Waste, Recycle, Cost, and Solutions in Semiconductor Industry

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WORLD MATERIALS FORUM

NANO-X 中国科学院苏州纳米技术与纳米仿生研究所 纳米真空互联实验站 Vacuum Interconnected Nanotech Workstation

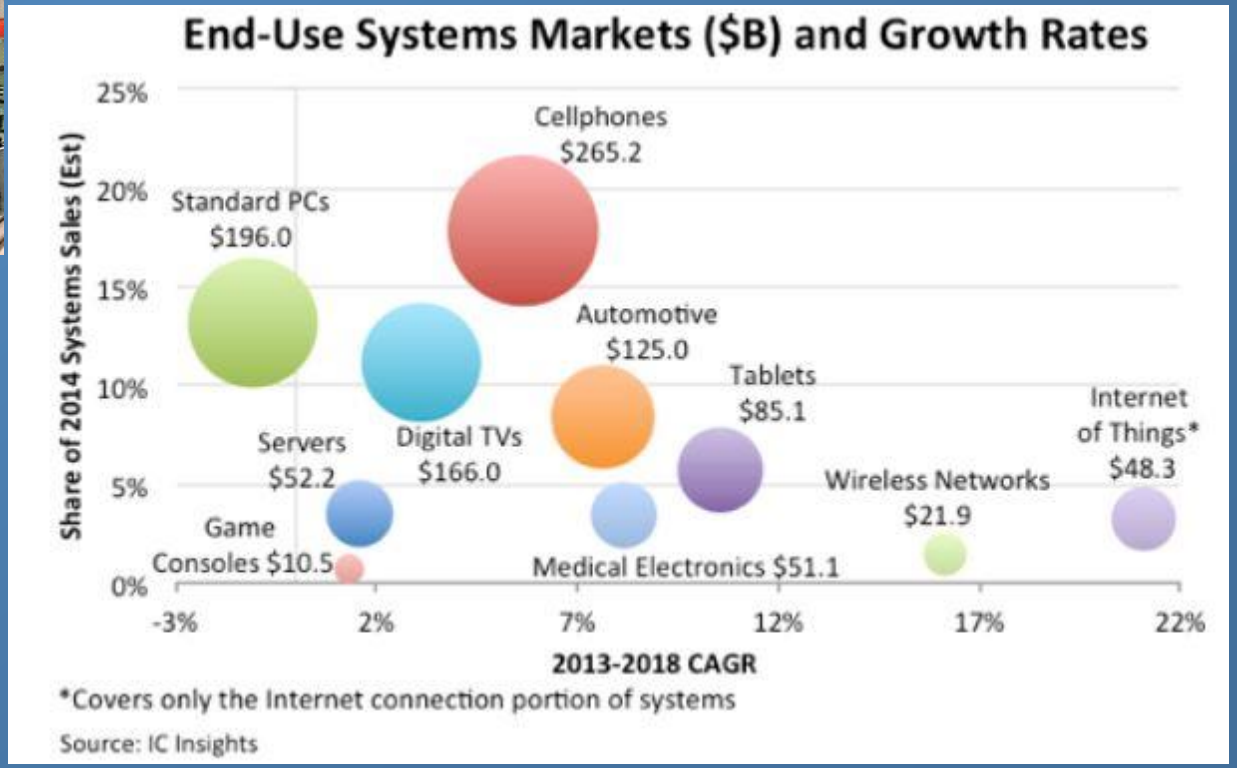
Outline

- Electronic products and wastes
- Recycling and costs
- Challenges of semiconductor manufacturing
- New processing technology in future

Electronic Products Everywhere

Over 200 million LCD TV products every year and still increasing

Over 1 billion cell phone sold every year



e-Products Upgrading Fast

IC Insights: in 2014
smart phone sales over $265.2 billion, about 18% of total electronic products revenue;
PC sales $190.0 billion, about 13% of total revenue

Cell phone upgrades every 9 months.
New model coming…..

Table 1: Top Ten Smartphone Vendors Based on Market Share

Rankings	2013 Company	Market Share	2014 Company	Market Share	2015 Company	Market Share (F)
1	Samsung	32.5%	Samsung	28.0%	Samsung	26.6%
2	Apple	16.6%	Apple	16.4%	Apple	16.4%
3	Lenovo	4.9%	Lenovo + Motorola	7.9%	Lenovo	7.4%
4	Huawei	4.4%	LG	6.0%	Huawei	6.6%
5	LG	4.3%	Huawei	5.9%	Xiaomi	6.5%
6	Sony	4.1%	Xiaomi	5.2%	LG	6.1%
7	Coolpad	3.6%	Coolpad	4.2%	TCL	4.1%
8	ZTE	3.2%	Sony	3.9%	Coolpad	4.0%
9	Nokia	3.0%	ZTE	3.1%	ZTE	3.4%
10	RIM	2.5%	TCL	2.7%	Sony	3.1%
	Others	20.9%	Others	16.7%	Others	15.8%
Shipment Total (Unit:M)		**927.2**		**1,166.9**		**1,290.3**

Source: Trendforce, Jan., 2015

IC Chips vs Oil Imports of China

$231.3 billion
(20.5% increase）

$219.6 billion

2013 imports of China

(Resources: Department of Industry and Information, China)

More and More e-Wastes

Should We Recycle Valuables?

