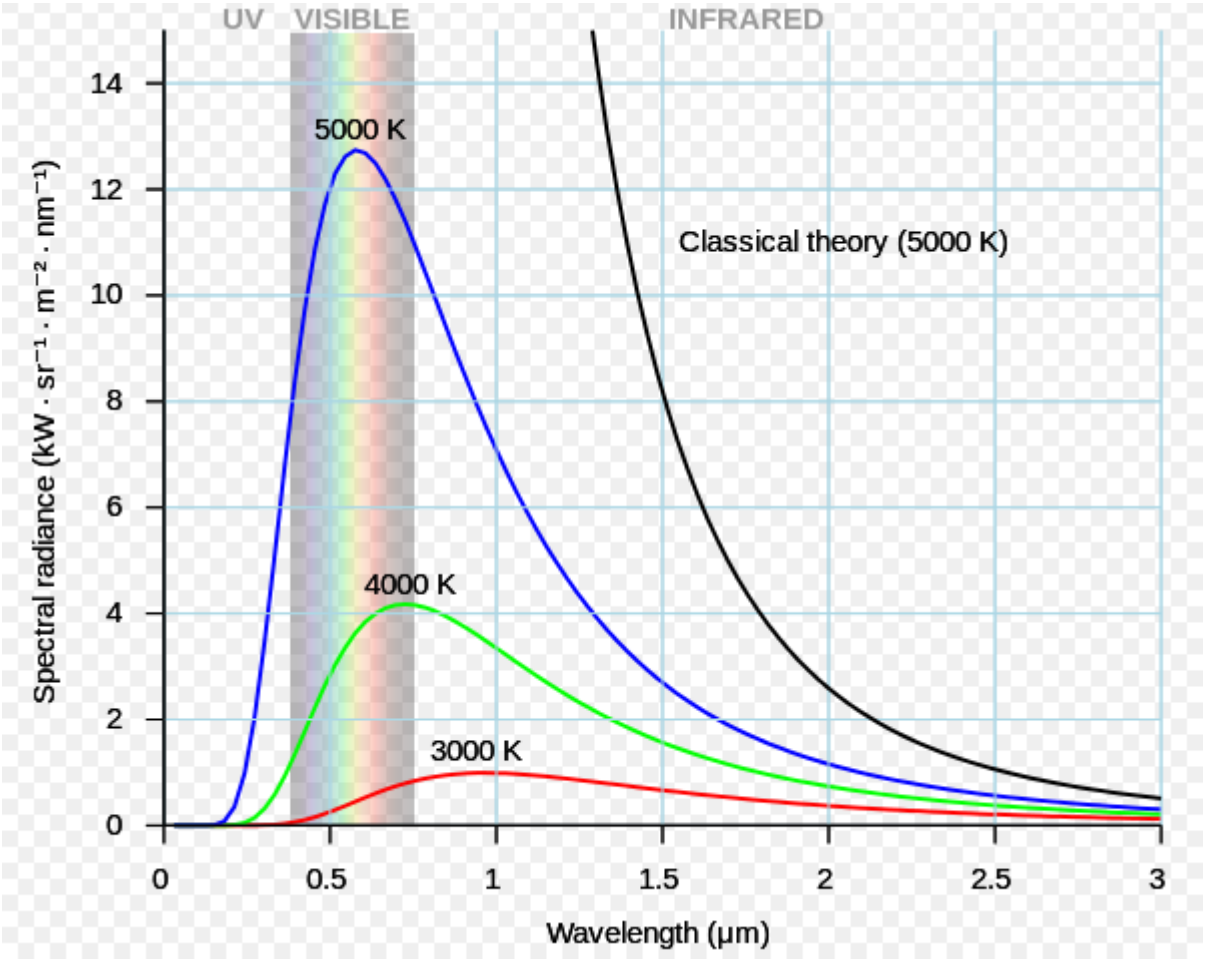
From Black-Body Radiation to Next-Generation Electronics

C.T. Liu

2014.11.19

Contents:

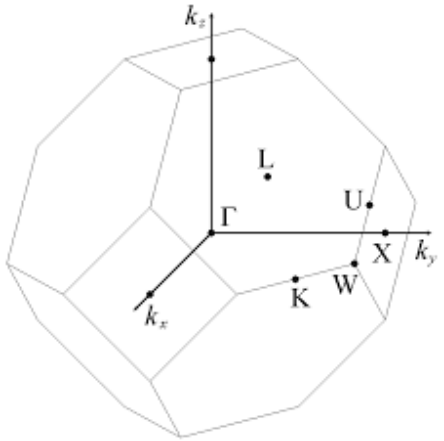
From Black-Body Radiation to Quantum Mechanics

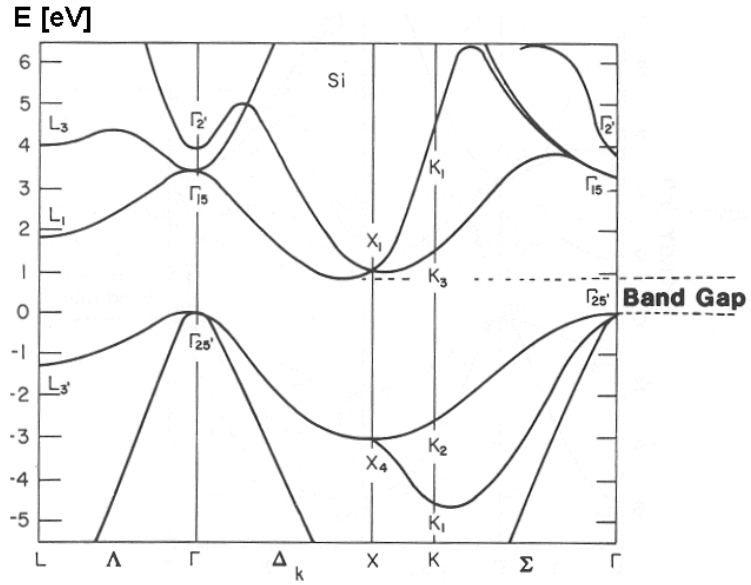


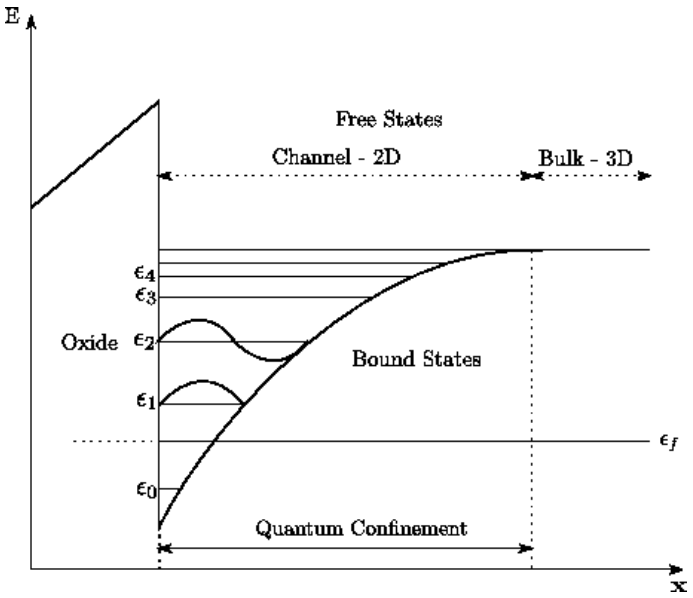
Planck discovered the empirically fitting function, and constructed a physical derivation of this law. In 1901, he expressed $\epsilon = h\nu$. h is now known as Planck's constant.

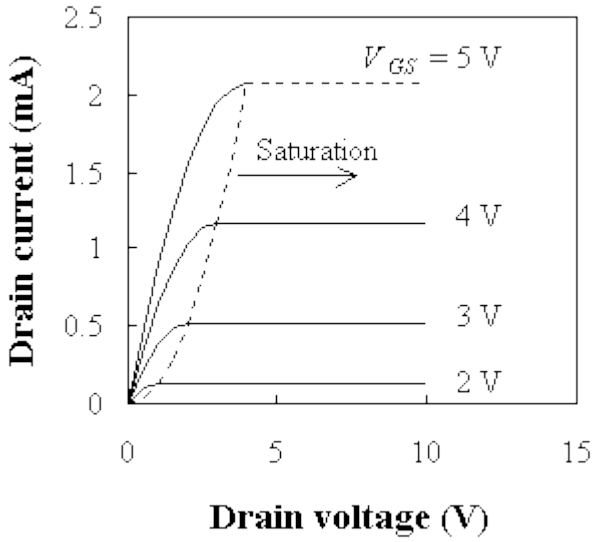
Ultimately, Planck's law of black-body radiation contributed to Einstein's concept of quanta of light, which became the fundamental basis for the development of quantum mechanics.

From Quantum Mechanics to Transistors

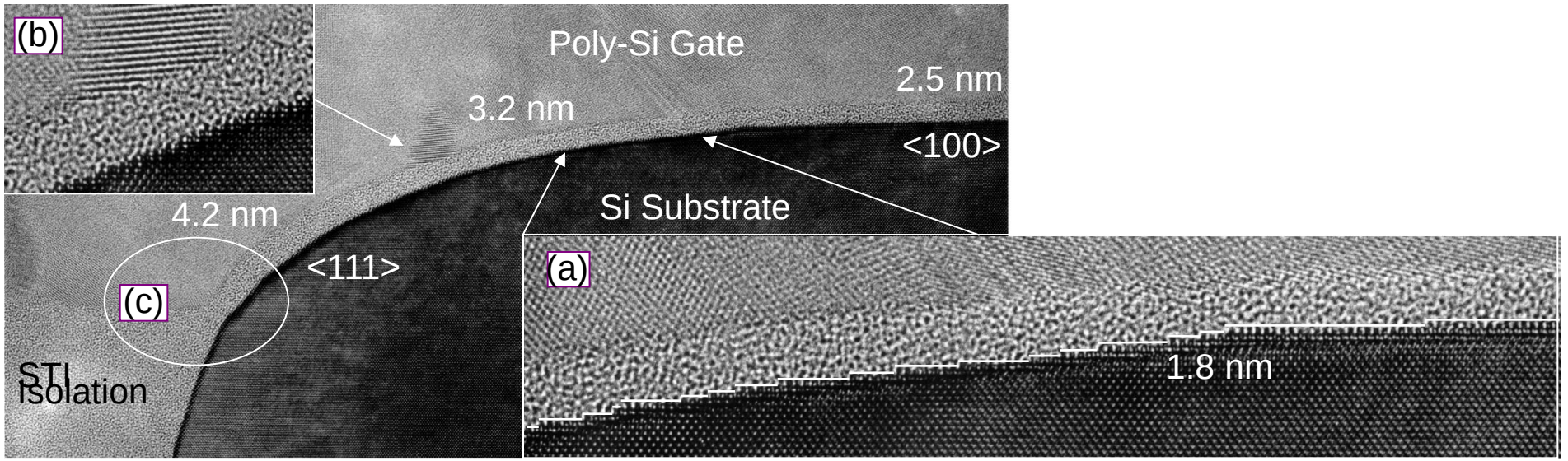


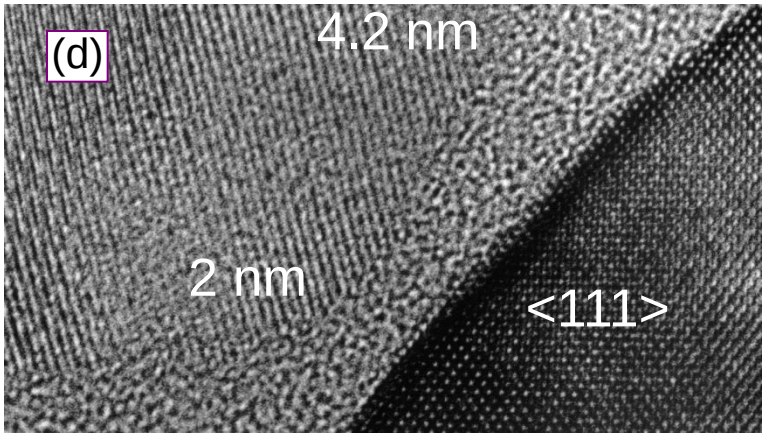


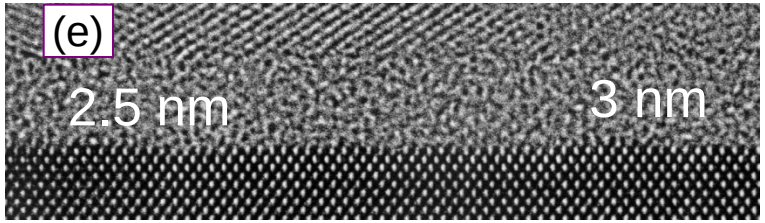




Thickness Variation

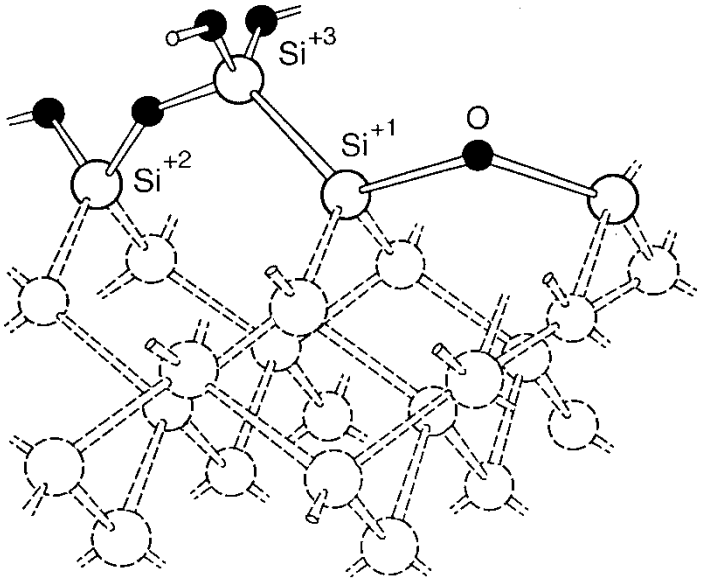


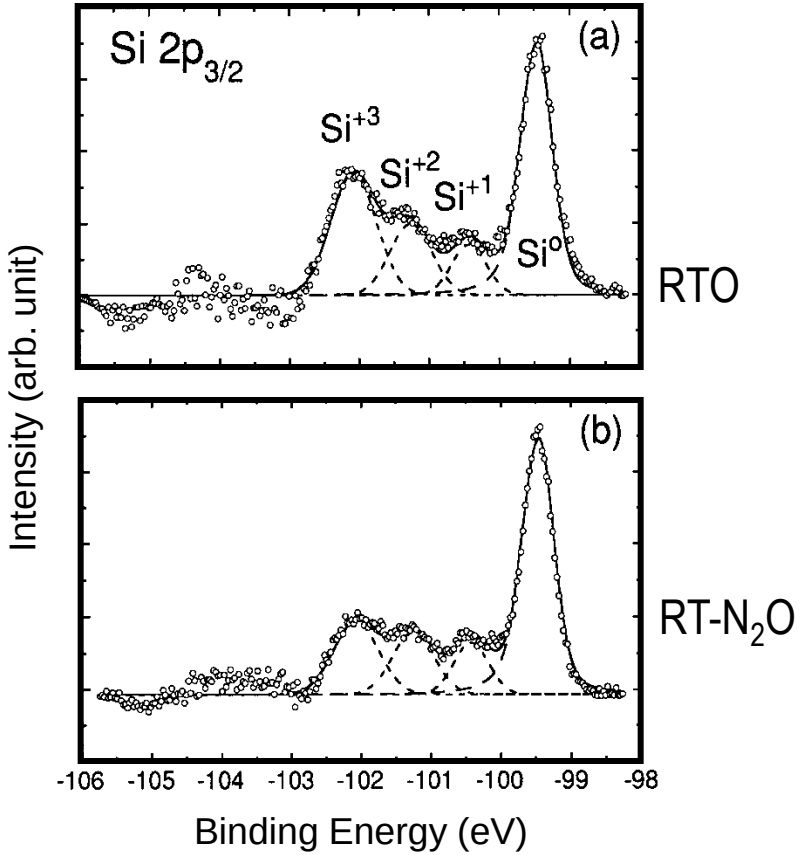




Sub-Oxide Structures

Interface imperfect bonds can be studied with high-resolution XPS.

