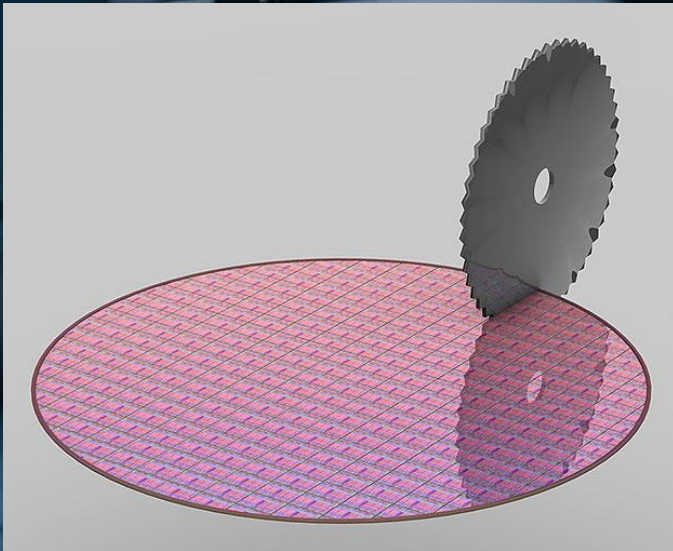
Helpful hint: This is where we come in

Wafer Process Outline

- **Diffusion.** A layer of material such as oxide is grown or deposited onto the wafer.
- **Coat / Bake.** The resist, a light sensitive protective layer, is applied and cured in place.
- **Align.** A reticule is positioned over the wafer. Ultraviolet light shines through the clear portions of the reticule exposing the pattern onto the photosensitive resist.
- **Measure.** A series of measurements are made to insure the process parameters are within specification tolerances. Inspectrology's specialty.
- **Develop.** The resist is developed and unwanted resist is washed away.
- **Dry Etch.** Dry etch removes oxide not protected by resist.
- **Wet Etch and Clean.** The remaining resist is removed in wet etch to reveal the patterned oxide layer.
- **Measure.** Another series of measurements are made to insure the process parameters are within specification tolerances. Inspectrology's specialty.
- Then the wafer is cleaned. The process is repeated up to 18 times to create the various layers necessary to create a working microchip.

How are Microprocessors Made?

Wafers are cut into die or chips and then encapsulated to be mounted on a circuit board.



The background of the slide is a blue-tinted image of a lithography machine, showing various components like lenses and stages. In the bottom left corner, there is a pattern of binary code (0s and 1s).

SPIE



Advanced Lithography

The Society of Professional Imaging Engineers gets together in San Jose once per year to discuss exciting things like:

- Materials design for 15nm process
- Implementation of hybrid metrology for 20nm
- Extension of patterning technologies down to sub-10nm
- Sub-12nm logic optical lithography
- Metrology

What is Metrology?

- **Metrology** is the science of measurement.
- **Metrology** includes all theoretical and practical aspects of measurement.
- The word comes from Greek μέτρον (*metron*), "measure" + "λόγος" (*logos*), amongst others meaning "speech, oration, discourse, quote, study, calculation, reason". In Ancient Greek the term μετρολογία (*metrologia*) meant "theory of ratios".

—Source - Wikipedia

Stepper/Scanner Prints a pattern on the wafer

- ASML 193nm Immersion Stepper/scanner for 14nm process



- - Cost - \$60M

Stepper/Scanner Prints a pattern on the wafer

- ASML's EUV Scanner can print 7nm features and smaller



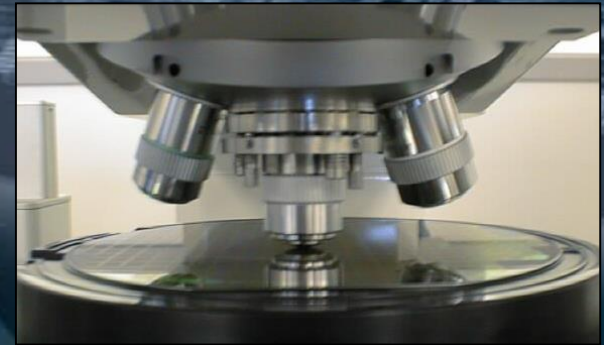
- Cost \$100M+

How do we fit in?