~70% of electronic products end as trashes

There are 16,000 kg copper, 350 kg silver, 34 kg gold, and 15 kg palladium in 1 million smart phone;

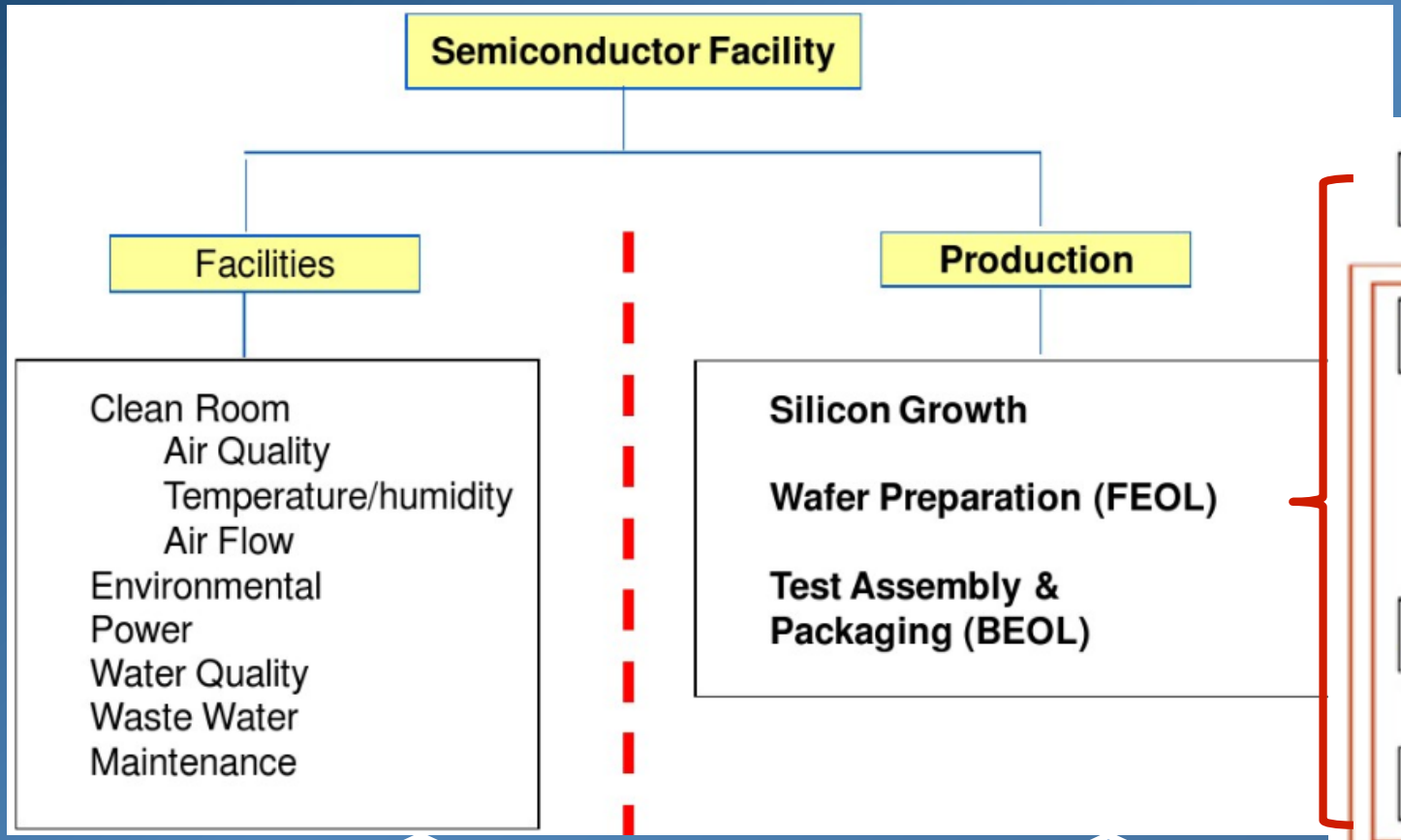
High Costs for Recycle

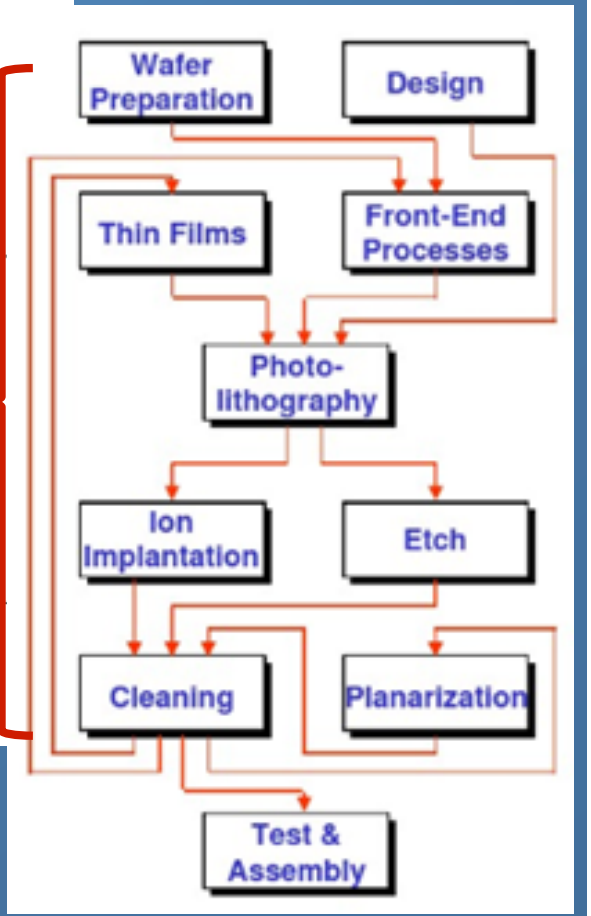
According to author Harvey Black of the *Environmental Health Perspectives Journal,* in San Jose, California "it costs $28 per ton to landfill waste compared with $147 a ton to recycle"

In Atlantic County, New Jersey: selling recyclable goods brings in **$2.45** million. However, the cost of collecting and sorting these recycled materials plus interest payments on the recycling facility costs the county over **$3** million

Recycling facilities not only cost a great deal of money, but they also damage the environment by generating large amounts of waste and endanger human health by emitting numerous toxic pollutants (chemical, heavy metal,..), and children labors….