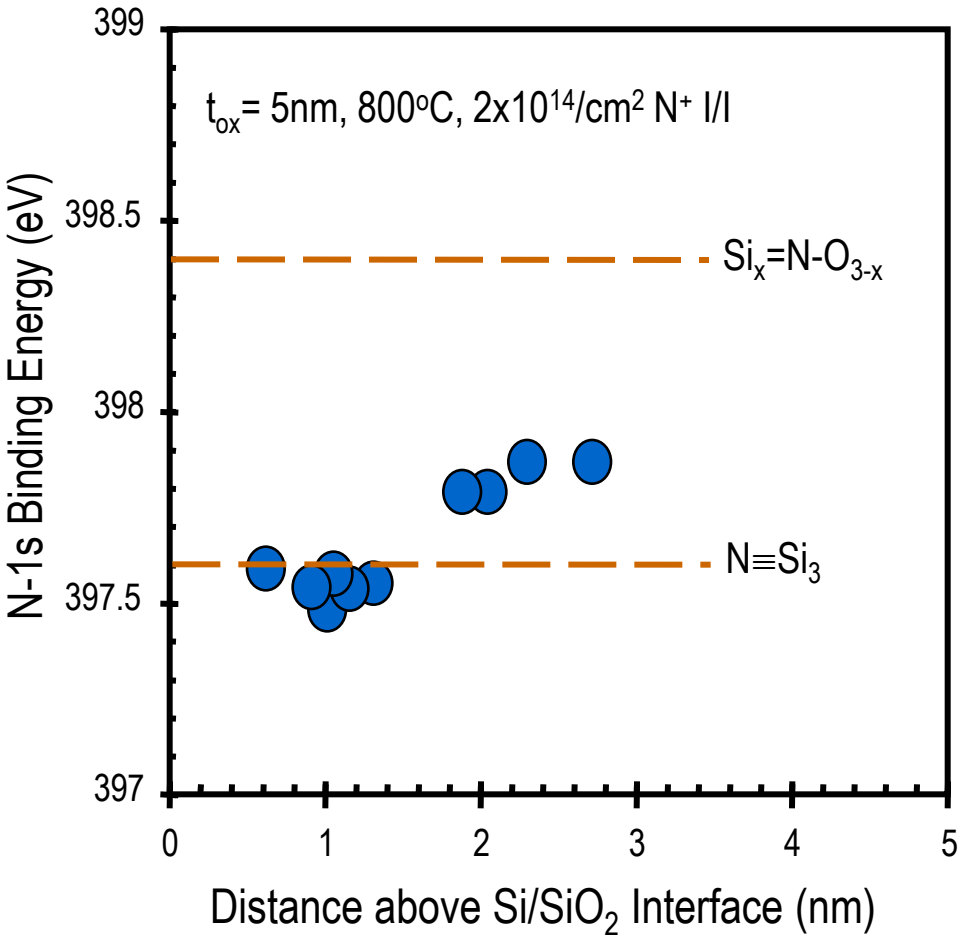




Z.H. Lu, "Synchrotron and Conventional Photoemission Studies of Oxides and N_2O Oxynitrides," in "Fundamental Aspects of Ultrathin Dielectrics on Si-Based Devices," edited by E. Garfunkel et al., Kluwer Academic Publishers, Netherlands, 1998, p.49.

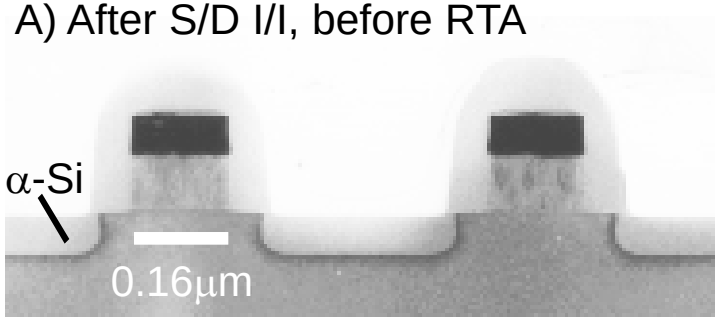
Nitrogen Binding Energy

1. N-1s binding energy ~ 397.6eV, same as Si_3N_4.
2. Longer oxidation increases the binding energy toward 398.4 eV of Si_x=N-O_{3-x}.
3. Wet-oxidation also shifts the binding energy to 398.4 eV.