INSPECTROLOGY

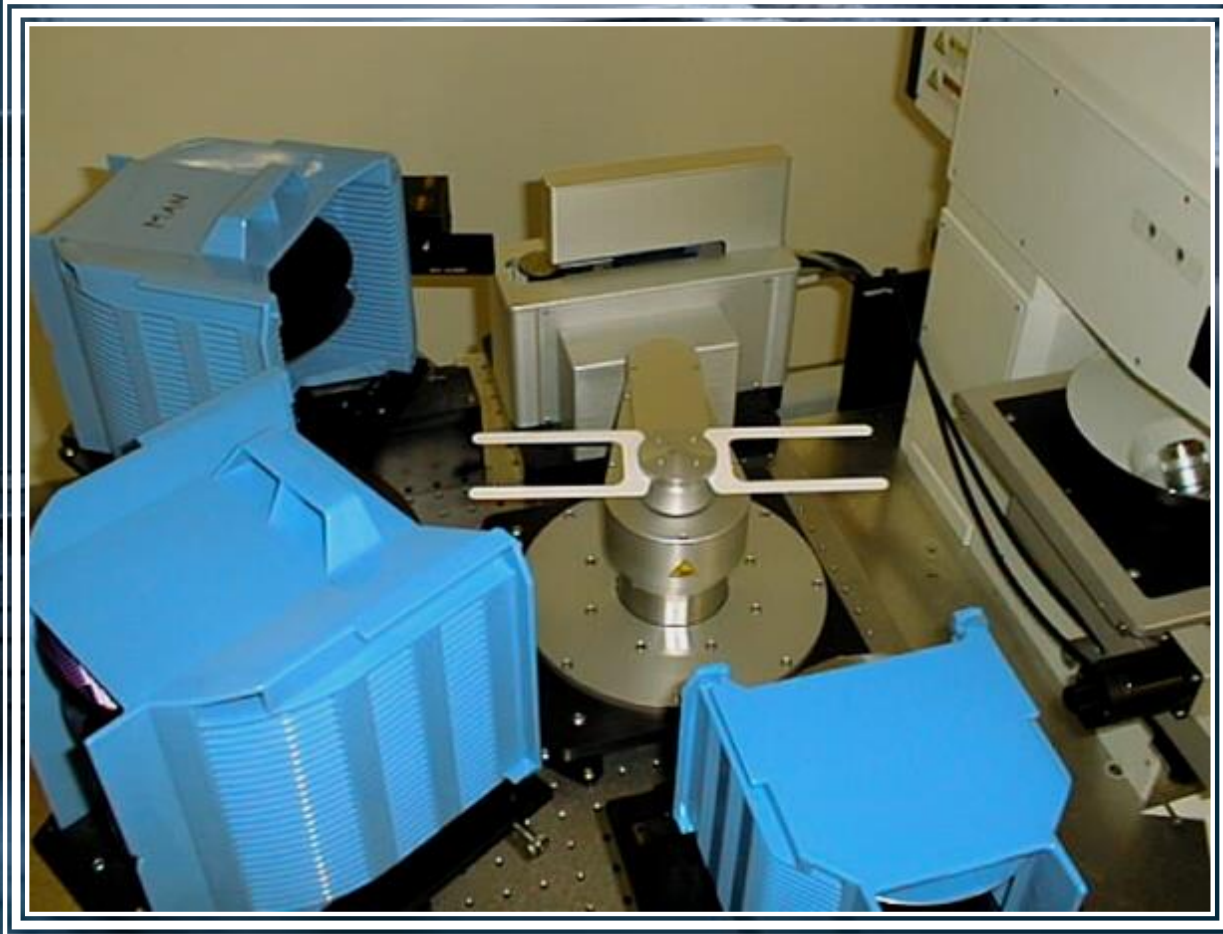


Using a Microscope and Systems Automation, the IVS 200 measures features with no operator required.