Semiconductor Chip Fabrication





To amortize a $5 billion investment in a fab over a five-year schedule costs more than $3 million a day

To complete a whole cycle of a product takes 6-8 weeks for hundreds steps of processes

Semiconductor Device Processes

Front End

- Wafer processing
- Wet cleans
- Photolithography
- Ion implantation
- Dry etching
- Wet etching
- Plasma ashing
- Thermal treatments
- Rapid thermal anneal
- Furnace anneals
- Thermal oxidation
- Chemical vapor deposition (CVD)
- Physical vapor deposition (PVD)
- Molecular beam epitaxy (MBE)
- Electrochemical Deposition (ECD).
- Chemical-mechanical planarization (CMP)

Back End

- Wafer testing
- Wafer back grinding
- Die preparation
- Wafer mounting
- Die cutting
- IC packaging
- Die attachment
- IC Bonding
- Wire bonding
- Flip chip
- Tab bonding
- IC encapsulation
- Baking
- Plating
- Laser marking
- Trim and form
- IC testing

Costs of IC Manufacture

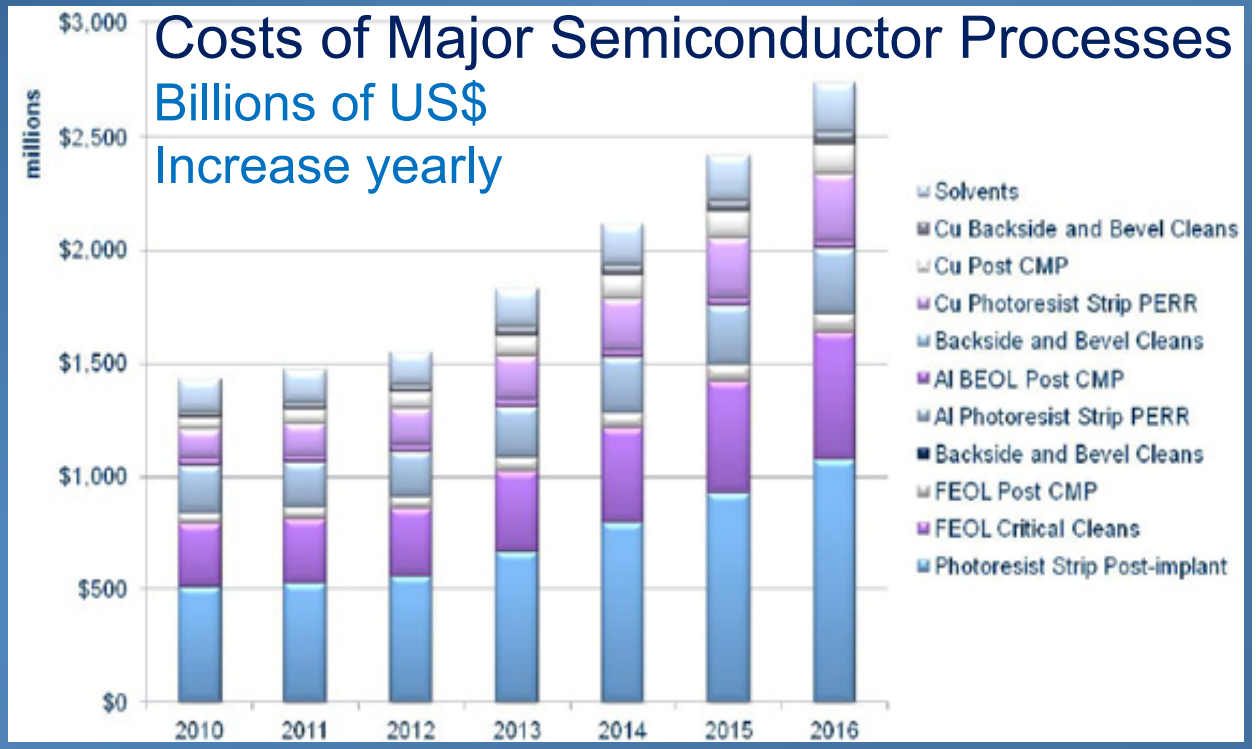
Massive consumptions:

energy (power for clean room, tools, and processing);

water (PCW and ultra-pure water);

chemicals and gases (wet etching, dry etching, …);

noble metals (Pt, Au, Ag, rare earth…)