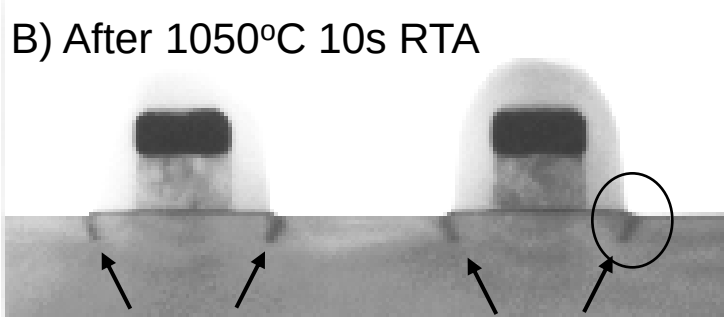


Substrate Defects

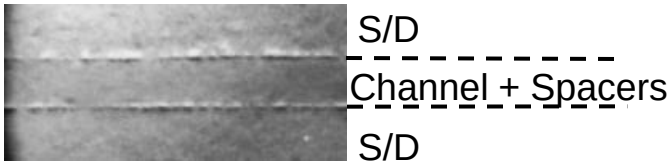
A) After S/D I/I, before RTA



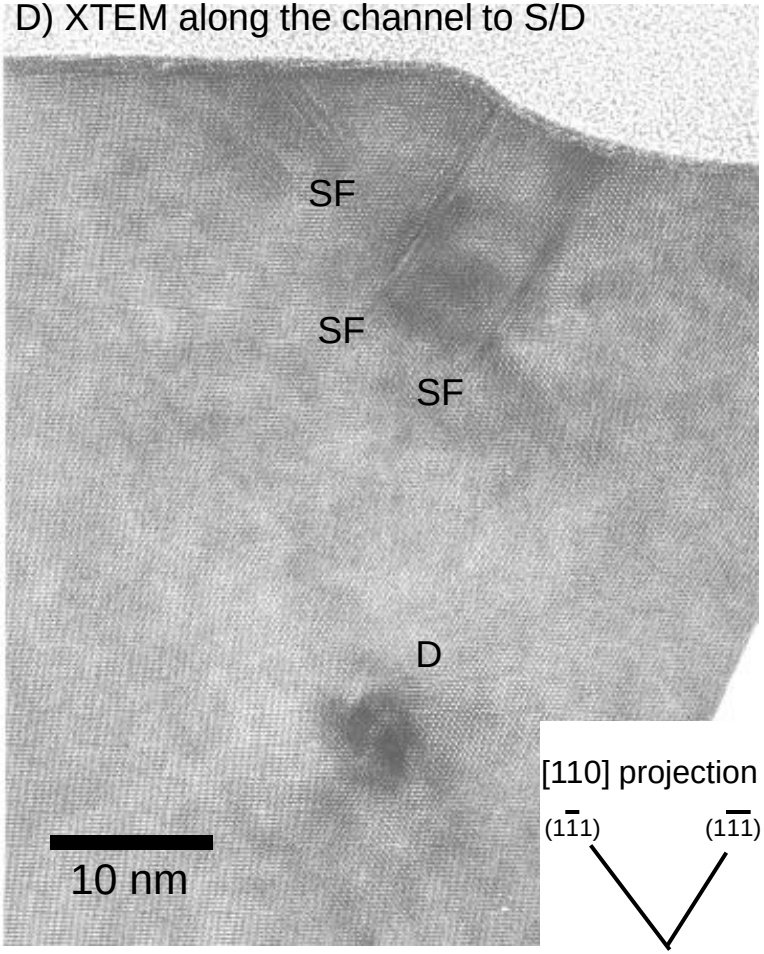
B) After 1050°C 10s RTA



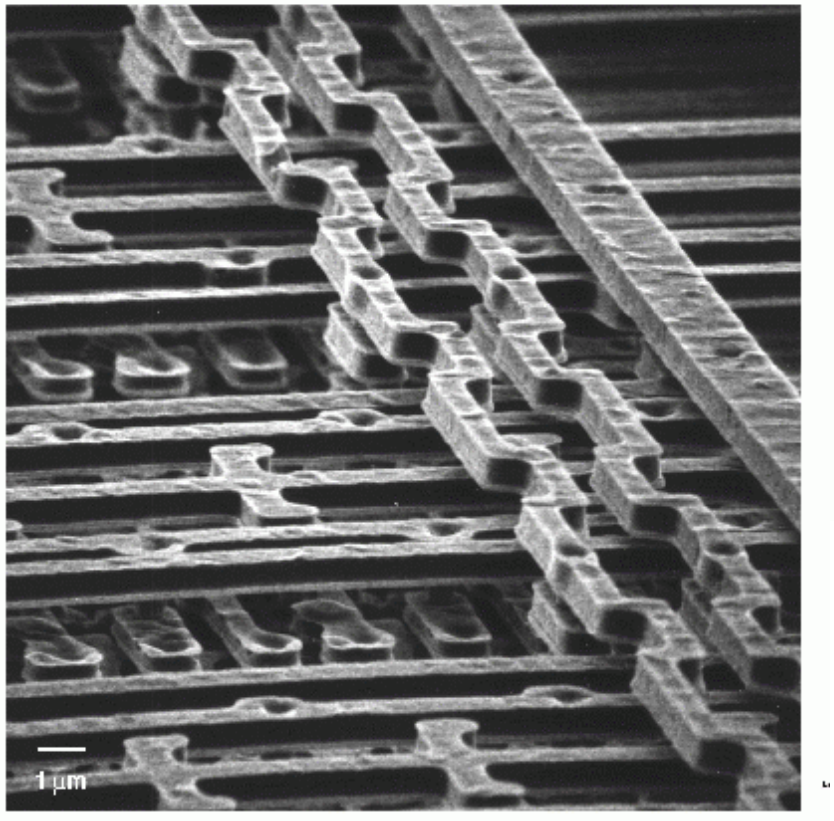
C) Top-Plan View TEM

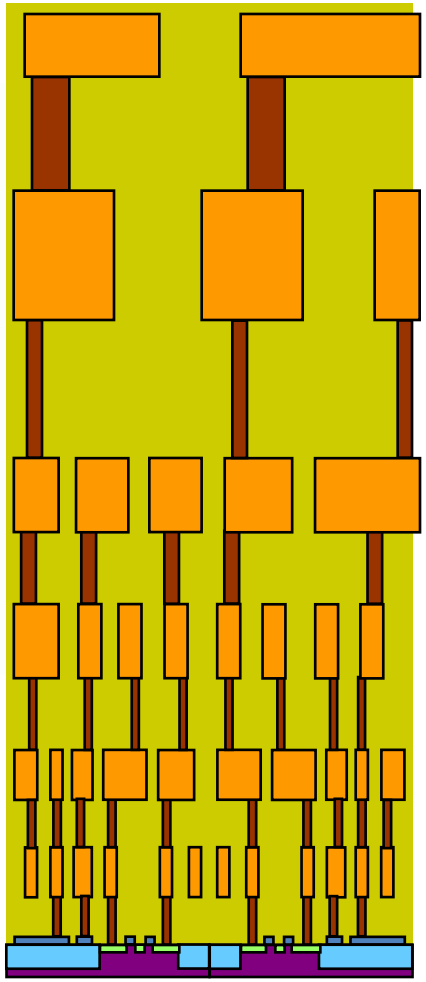


D) XTEM along the channel to S/D

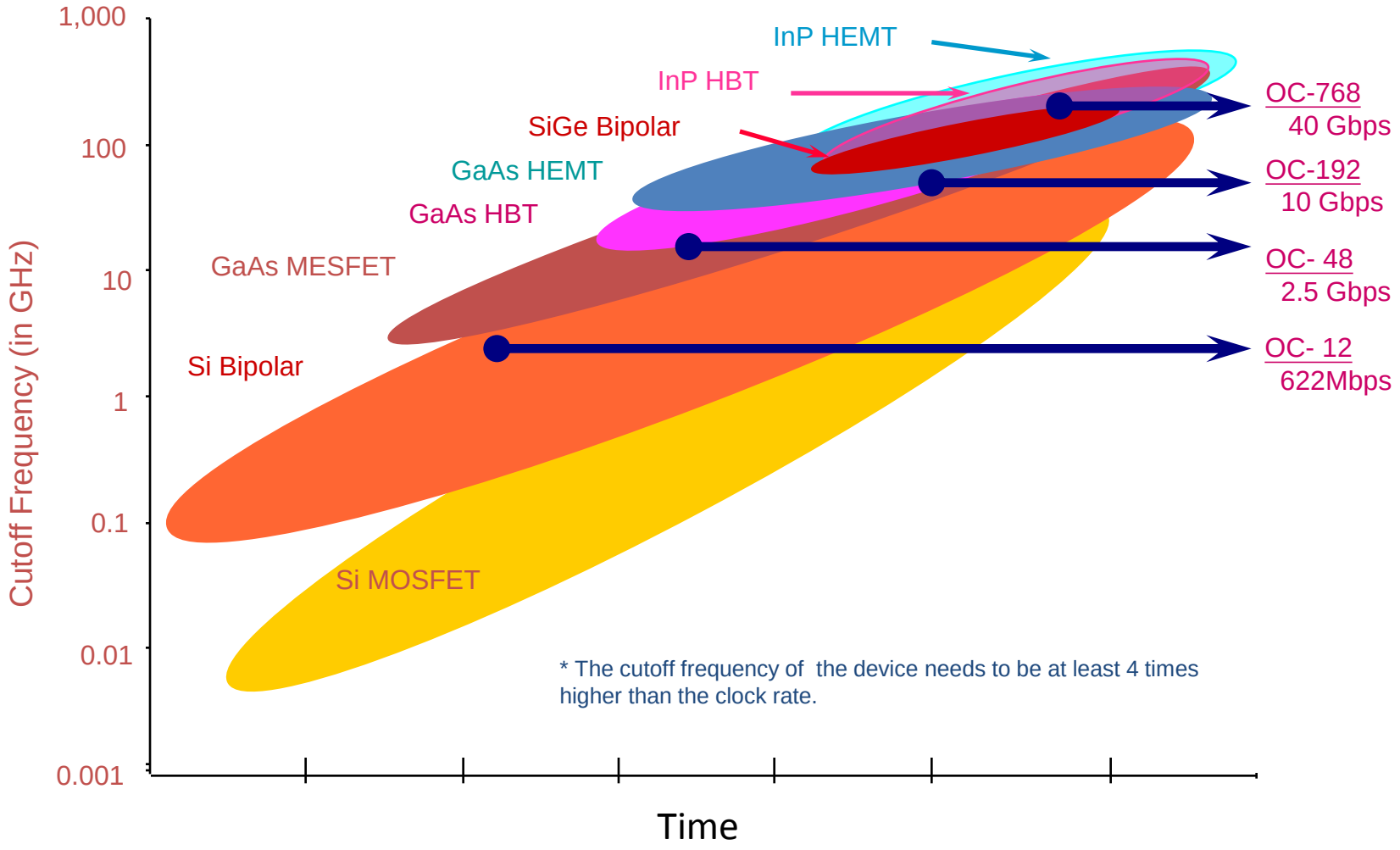


Interconnect Challenges

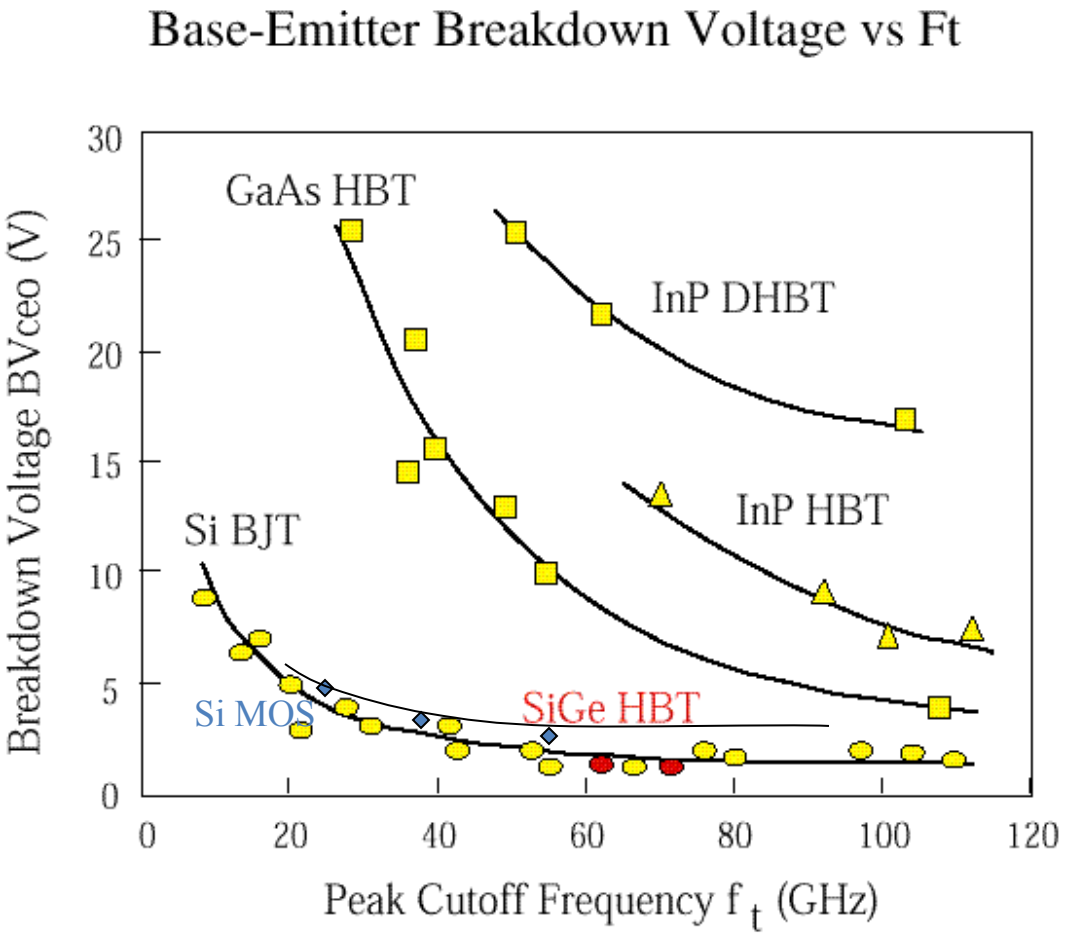




Communication IC Technology Roadmap



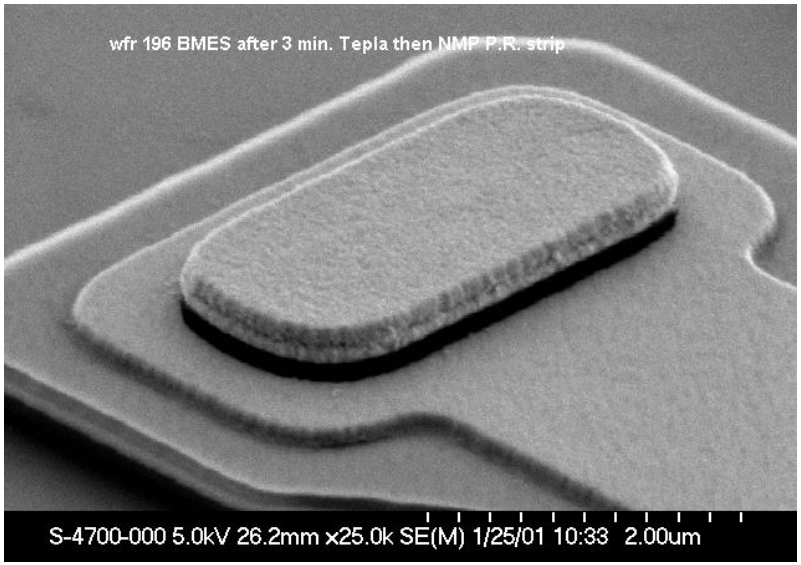
High-Speed Technologies

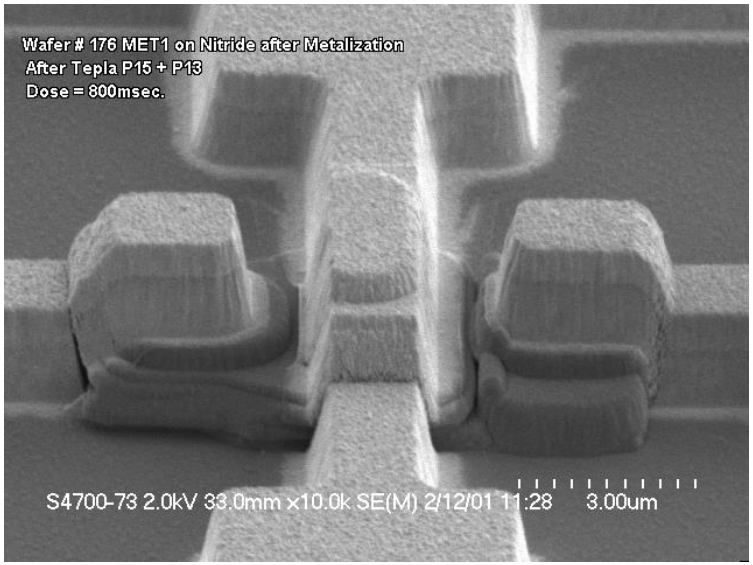


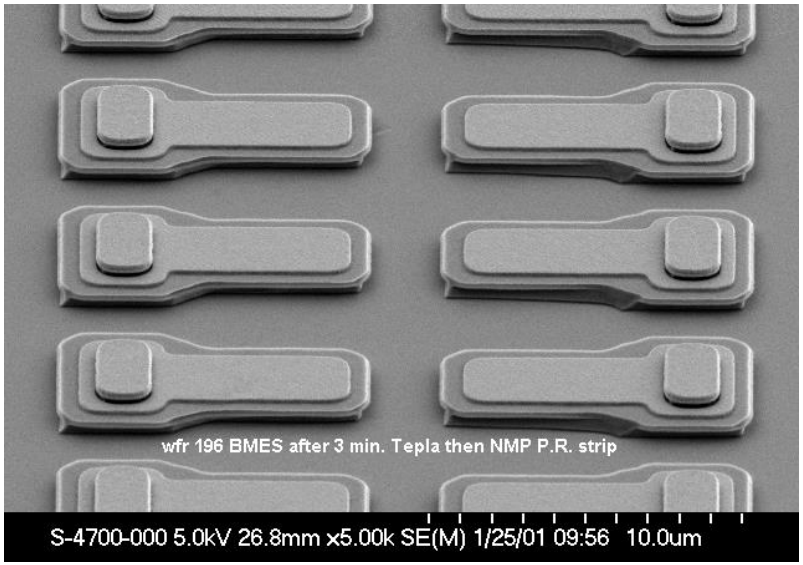
Parameters for Device Breakdown:

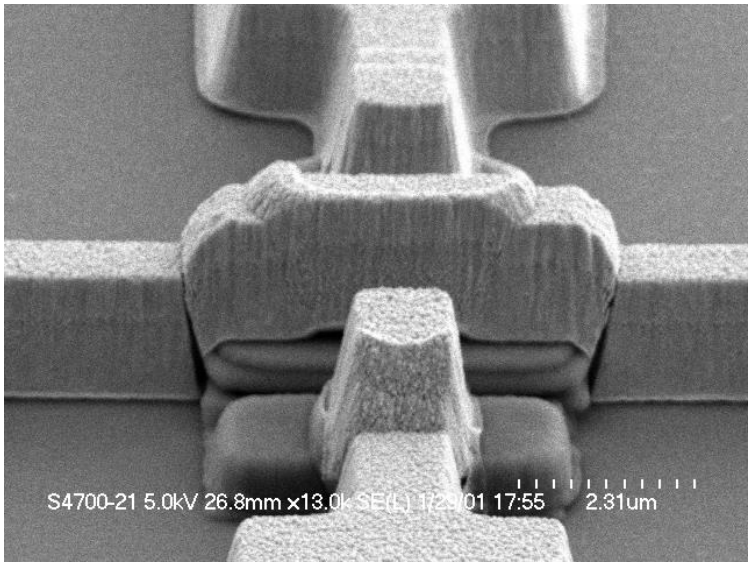
- bandgap energy
- doping density
  - short-channel FETs
- dielectric breakdown
  - short-channel MOS
- space-charge limiting current
  - collector current of BJTs

InP HBT Device SEMs







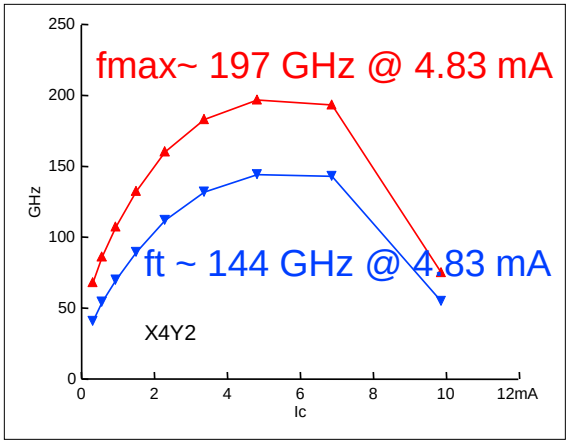


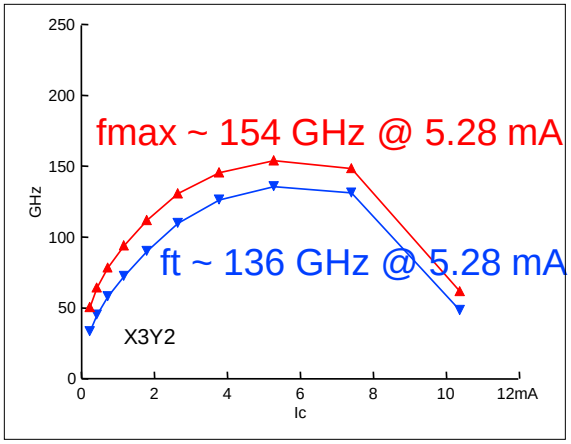
InP DHBT --- RF Performance

ft fmax Plot

Lot 51, wafer 203, RF tester 1.6 x 3.4

------- ft ------- fmax

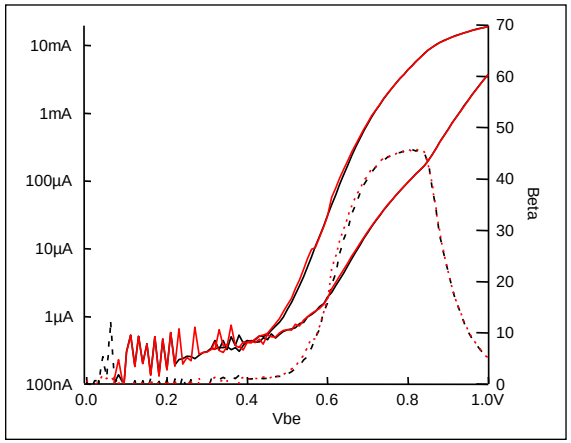


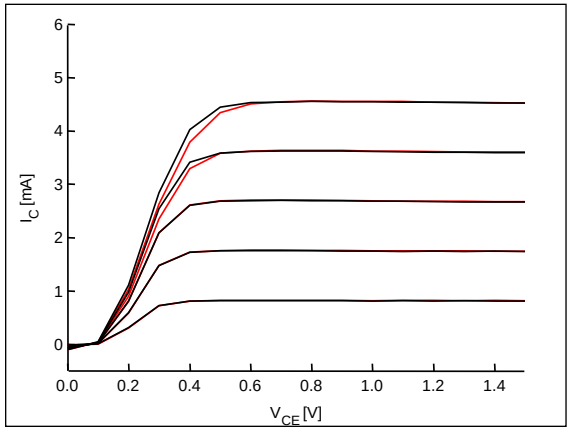


DC degradation after RF excitation

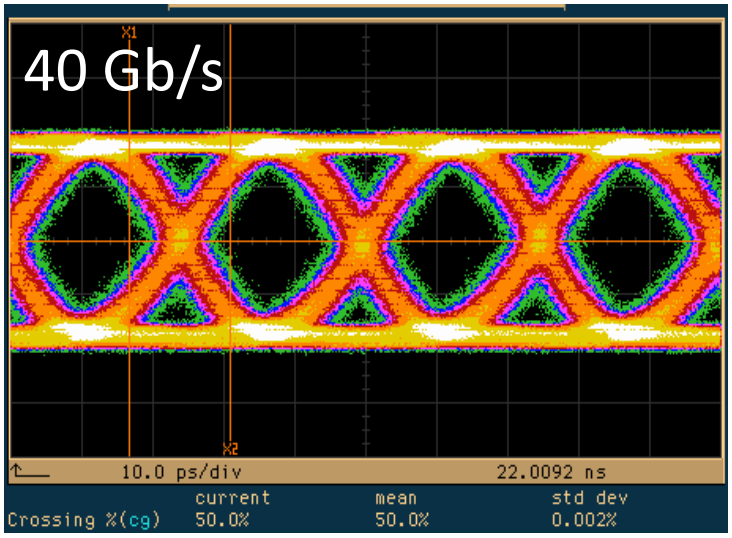
Lot 51, wafer 203, RF tester 1.6 x 3.4

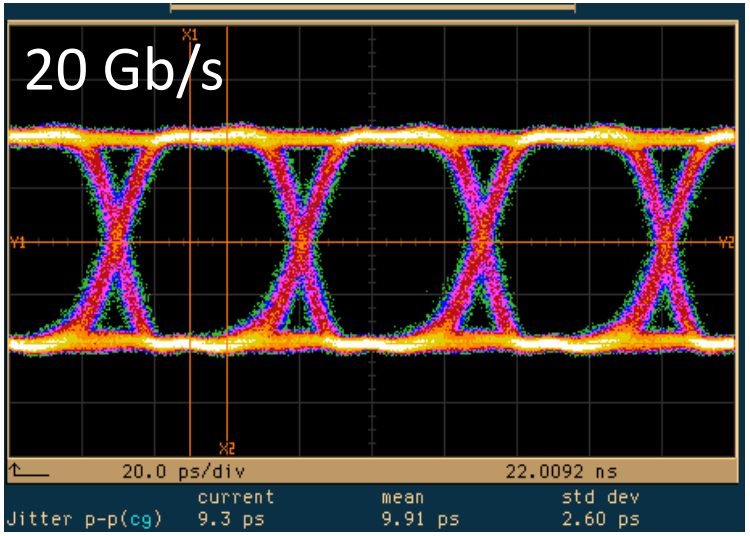
------- before ------- after





40Gb/s Driver Amplifier

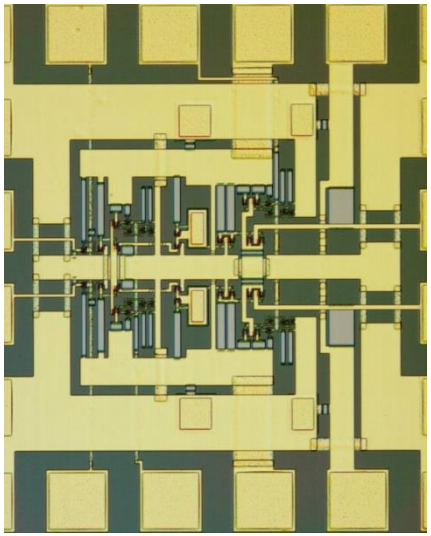




Output up to 4.5V (5V simulated)

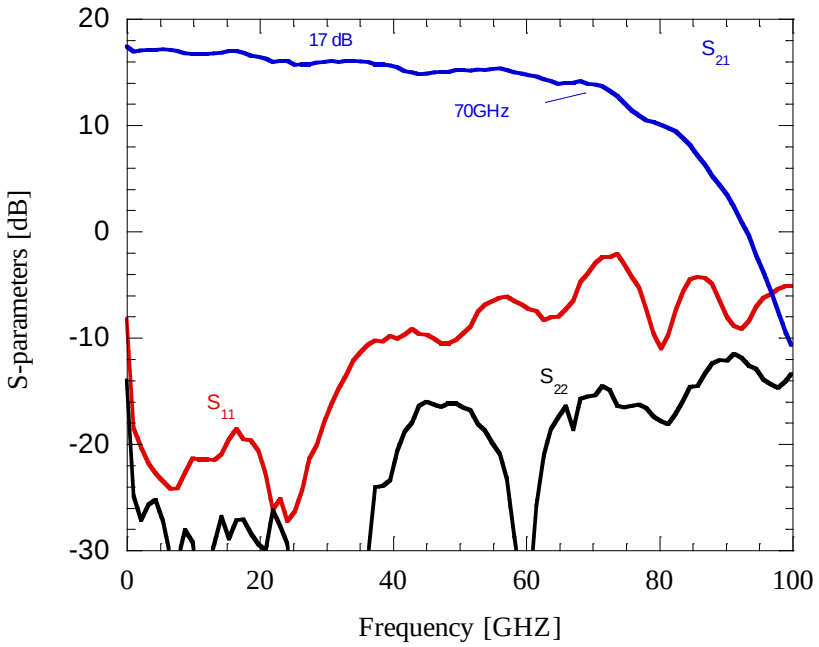
Bias for this measurement:
Vee=-5.3V, I=190 mA
Vcc1=0.6V
Vcc2=2.5V, I=50 mA
Very low power consumption: 1.2 W!!