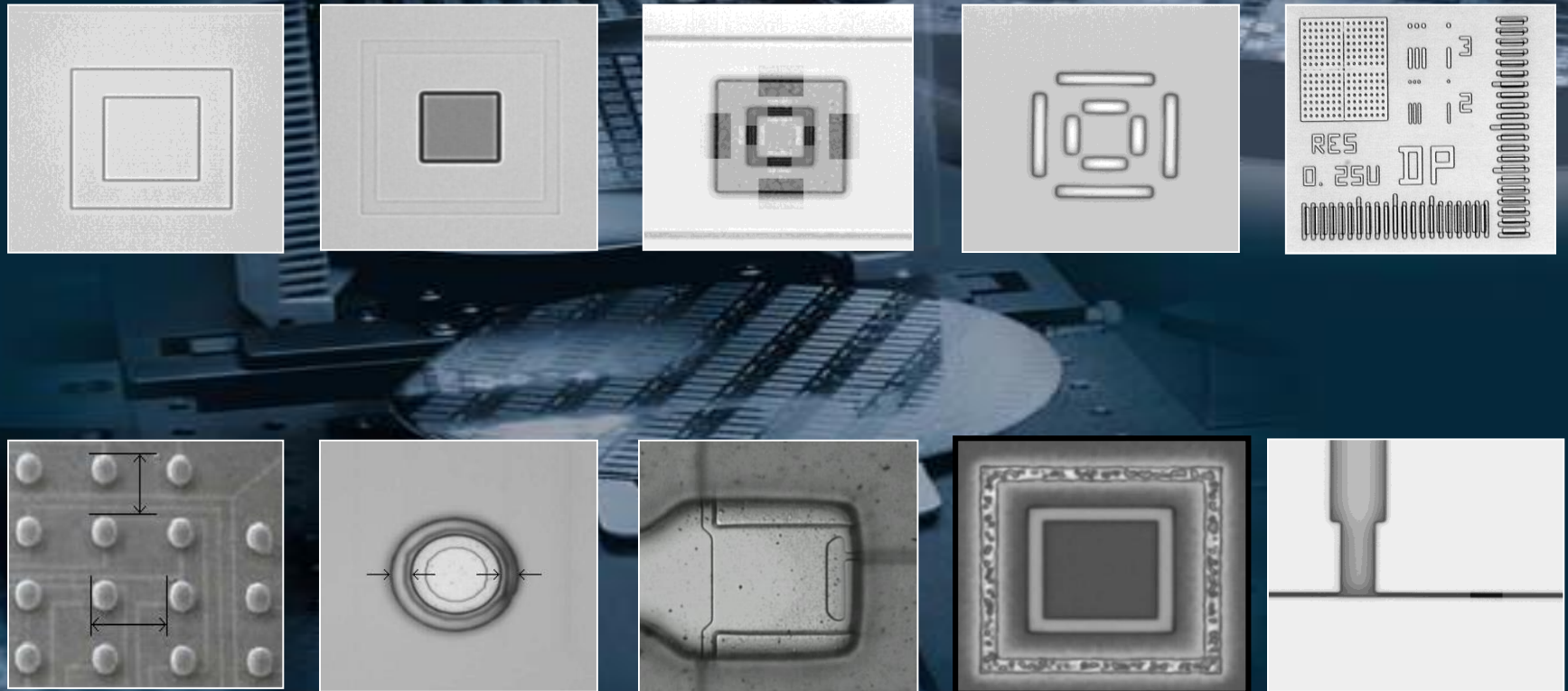


A robot loads a wafer onto the microscope stage and then the measurements are made automatically.





Many different types of features can be measured from transistors to ink jet printer nozzles.





Inspectrology – The Best Value in Metrology

Inspectrology provides systems, support and service at more than 75 locations in over 18 countries from Austria to Singapore, Canada to Israel.

We Specialize in supporting small factories where 1-4 systems are installed. We understand the needs to keep up time at 100% and mean time between failures to months and years instead of days and weeks.

With world wide support and representatives in every major market, Inspectrology is well positioned to provide the support needed to keep fabs running at peak efficiency.