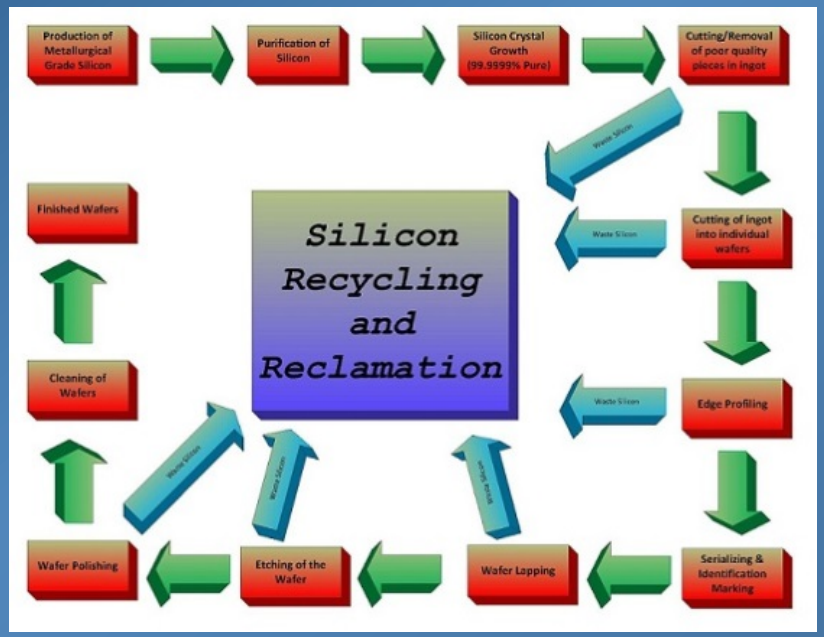


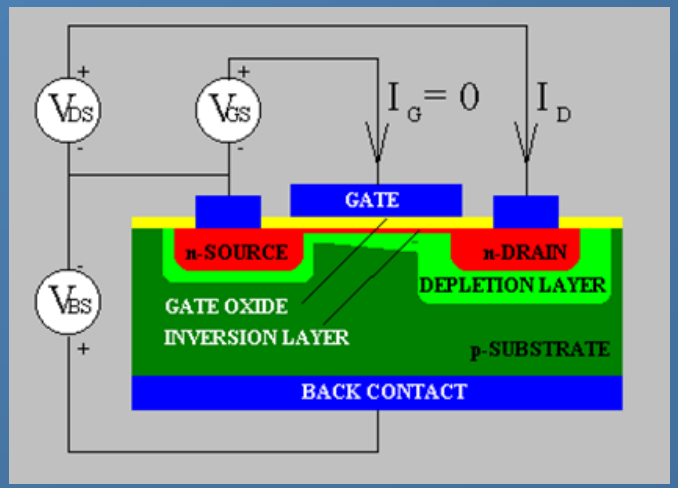
Strategies for Cost Reduction

Current saving strategies:

- large wafer and batch processes;
- smaller chips and ultra-high integration;
- automation;
- new structure and materials;
- yield and reliability….

As chip production volumes increases, the per unit cost inevitably goes down





30 million transistors on a head of pin; Over billions of transistor on a CPU chip

Challenges in Traditional Fab

- Huge investment (more than billions US$)
- Complicated process (hundreds of process steps)
- Manufacturing ambient control (super-clean room)
- Consumables (Noble-metals/chemicals/gases/water/power..)
- Impacts on environment (easy to dismantle at the end)

Manufacturing in the Future

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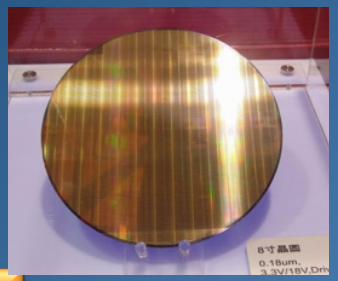
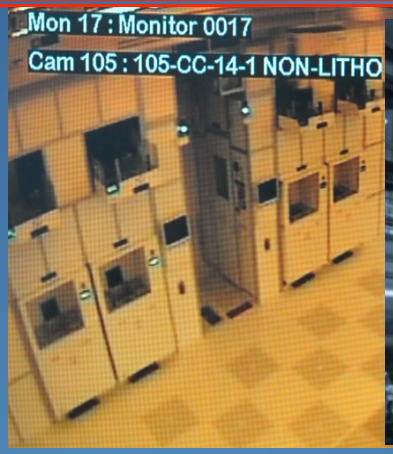
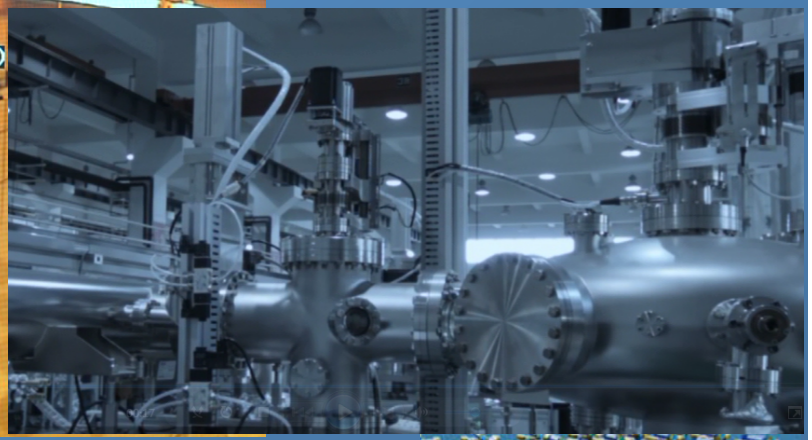
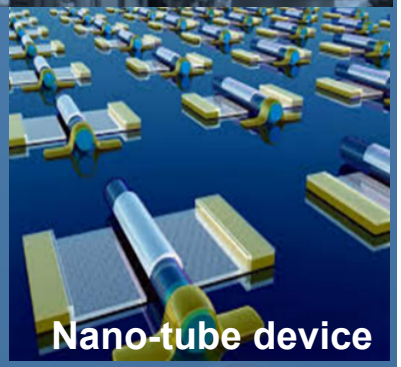
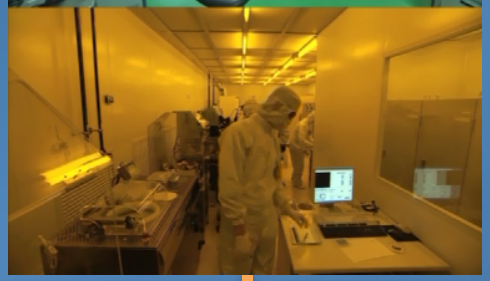