- most of jitter caused by 40 Gb/s source
- rise time @ 40Gb/s limited by source, and on-wafer measurement: cables and probes



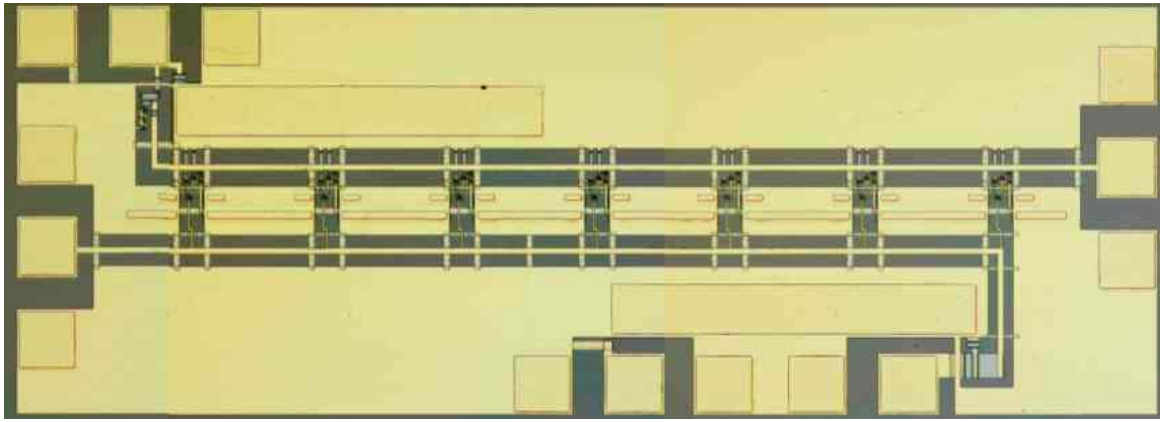
Very compact circuit size: 850x850 μm

High Gain-BW Distributed Amplifier for 40Gbps

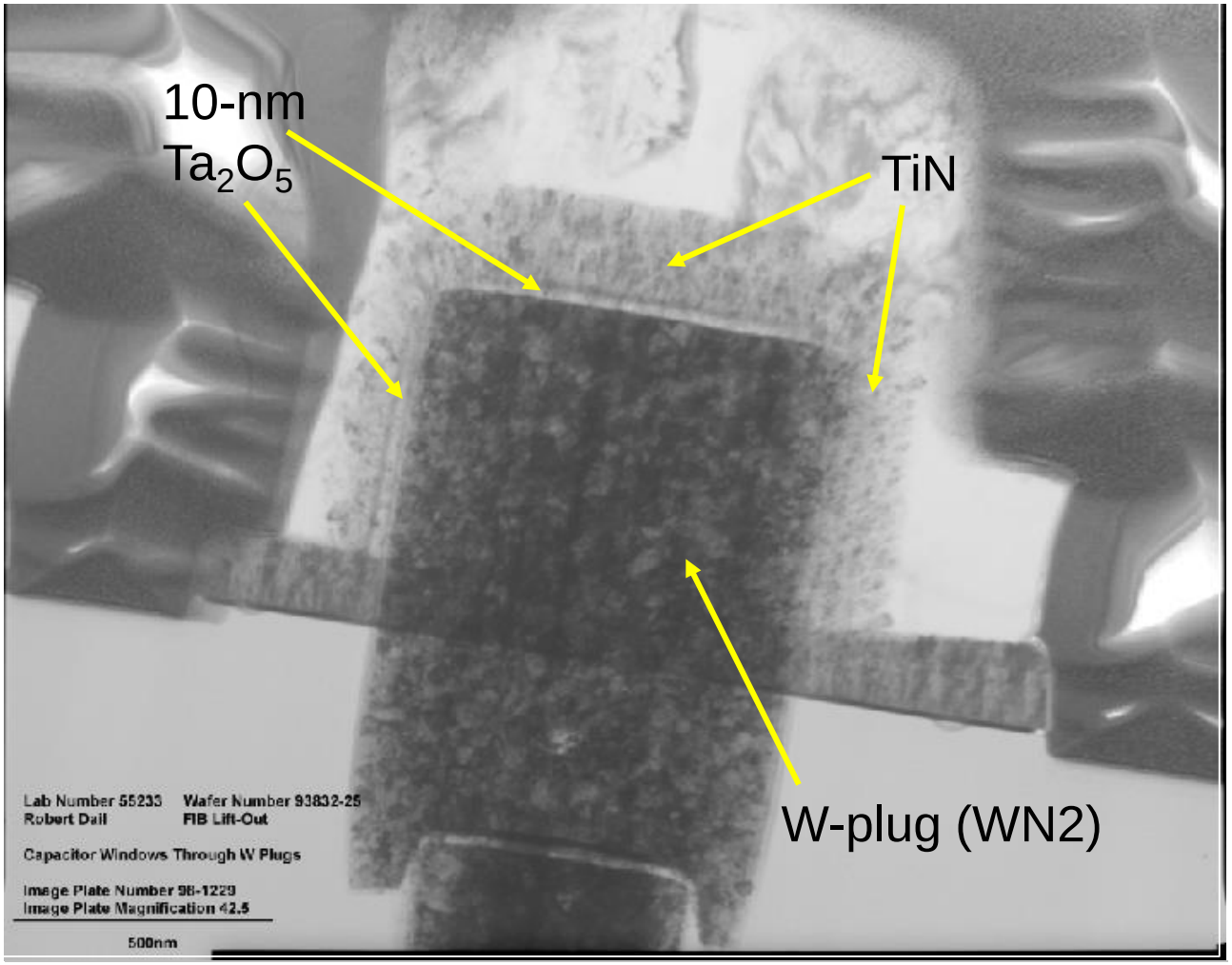


Gain=17 dB
BW>70 GHz
GBW>500 GHz
(record GBW for single-stage DA)

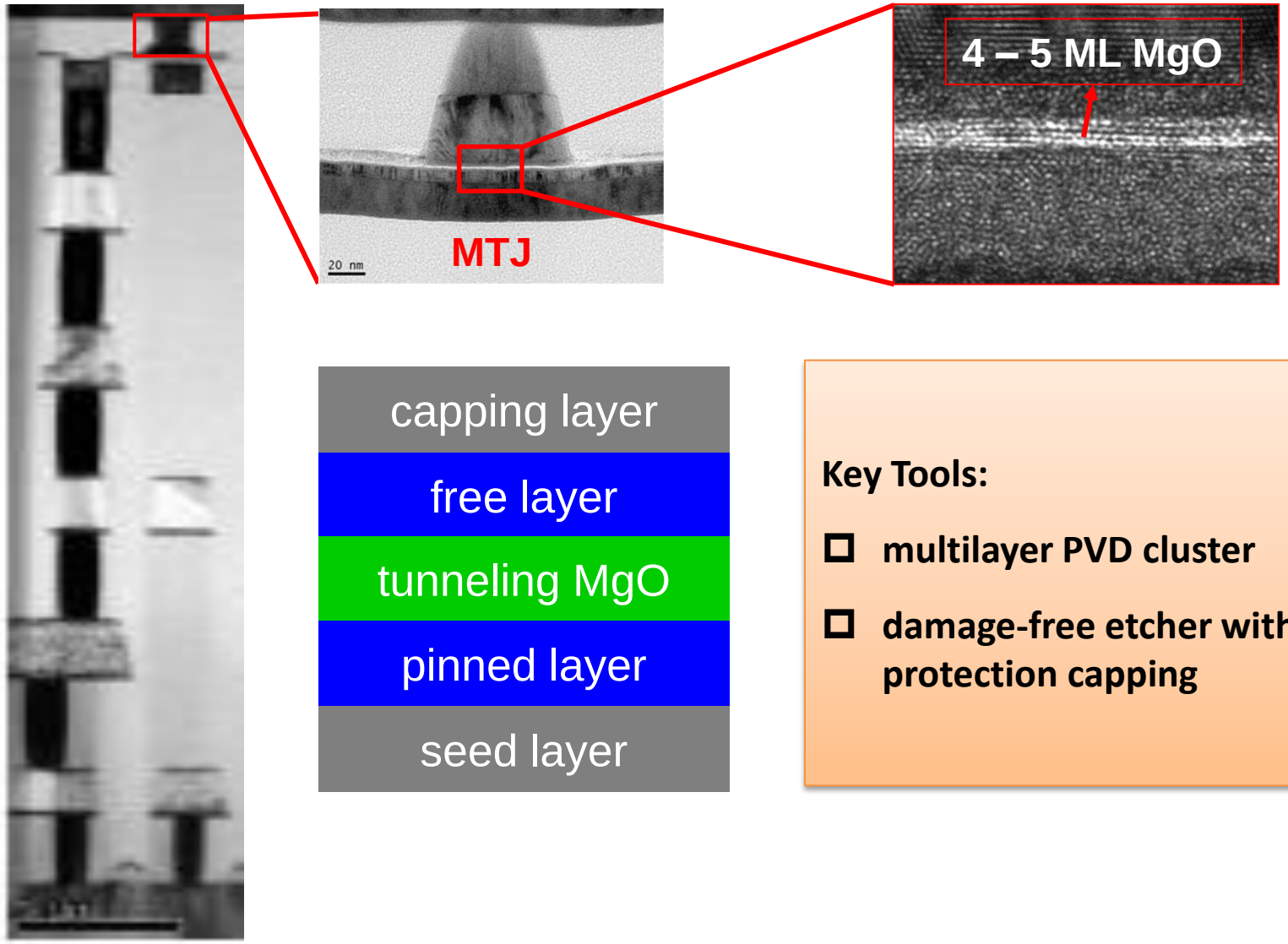
Size:0.7x2mm



Metal Ta_2O_5 MIM Capacitor



MRAM: Spintronics



capping layer

free layer

tunneling MgO

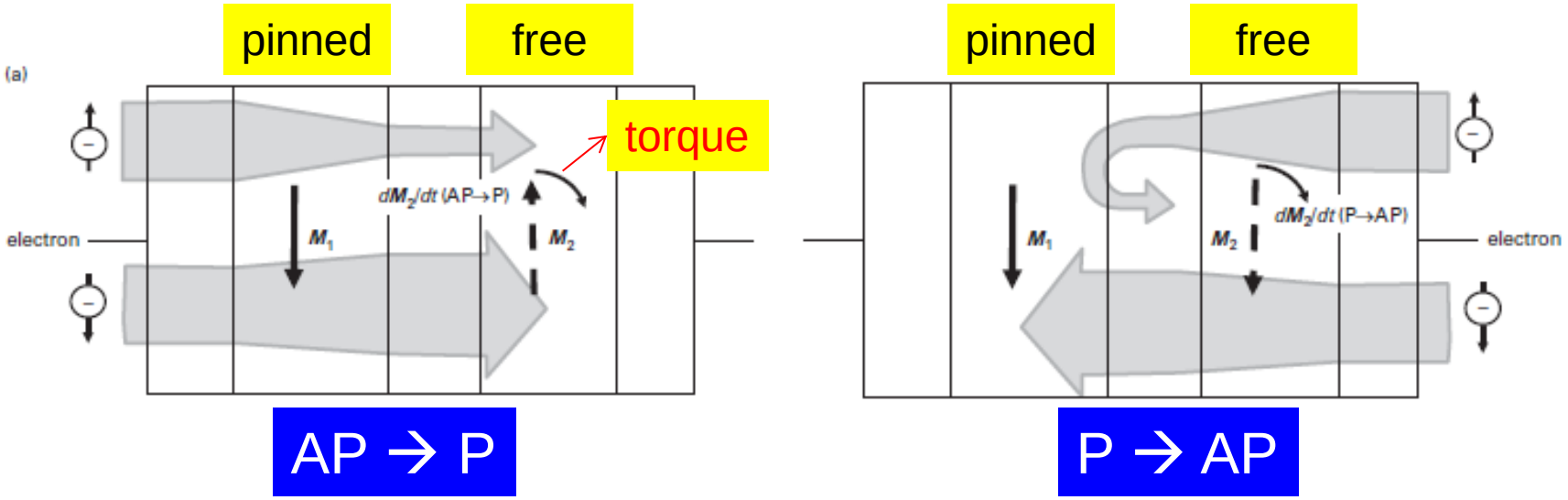
pinned layer

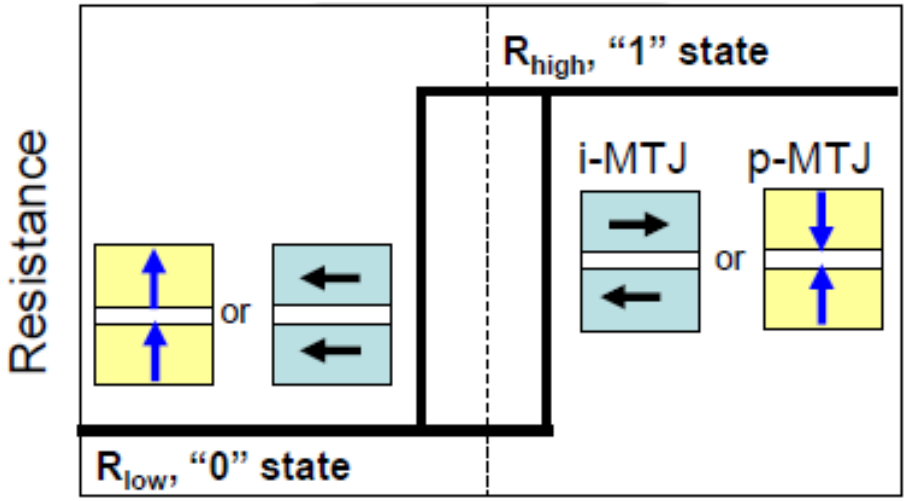
seed layer

Key Tools:

- **multilayer PVD cluster**
- **damage-free etcher with protection capping**

Spin-Torque Transfer (STT)





Field or Current

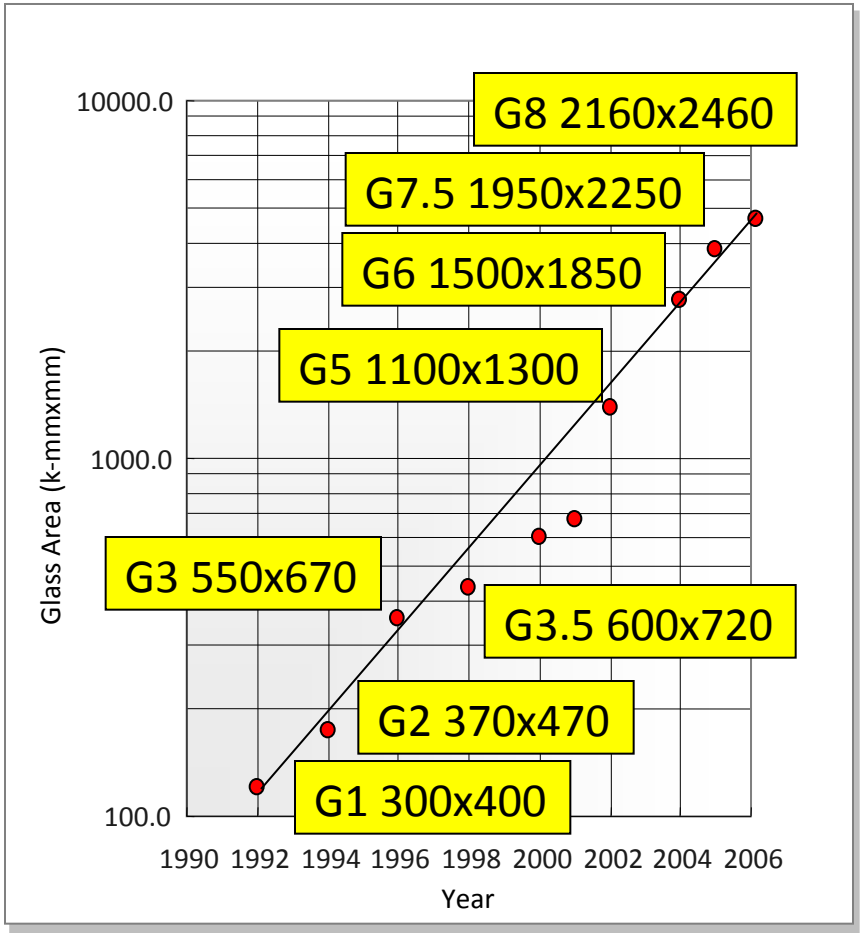
Ref: Magnetic Memory
(Cambridge University Press)