Thank you

Takk

谢谢

多謝

Děkuju

감사합니다

Merci

Terima kasih

Danke

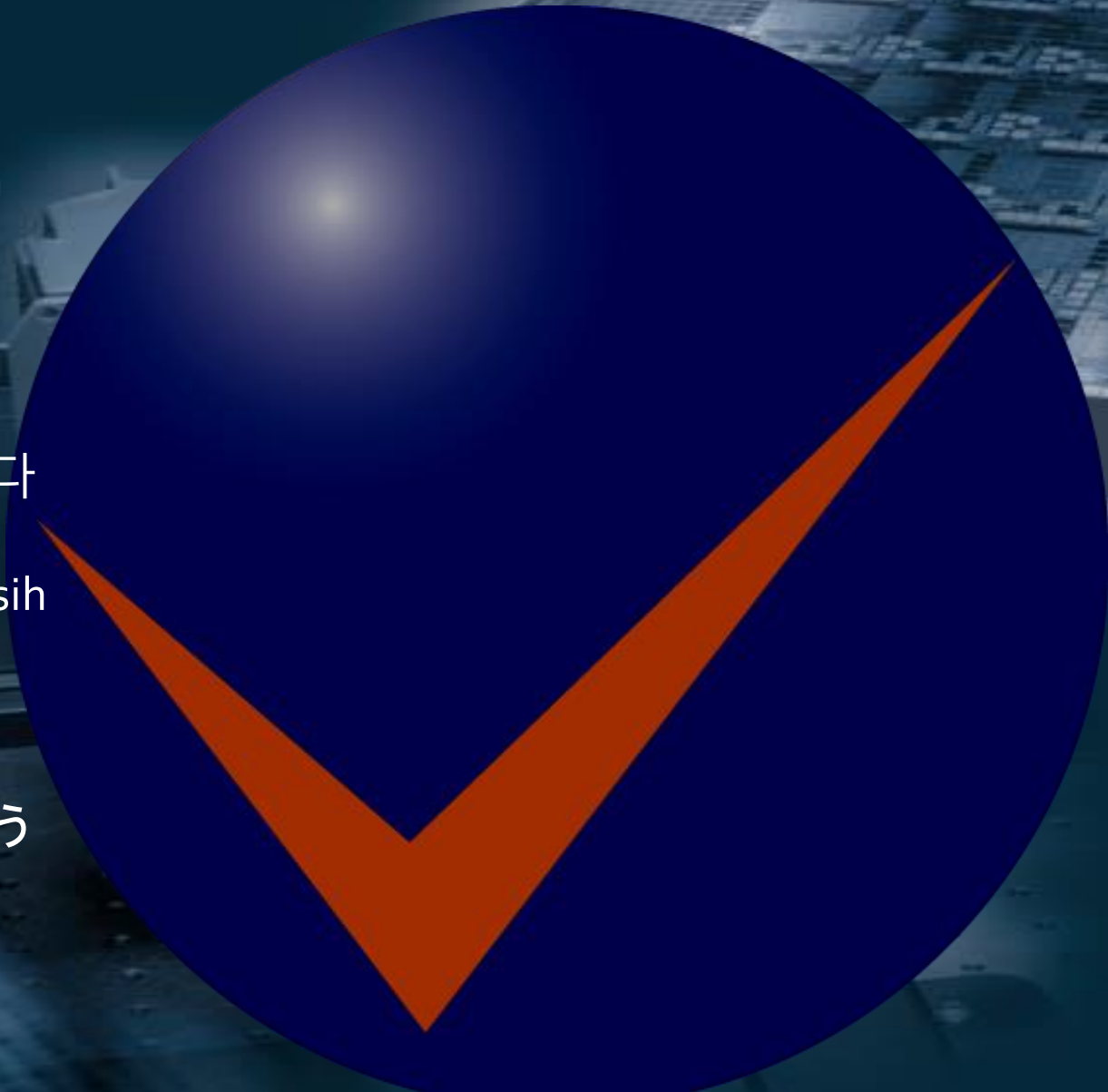
תודה רבה

Grazie

ありがとう

Спасибо

Dank u



INSPECTROLOGY

2/9/2015