µm

1.00

0.10

0.01

0.5µm

0.25µm

0.13µm

65nm

32nm

20nm

5nm

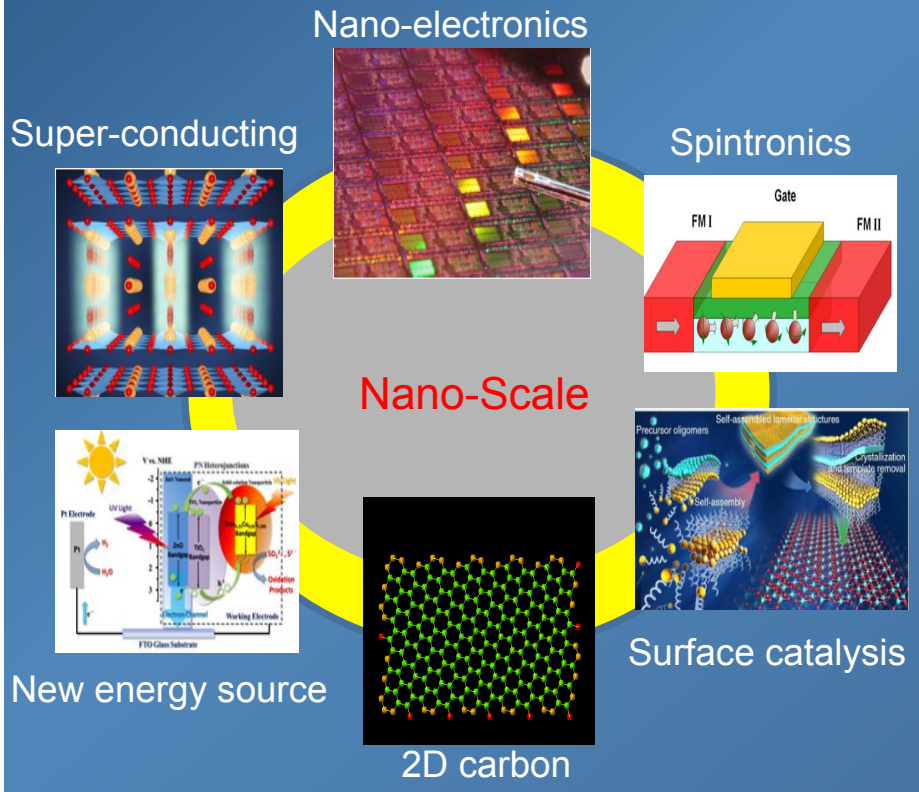
Moore's Law

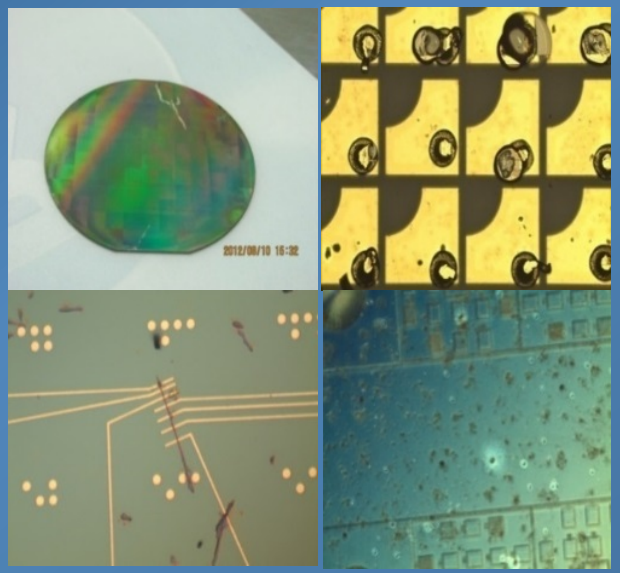
1990 1995 2000 2005 2010 2015 Near Future

Why is Vacuum so Important?

Specials of nano-materials

- Size effects
- Quantum effects
- Surface effects
- Interface effects





~ 80% failure root causes: surface/ interface contaminations

---Not only particles, but H_2O, O_2, C, CH- etc. on surfaces

Vacuum and surface adsorption

Ambient pressure (Pa)	Molecular density (Parts /cm^{-3})	Time for 1 ML adsorption
10^5 (1 atm)	2.7×10^{19}	3×10^{-19} 秒
10^{-4}	2.7×10^{10}	3 s
10^{-6}	2.7×10^{8}	5 min
10^{-8}	**2.7×10^{6}**	**8.5 hrs**
10^{-10} （The Moon）	2.7×10^{4}	35 days