Contents:

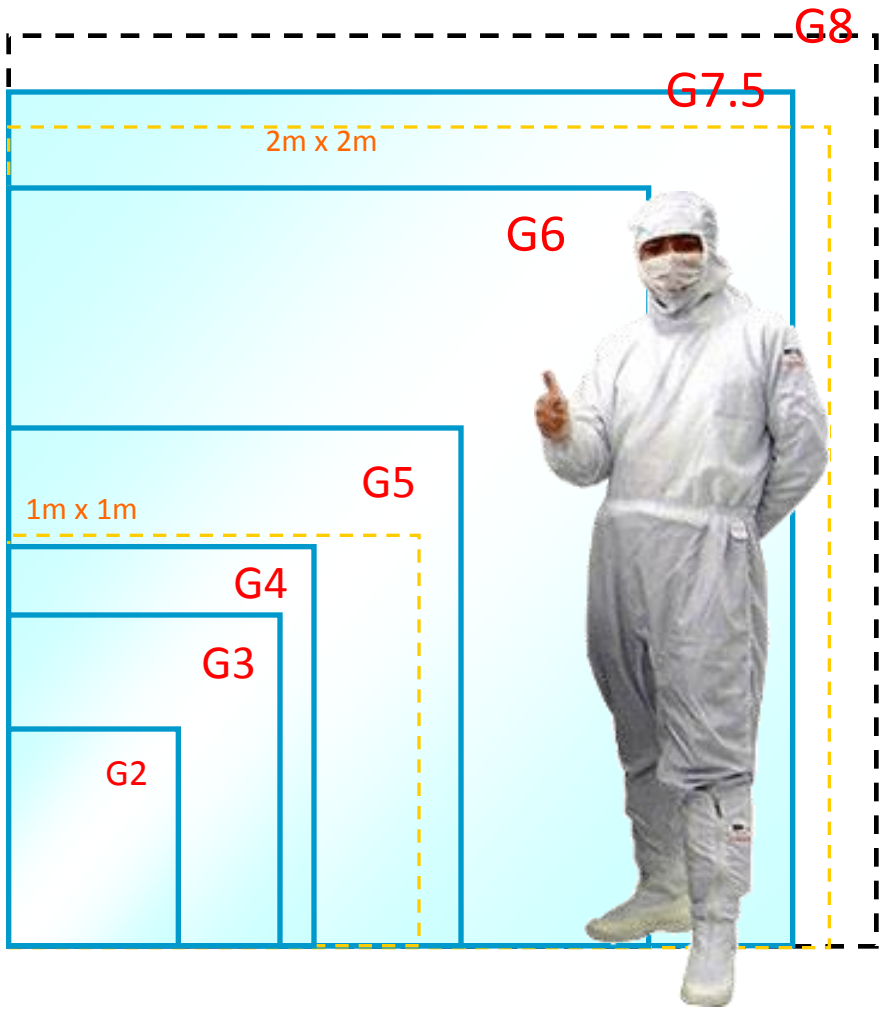
Generation Migration in TFT-LCD

Mother Glass size grew 1.5 times every 1.5 years

TFT LCD Generation Migration

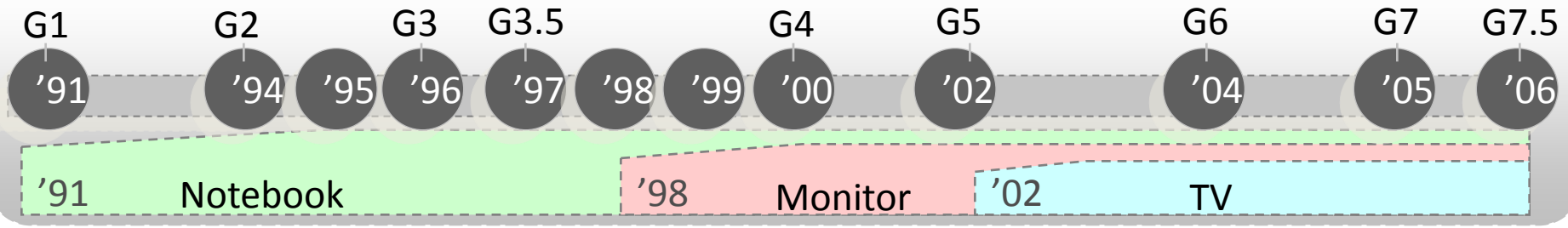


Relative Glass Size in Each Generation

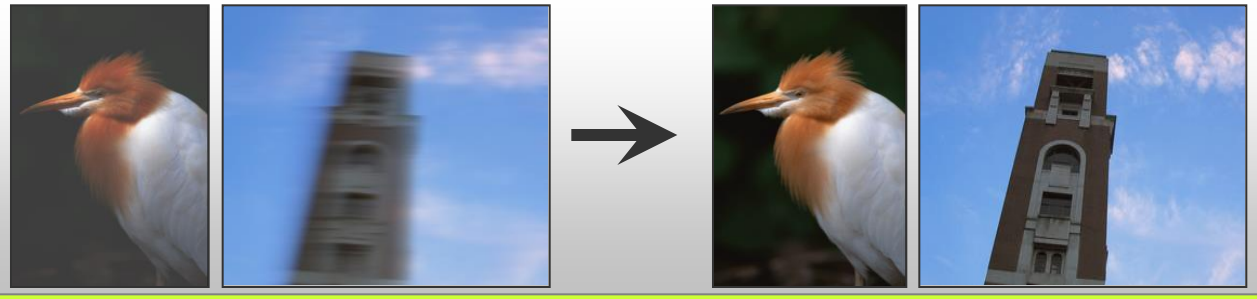


Revolution Waves of TFT LCD

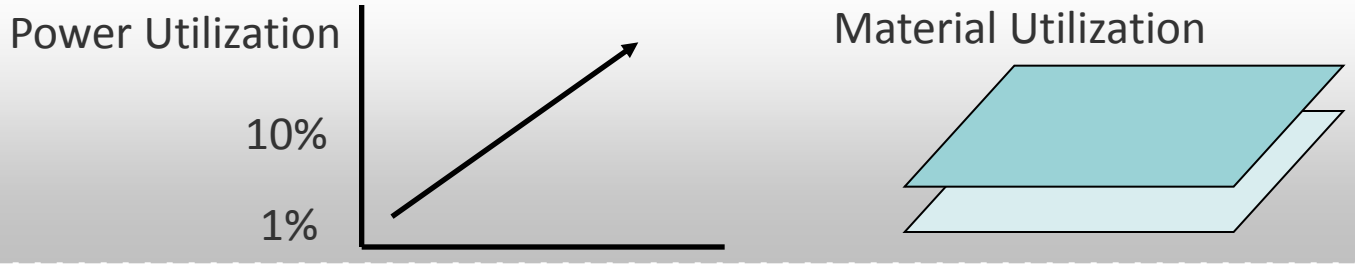
1st Wave: Product Introduction – Make The World Flat!



2nd Wave: Performance Enrichment – Make The World Gorgeous!

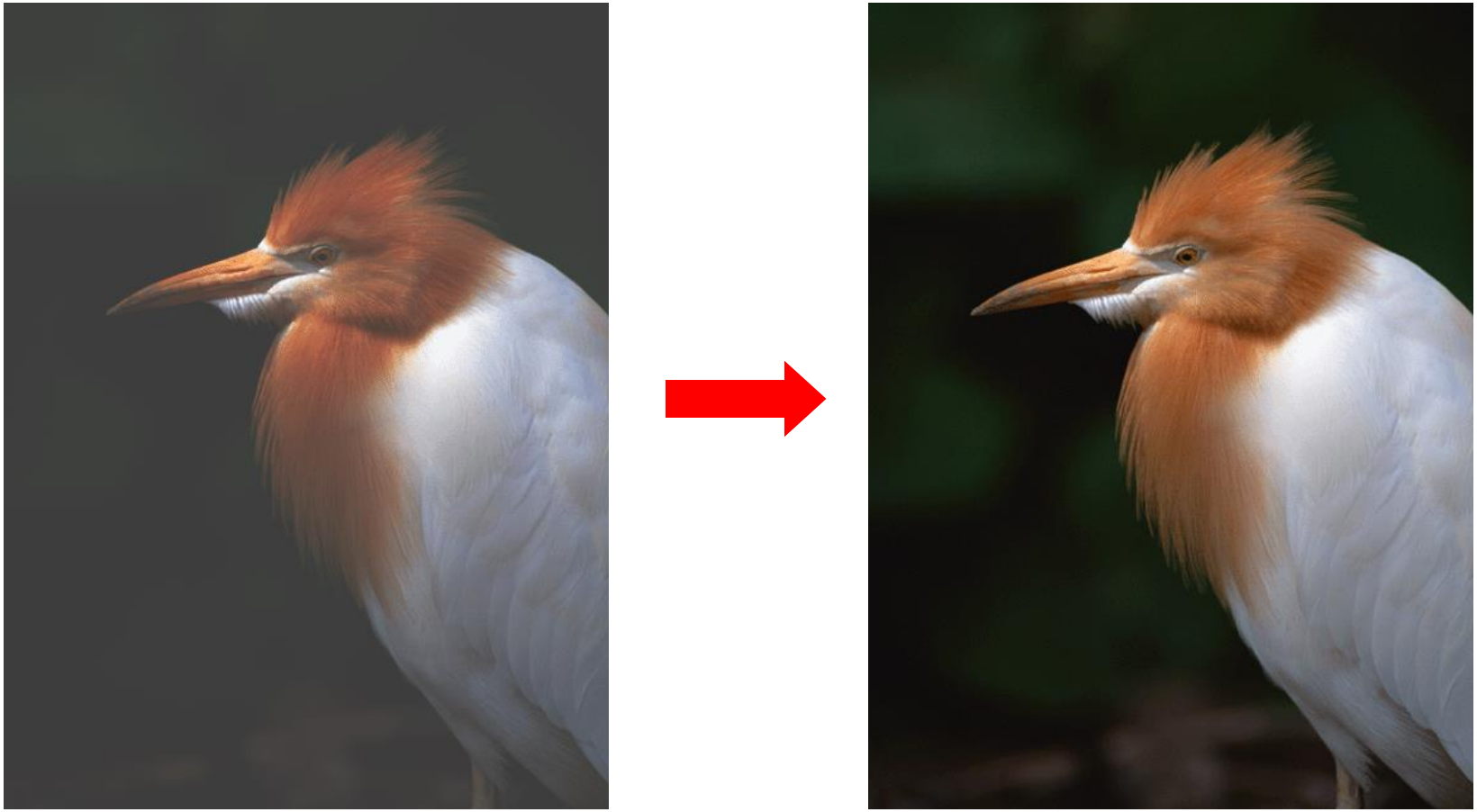


3rd Wave: Power & Material Efficiency – Make The World Green!



4th Wave: Functions for Human Interface – Make The World No Gap!

Importance of High Contrast Ratio



Contrast Ratio Improvement can increase dark color performance.

Advanced MVA-mobile Technology

Features

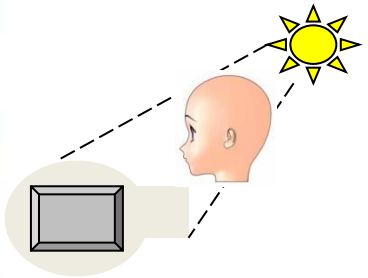
- Wide Viewing Angle (160^{o} / 160^{o})
- Low Color Washout
- High Contrast Ratio (2100:1)

Product Applications

- Mobile Phone
- DSC
- Mobile TV

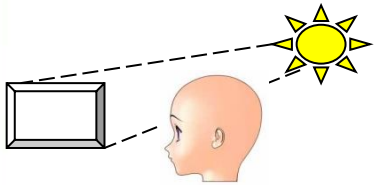
Sunlight Readable Display

ATR-MVA

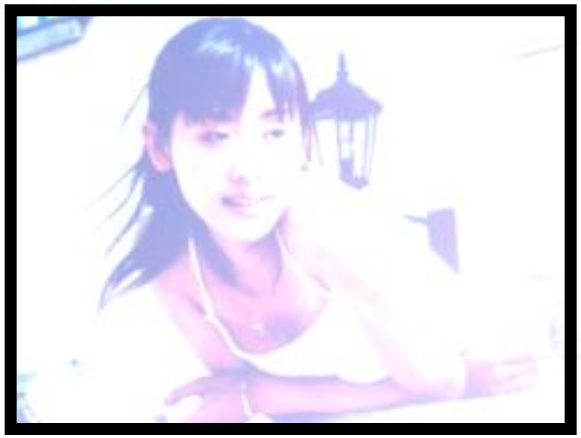


Under shadow
30000 Lux

TMR+TN/WV



Direct sunlight
80000 Lux



Advanced Simulated Pulsed Driving

ASPD mobile

Features

Fast response time to reduce motion blur
(4ms Grey to Grey / 8ms MPRT)

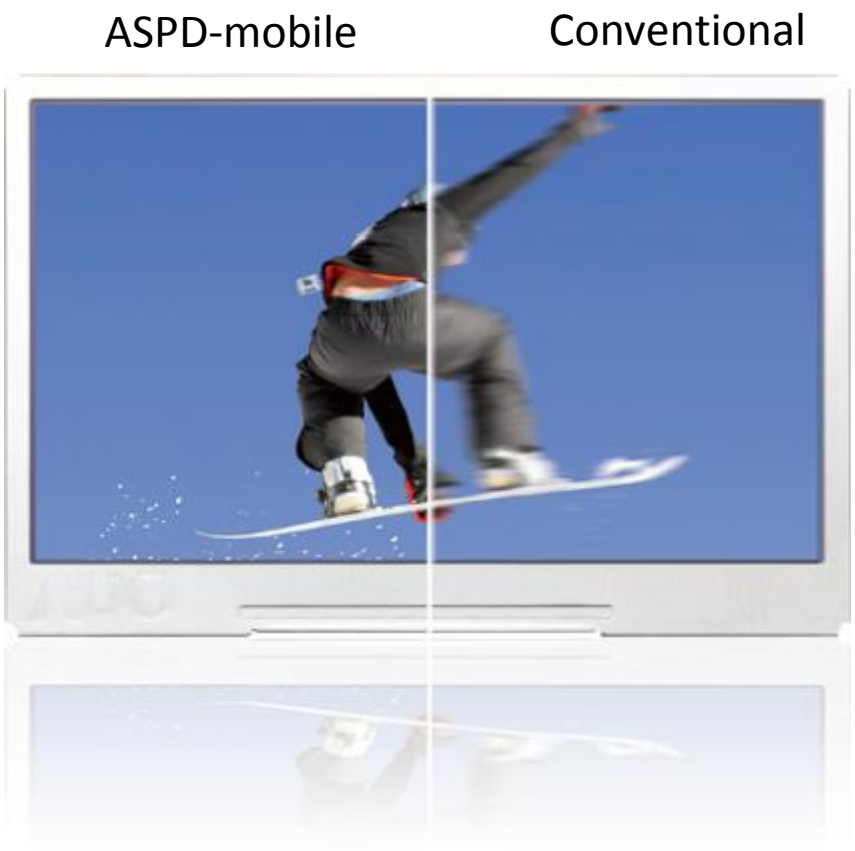
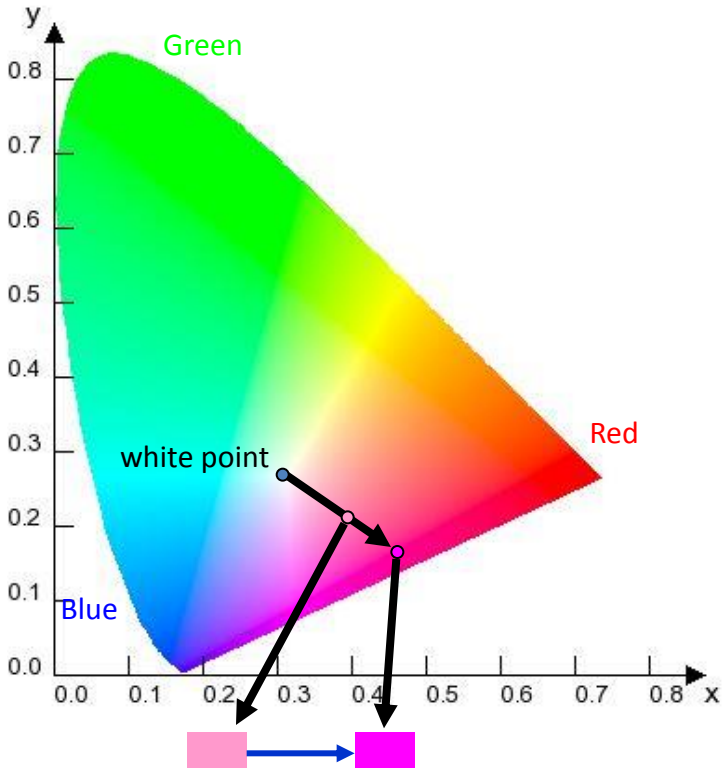


Image Processing for Vivid Picture

✓Saturation Enhancement

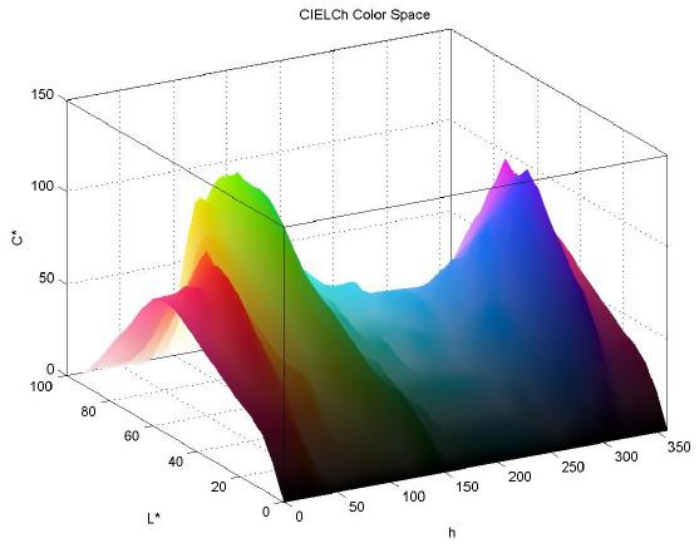


original color vivid color

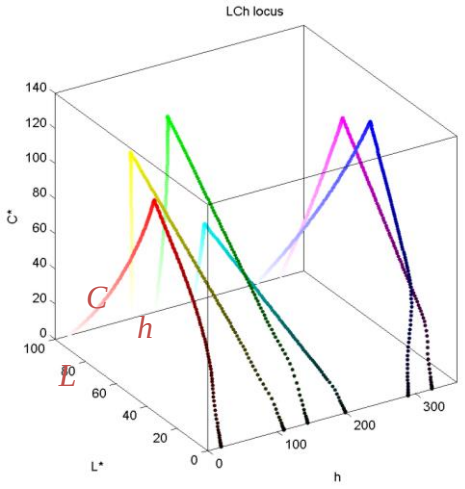
Image Gamut Extension

- **Hue Division**
  - Outline panel's color characteristics
  - Find image gamut boundaries
  - Choose certain hue pages to decide image color templates

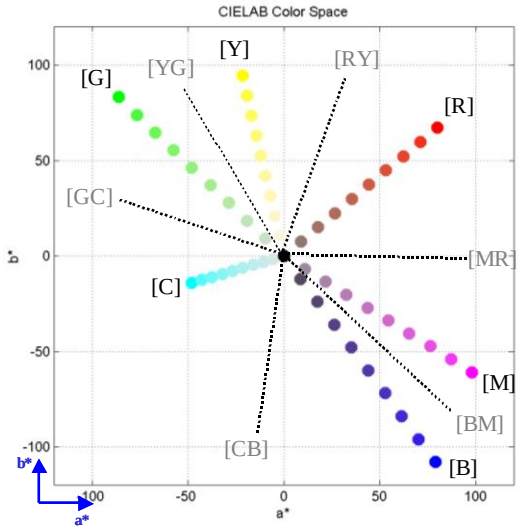
Display's Color Gamut



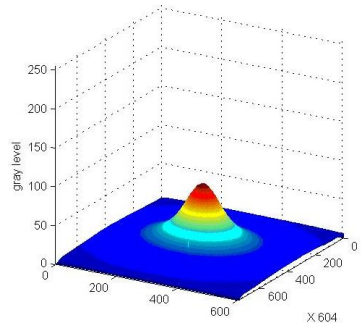
Hue Pages



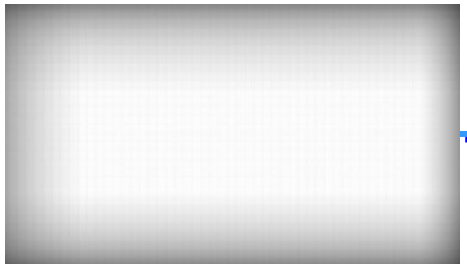
Hue Division



High Dynamic Contrast



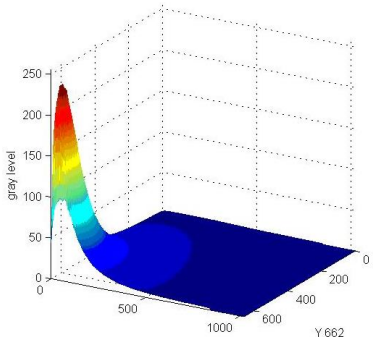
PSF - Center



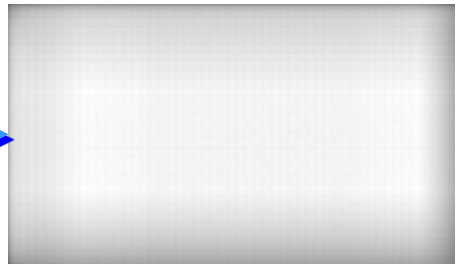
Convolution Process

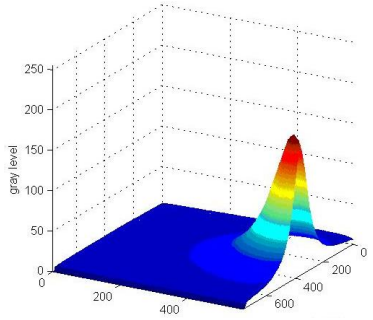
Measure PSF
(Point Spread Function)

Calculate LED and LCD Control Signals.

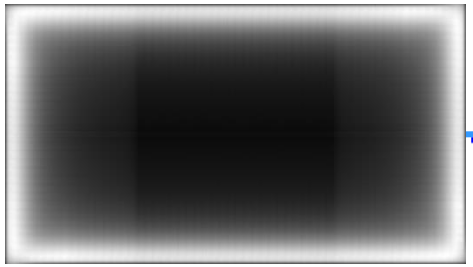


PSF - Corner

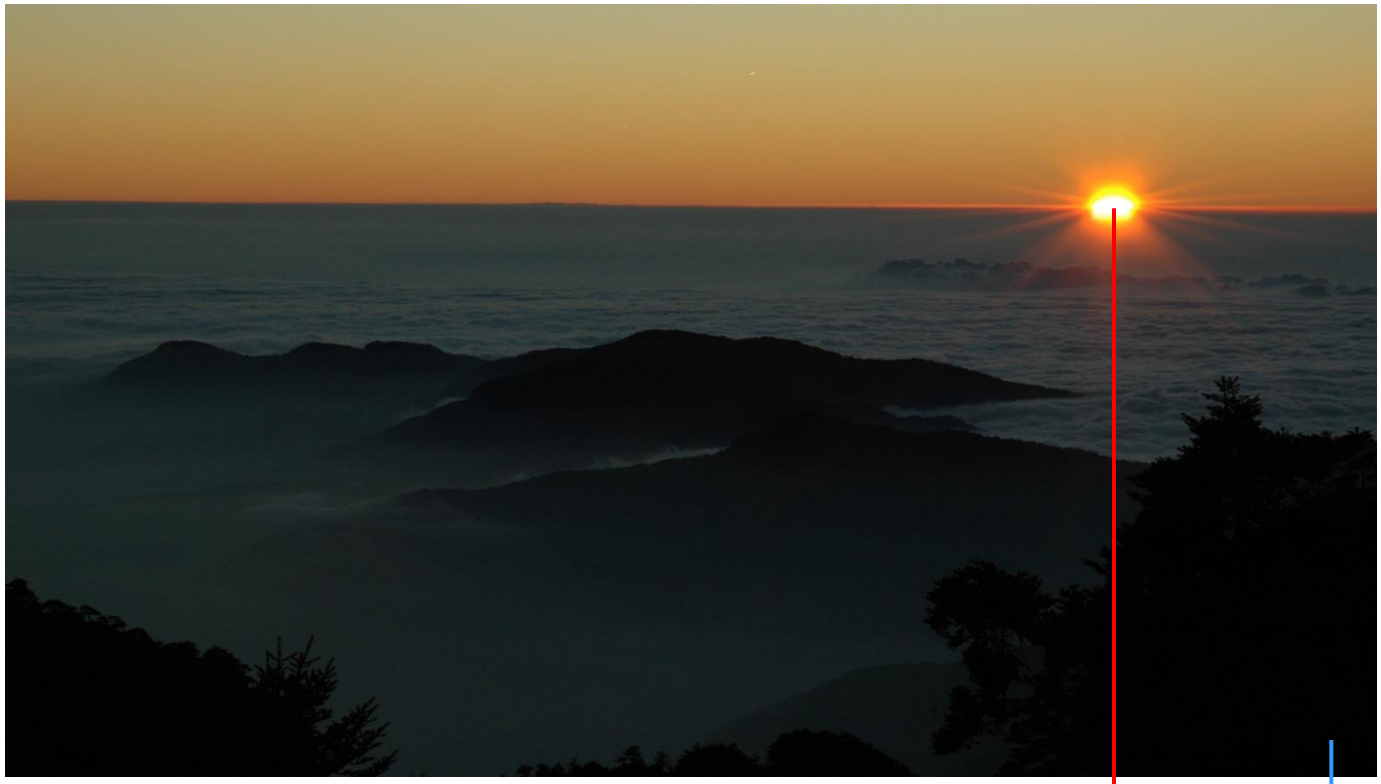




PSF - Side



High Dynamic Contrast



Current = 9.5 A

Voltage = 10.95 V

Power Saving = 58% = 1 — (9.5 × 10.95) / 245.28

* LED B/L Full ON = 22.4A × 10.95V = 245.28 W

Lmax = 418 cd/m^2

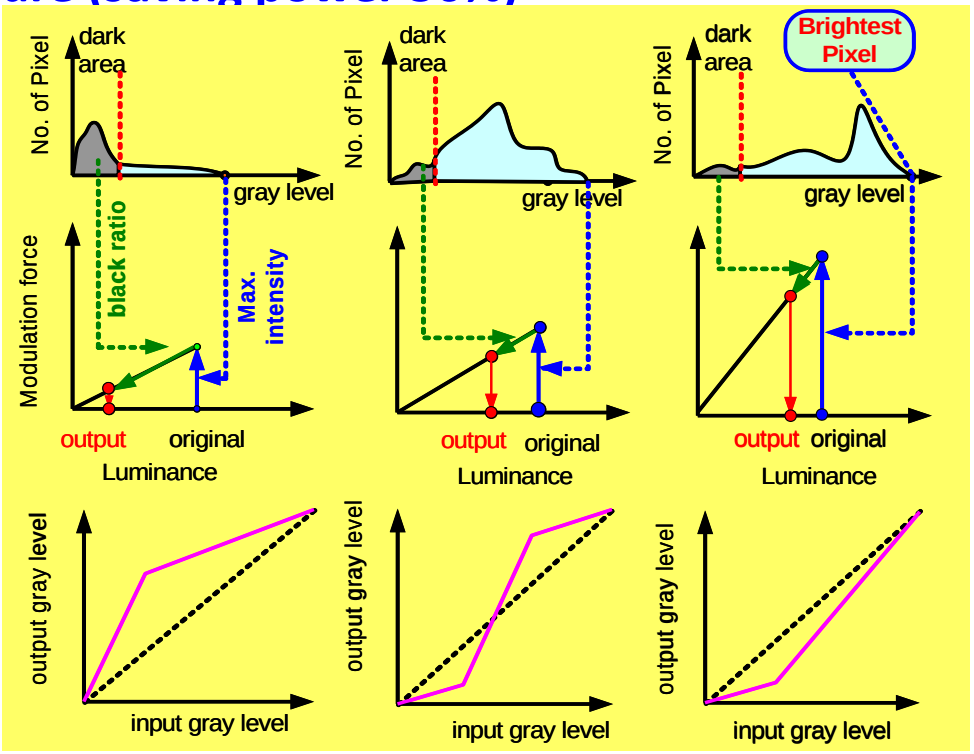
Lmin = 0.04 cd/m^2

CR = 418 / 0.04 = 10,450

CABC Function

- **Purpose**
  - To detect the image content and keep the same image quality with dimming.
  - To reduce power consumption 50% in darker image.

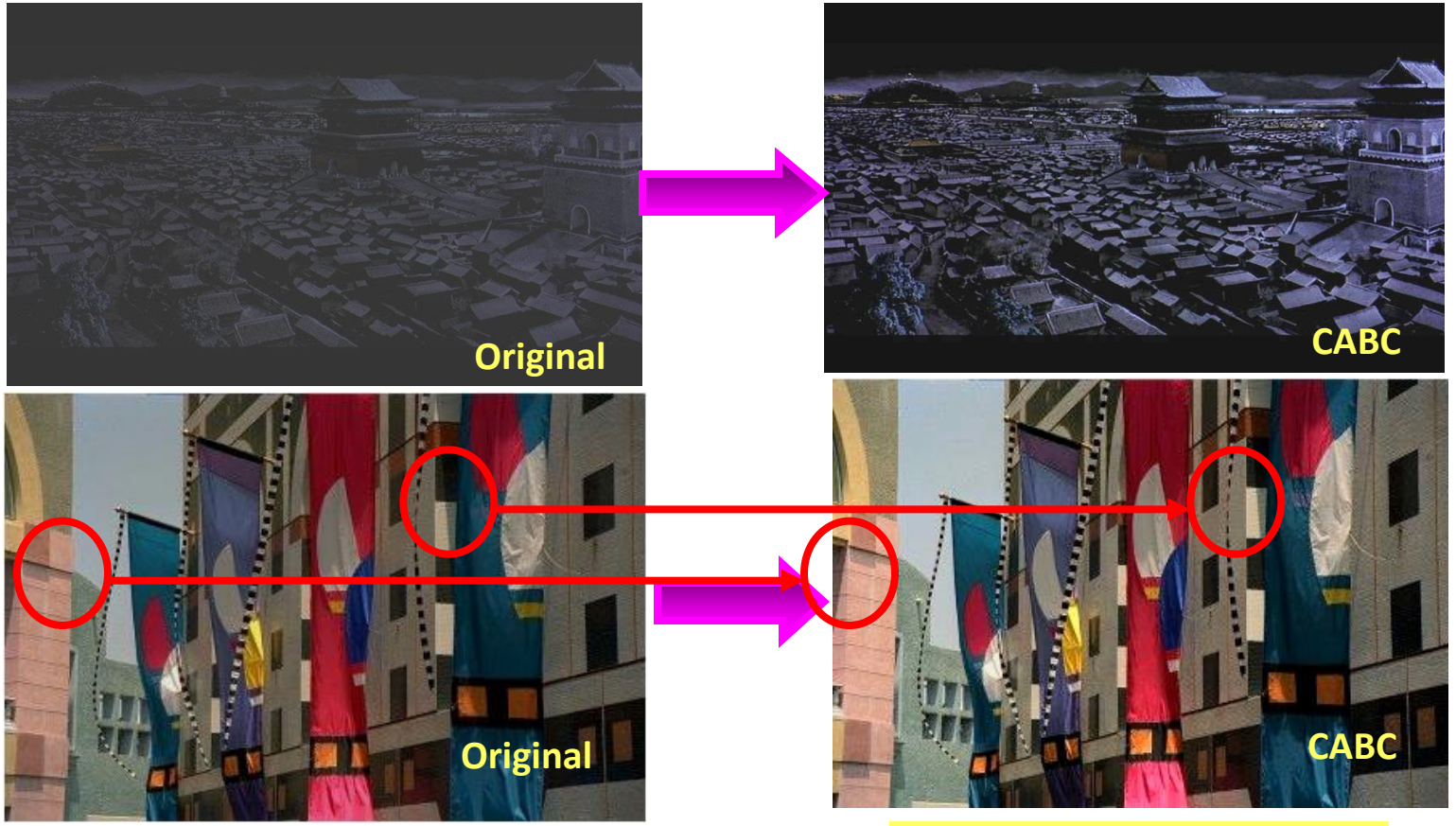
CABC Structure (saving power 50%)