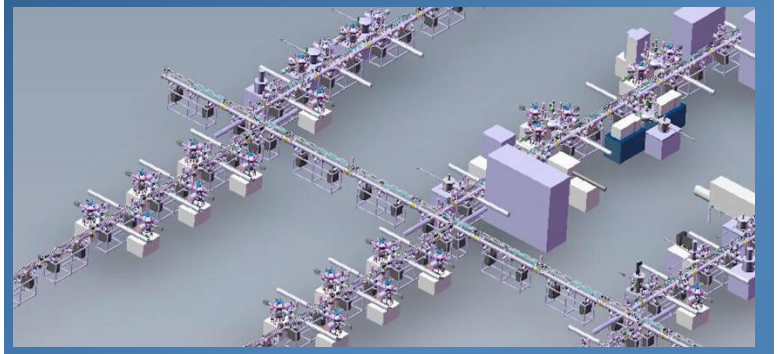
The Project of Nano-X

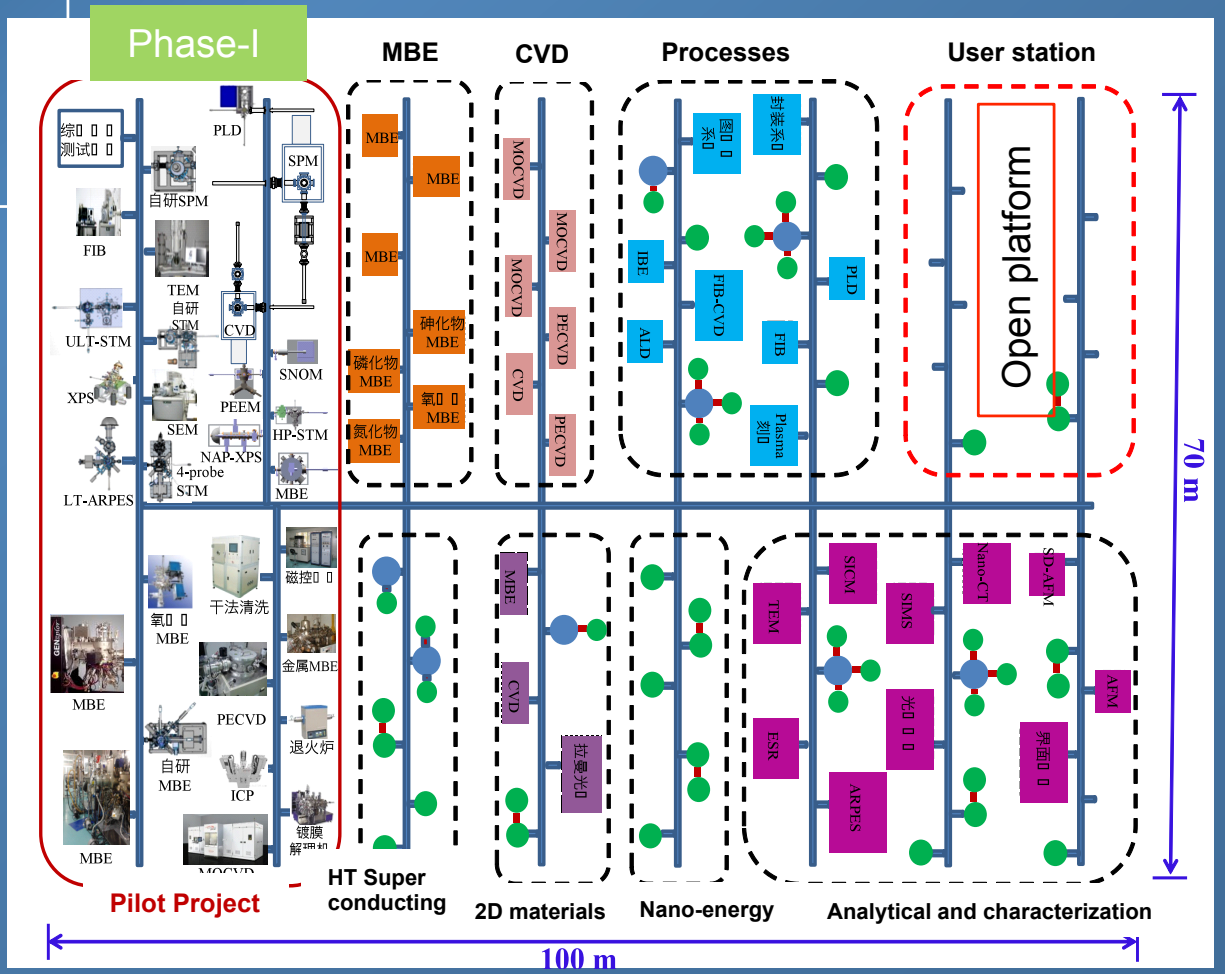
NANO-X：Opened and multifunctional UHV-interconnected system for materials growth, device processing, analysis and characterizations