Technology	'07 H1	'07 H2	'08	Remark
CABC	'07 1Q: CABC FPGA Proto type; '07 3Q: Integrated IC cut1; '07 4Q: MP			C.i.1

Dynamic Backlight + Dynamic Contrast + Dynamic Gamma

- Improve contrast and detail
- Lower Power consumption



Contrast Ratio: 300

Contrast Ratio: 700
Power saving 50%

C.i.1

Slim & Light

0.9mm slim boarder (2.2”)

Features

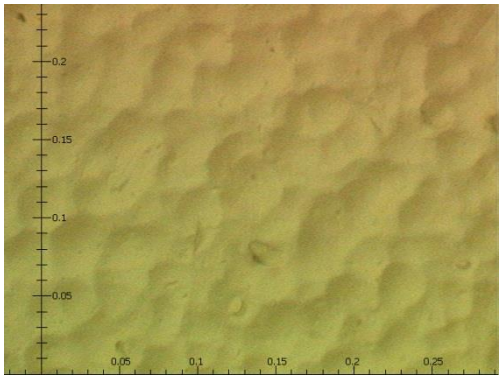
- Possesses the slim border of 0.9mm on both the right and left sides
- The upper side border width of merely 1.2mm
- Be able to increase the active area and enhance the image sleekness

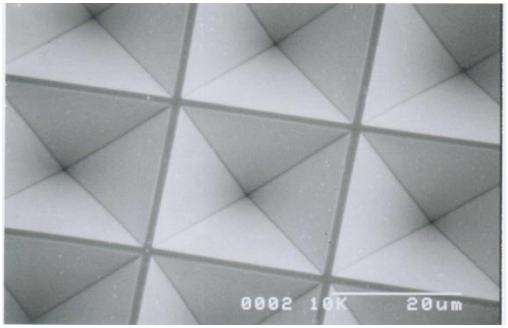
0.69mm mobile module (1.9”)

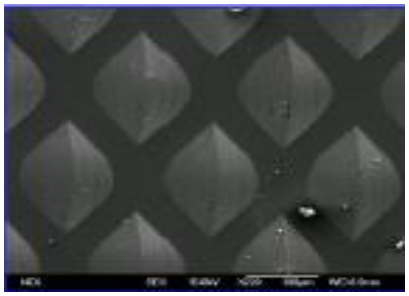
Features

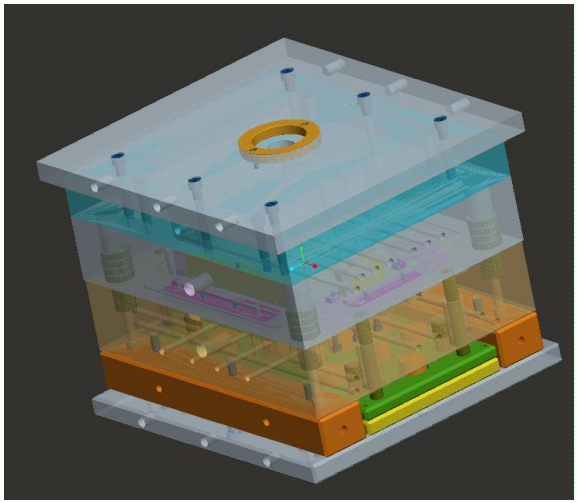
- Implement the latest glass thinning technology and shrink the thickness of related components
- 13% thinner than the thickness of a credit card
- Weight of 2.2 grams
- 400-nit high brightness
- Accomplish a multitude of features - light, slim, elegant and bright

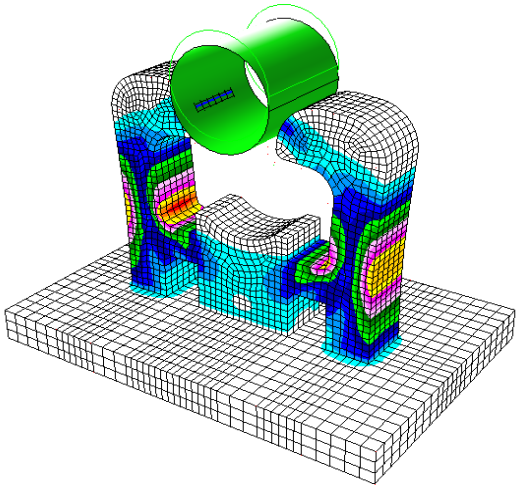
Precision Machinery Technology
-- integrated micro-optics, molding, thermal

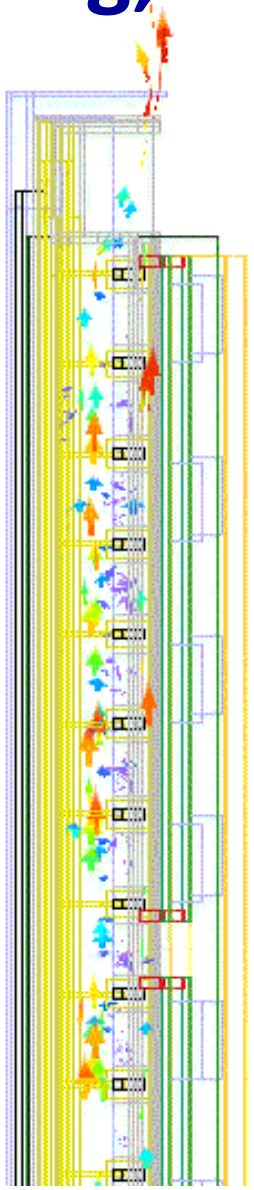


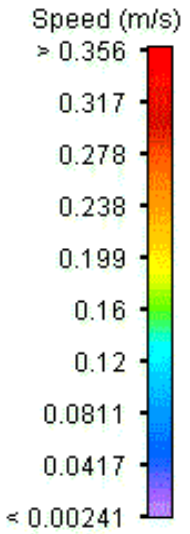












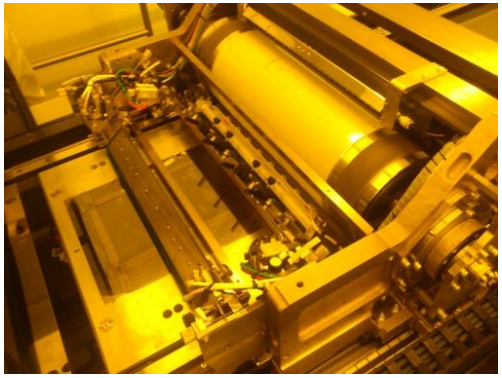
Roll-to-Roll 3μm Direct Printing

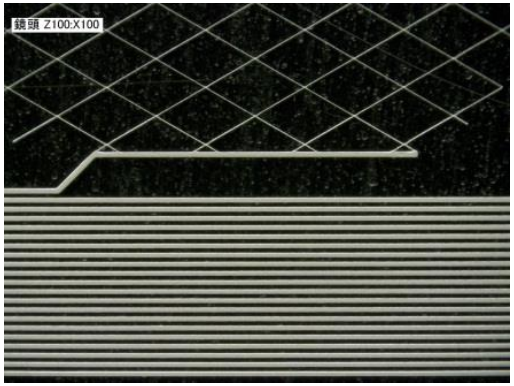
Patterning Technology Revolution

Now		Future
7-step process	>>>	1-step
film deposition	>>>	fine-line direct printing
photo resist coating	>>>	
resist baking	>>>	
photo exposure	>>>	
resist development	>>>	
film etching	>>>	
resist stripping	>>>	

- **Replace 7 process equipment with 1**
- **Increase material usage from 5% to 95%**

- **Industry status: sheet process, > 30μm**
- **Komori-ITRI: roll-to-roll process, 3μm**





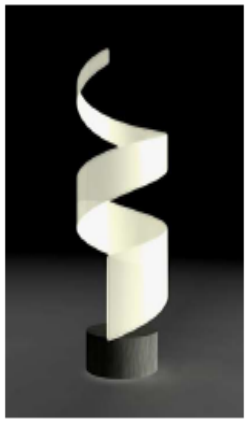
3μm

30μm

Contents:

OLED Lighting Features

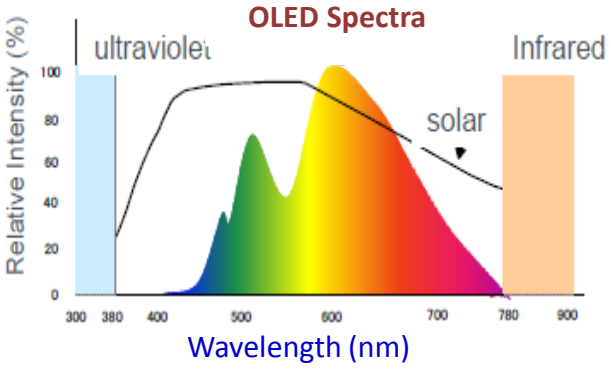
- ***Simple:*** **surface light source**
- ***Innovative:*** **thin and light**
- ***Harmless:*** **UV-less, IR-less, Hg-free**
- ***Truthful:*** **closest to natural light**
- ***Beautiful:*** **high color rendering**
- ***Comfortable:*** **diffusive, non-glare**
- ***Power & material saving***

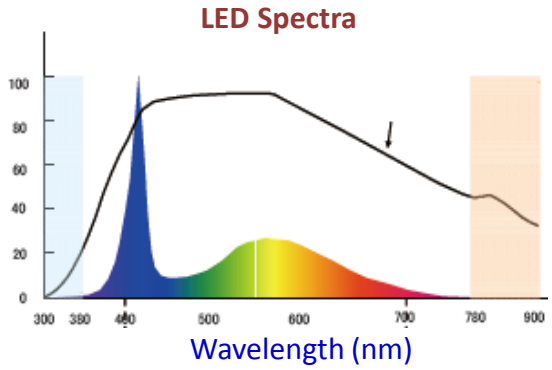


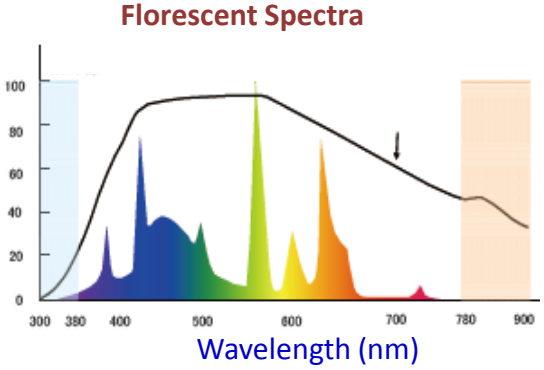
Bendable

Very Thin *0.3 mm thick*

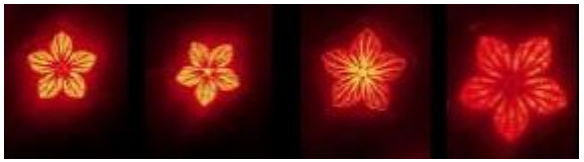
Very Light *0.05 g/cm²*







customized

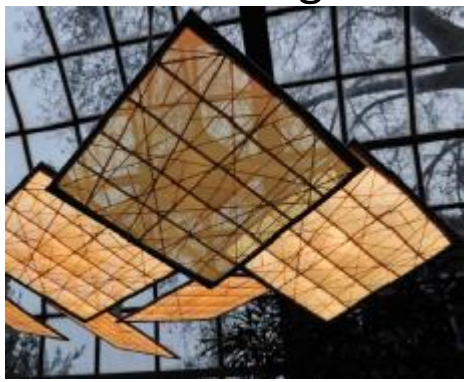


transparent

flexible

Interior designs

See through it



luminaire designs

Audi

OLED desk lamps

O'Leaf Luminaire
Source: Philips

Wall Blade from Astron Fiamm

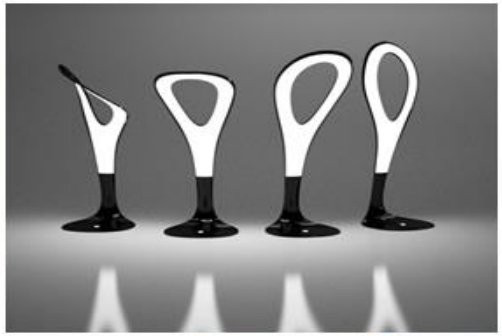
Victory – Brand Liternity
Source: Novaled

Vanity from Lumiotec

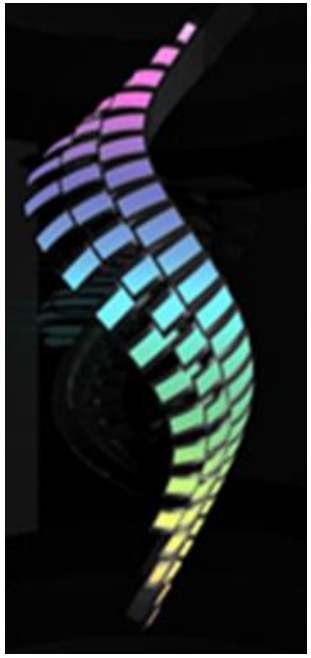
Folz
Source: Astron Fiamm

Olé
Source: Astron Fiamm

flexible OLED lighting

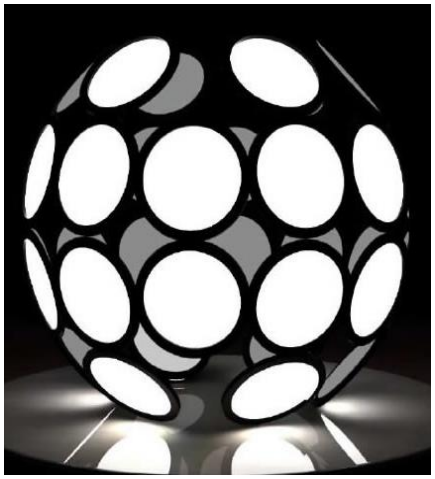


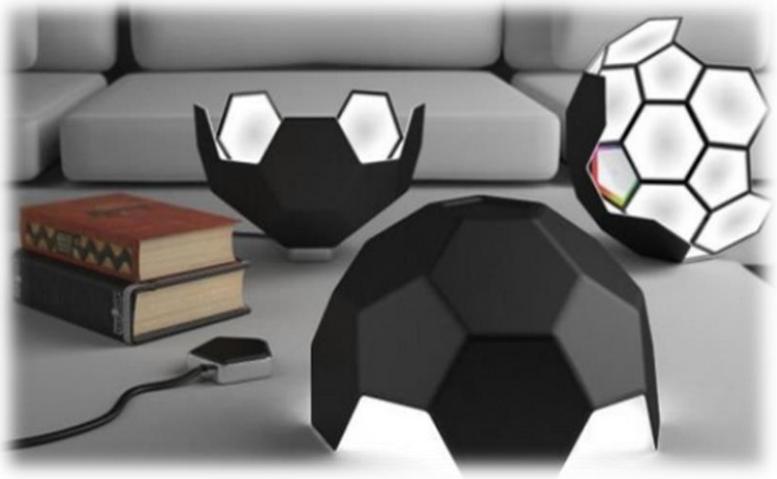
large area and transparent

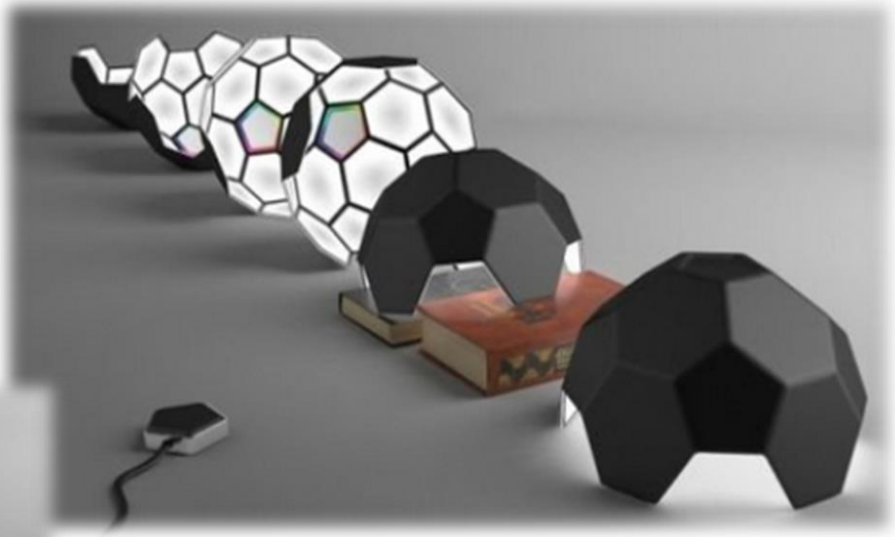


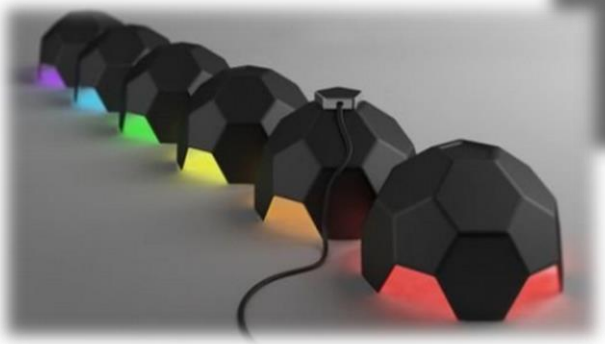
curved

3D

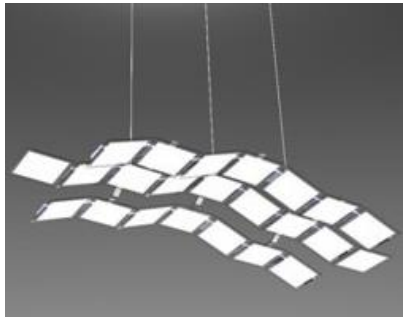


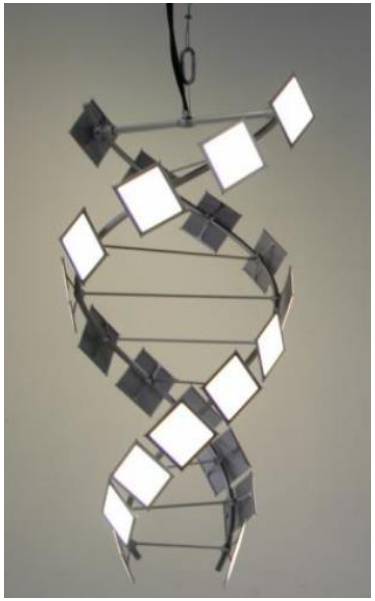


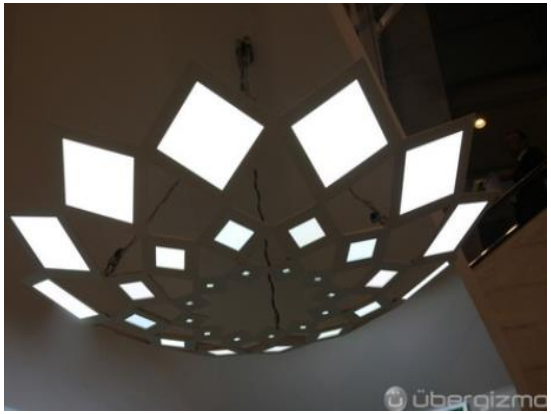


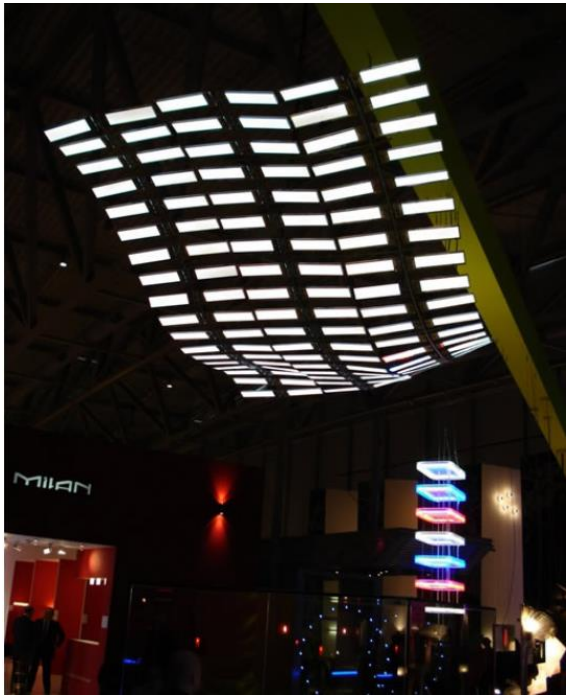


lamps





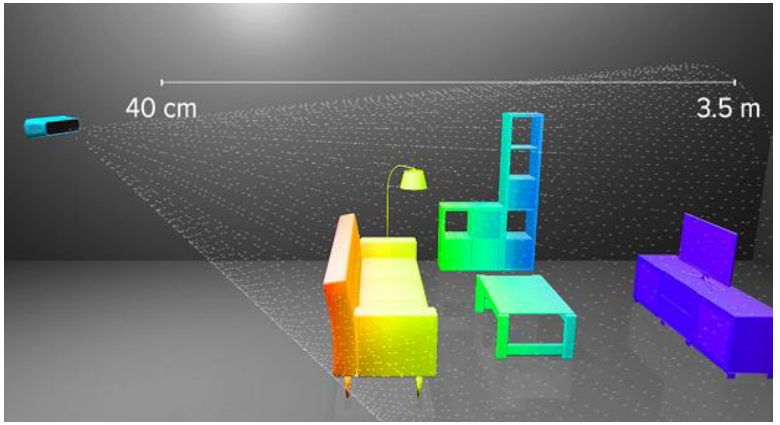




Contents:

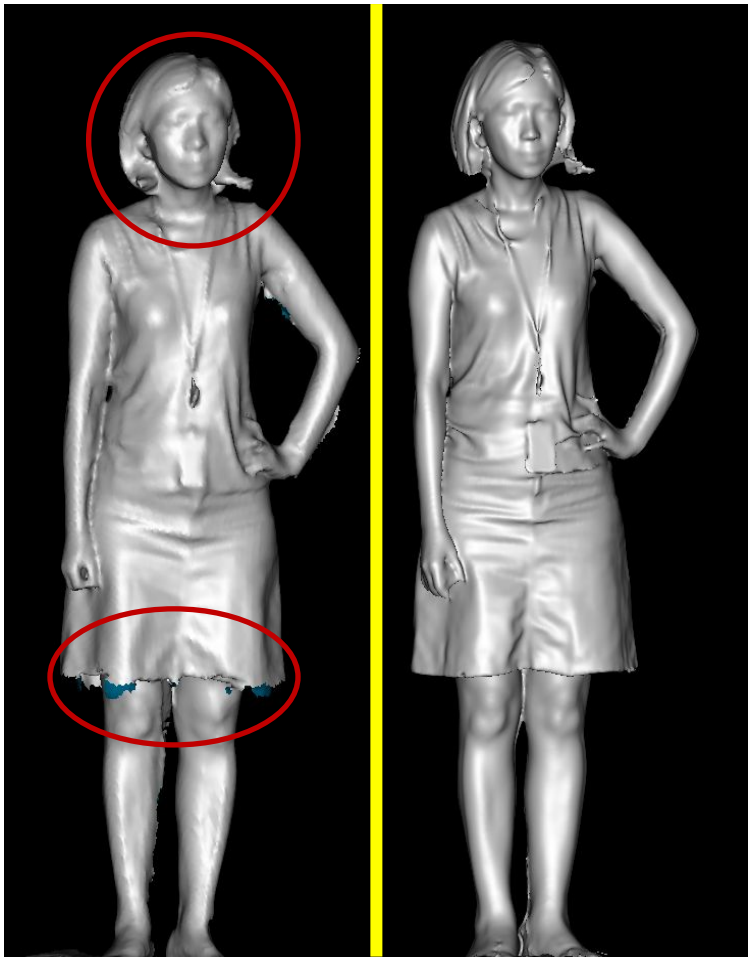
Object Reconstruction – Handheld 3D Scanner

Capture the World in 3D



Comparisons of 3D Scanners

	3D Systems Sense
Resolution	1 mm
Accuracy	0.9 mm
Measurement Rate	< 5 fps
Working Distance	35 ~300cm
Scan Area	57.5度
Weight	0.38 kg
Color	Yes
Light Source	IR Laser
Price	US 419



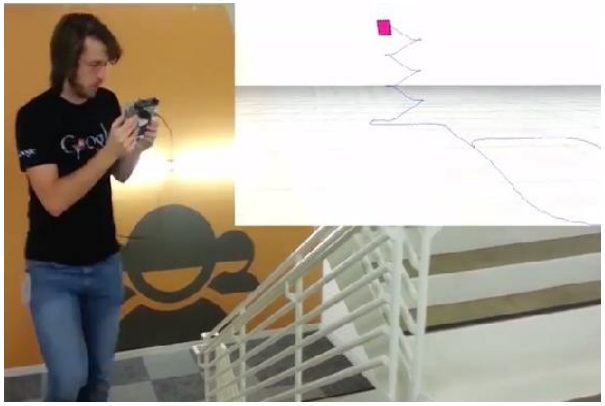
電光所 (Target)	
0.5~1 mm	**Resolution**
0.1mm	**Accuracy**
10 fps	**Measurement Rate**
35 ~ 65cm	**Working Distance**
45度	**Scan Area**
< 1.3kg	**Weight**
Yes	**Color**
IR LED	**Light Source**
	Price

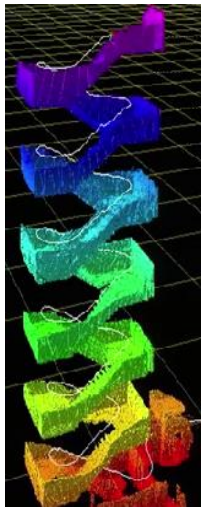
Indoor Space Reconstruction - Google

Tango project:
stereo camera combined with tablets and smartphones

Room reconstruction

Staircase reconstruction

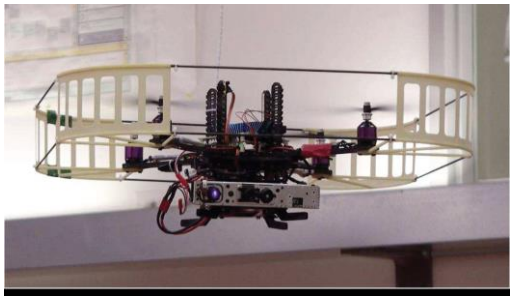




Google I/O 2014/6/26 : https://www.google.com/events/io/schedule/session/f47f19a5-63b9-e311-b297-00155d5066d7

From On-Site Control to Cloud Control

- Stage 1: On-Site Control



on-board with Intel 4-Core i7-3612QE, 2.1 GHz
➔ image process、SLAM、autopilot

Flight path control

- Stage 2: Cloud Control

autopilot

image process、SLAM
Flight path setting

Rendering
Flight path control

System Operation - Initialization

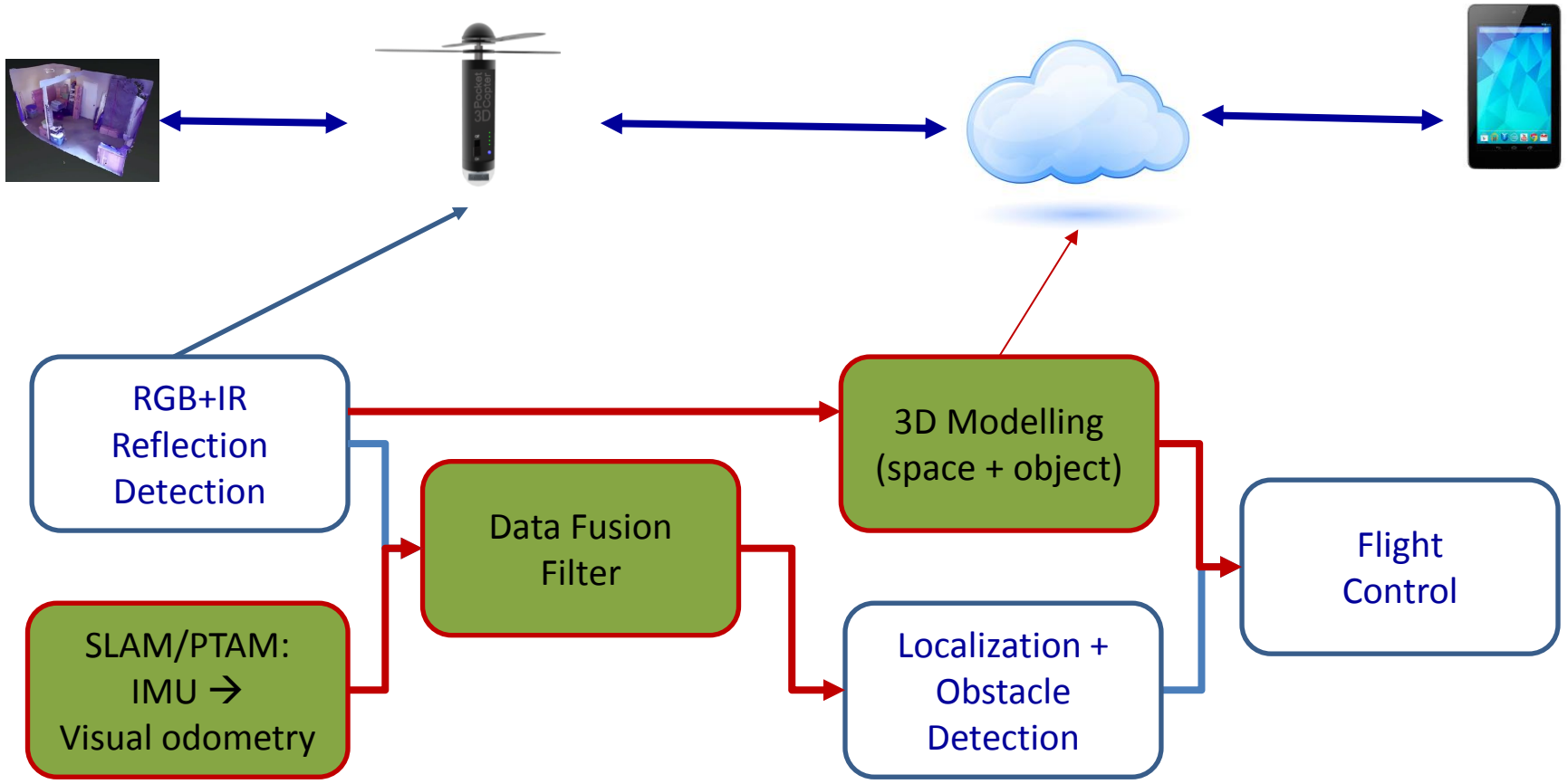
①

②

- Detect environment complexity
- Initialize position

- Assign flight path patterns (eq., 之) from learning database

System Operation - Scanning



➔ 3D modeling in cloud, real-time adjusting flight path (replace loop closure functions)

Hardware: MAV

- Ascending Technologies (Germany), NTD 50k: on-board with Intel 4-Core i7-3612QE, 2.1 GHz for autopilot

- Parrot AR. Drone 2.0 (France), NTD 15k: iPod and android have App for easy controls

- 雷虎科技 (TW) : carrying capacity 200g

- GETOP (TW) : carrying capacity 4.5kg including camera

MAV: micro air vehicle or micro aerial vehicle

Summary

1. It is a very exciting journey to do research.
2. From black-body radiation (1901) to next-generation electronics (2020-2050), we continue to explore amazing sciences and technologies.
3. Many frontier technologies will be in production 20 years from now and change our thinking completely.