>500m UHV Tube (<5e^{-8}Pa)；

100+ Tools；

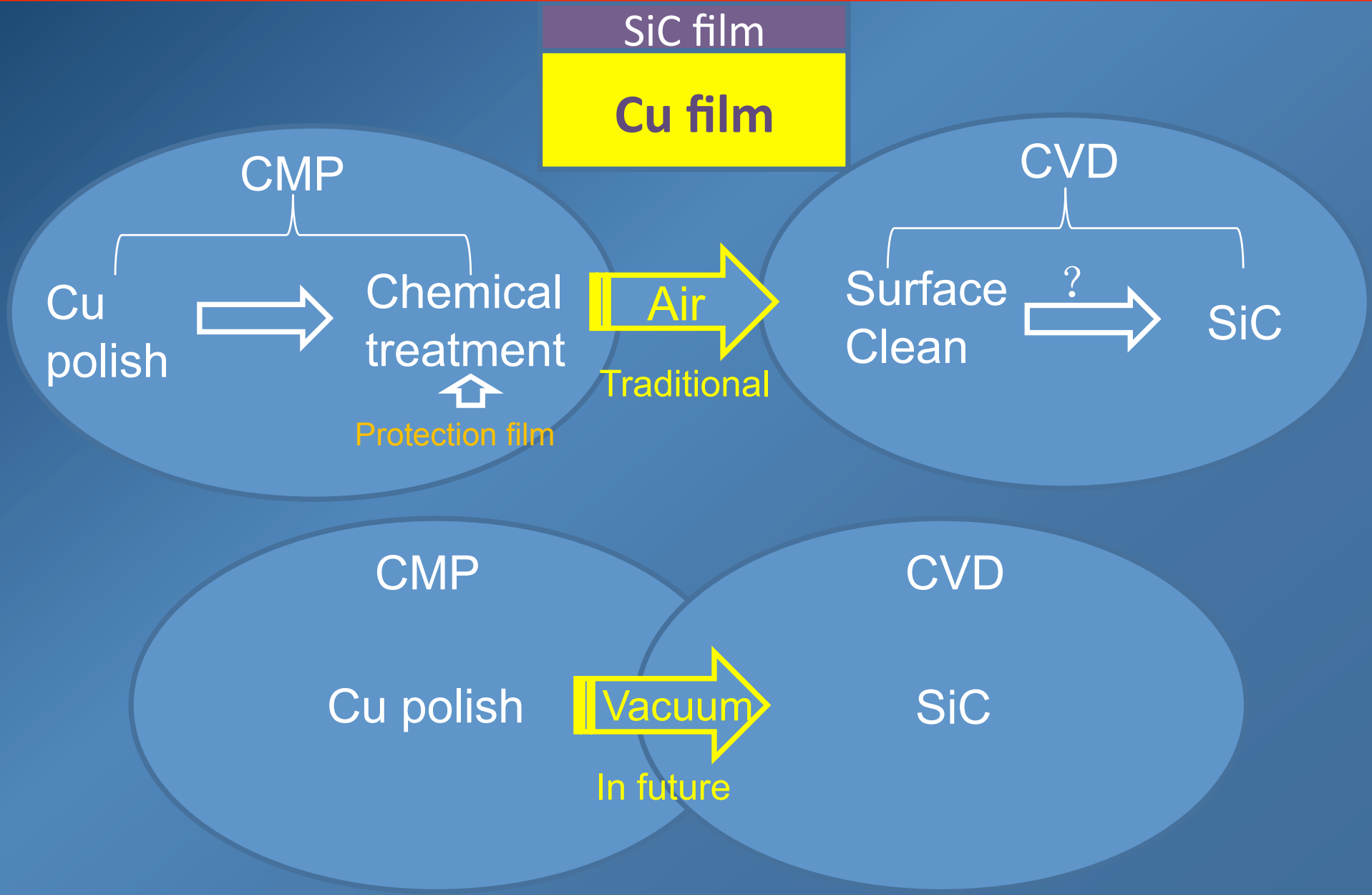
Budget: ~1.5B RMB





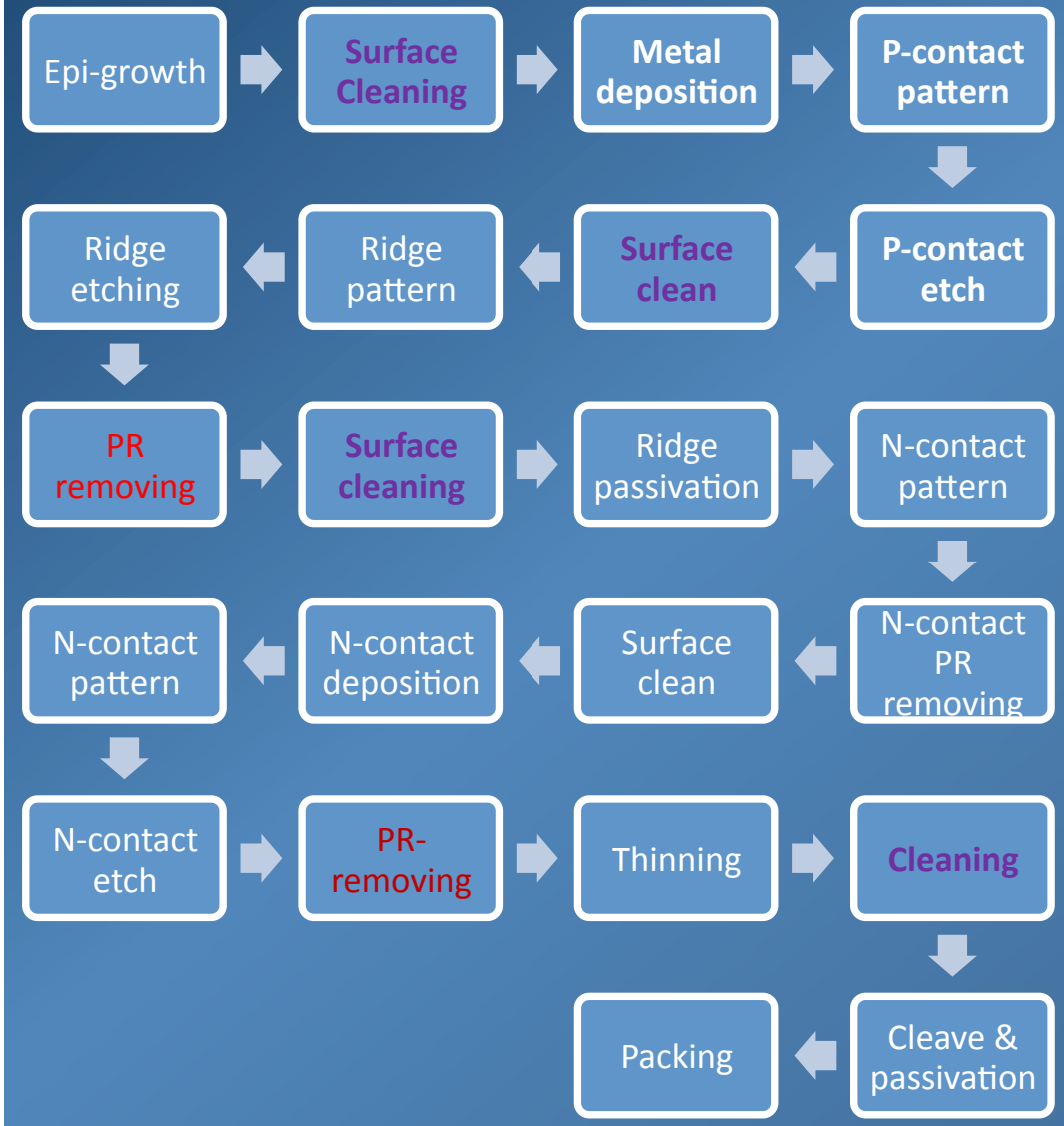
The Progress of Nano-X

The Application of Nano-X

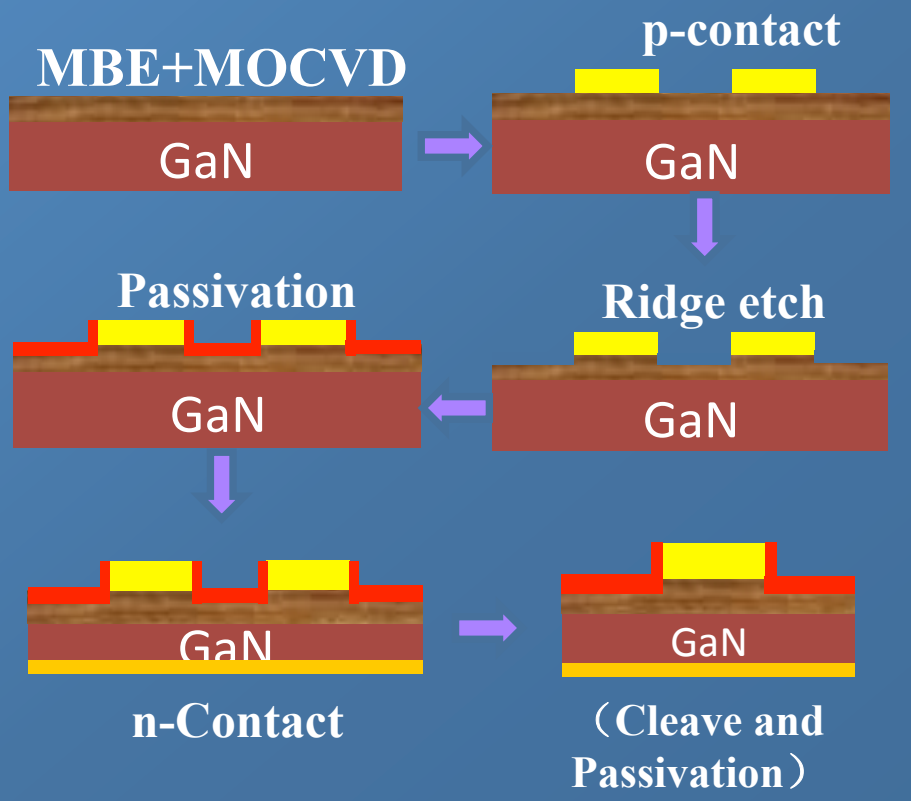


New Process Flow of Laser Diode

Traditional Processes of Laser Diode



Developing Novel Processes of Laser Diode



Summary

- The inundation of e-products has changed people's daily life remarkably in almost everywhere
- E-waste is a big issue has to be considered seriously
- Traditional semiconductor industry facing challenges: costs, pollution, and technology
- Innovative process technologies are explored for future semiconductor manufacturing model

Acknowledgements

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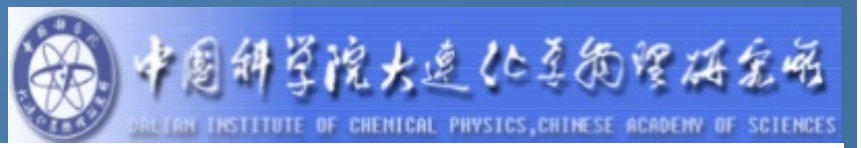

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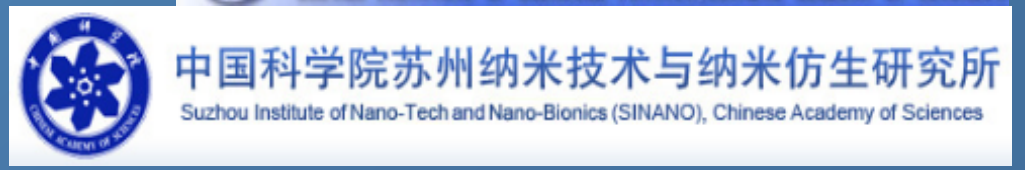


Thanks
Nano-x
The future….