NARLabs 國家實驗研究院

台灣半導體研究中心

Taiwan Semiconductor Research Institute

GaN Chip Implementation Platform

Hann-Huei Tsai

28th September 2023

NARLabs

Outline

- TSRI Introduction
- Process and Design Environment
- Heterogeneous Integration
- System Verification
- Summary

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- **TSRI Introduction**
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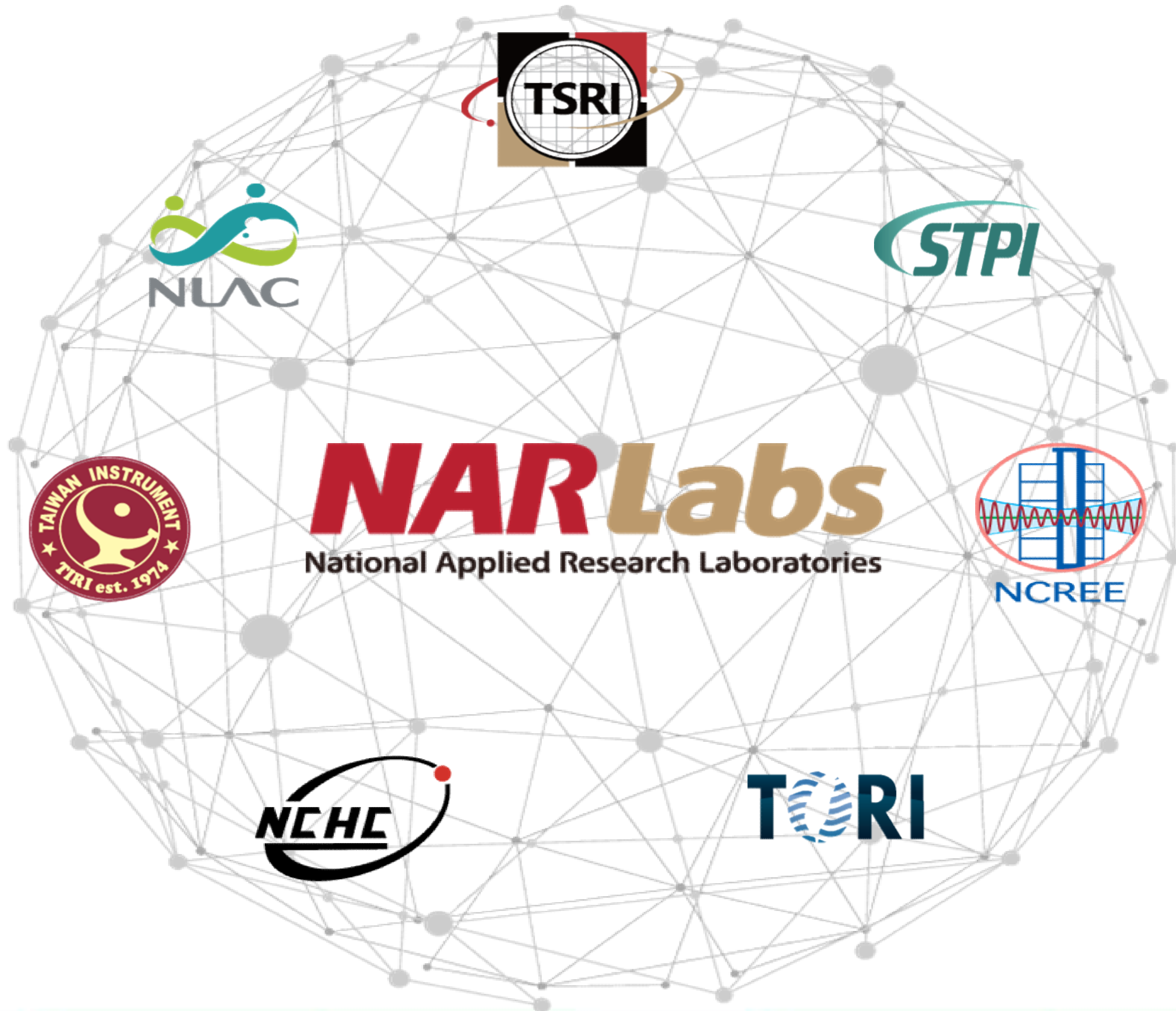

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TSRI Role and Mission

Cultivate Talents	Support Academic Research	Build-up R&D Platforms	Promote Advanced Tech.
T	**S**	**R**	**I**
Training	Service	R&D	Innovation

Fill the gap between academia and industry

Academia (R+d)

TSRI (R+D)

Industry (r+D)

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Technical Services

Process & IC Foundry

- Clean Room (~3200m^2)
- Class 10 to 10,000
- **Open 24/7 to qualified users**

1,000 students graduated / year

Chip Implementation

- 16nm FinFET
- GaN
- Silicon Photonics

1,800 chips implemented / year
1,200 students graduated / year

Emerging memory/ Advanced Packaging

- Embedded ReRAM, MRAM
- 2.5D/3D, TSV

Semiconductor Manufacture & Design

EDA Cloud Service

- ARM
- Cadence
- Synopsys
- Keysight
- Mentor Graphics

300 R&D teams per year

Electronic & Materials Measurement

- Silicon Photonics / Power & Nano Components
- High frequency/high speed measurement
- MEMS/Electrical Measurement

7,000 cases per year

Training Programs

- Semi-manufactures
- Chip Design & Implementation
- Basic e-learning courses

15,000 person (times) per year

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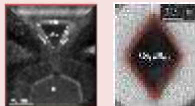
Fabrication Capabilities

2.5D、3D、TSV Advanced Packaging/ 3D Heterogeneous Integration/ Circuit Verification (Verification vehicle：Sensor/ Memory)

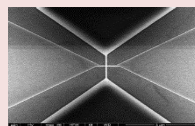
Lower power devices
(New structure development)

GAA



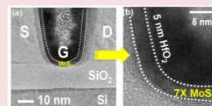
Non-planar

Planar



High speed transistor
(Introduction of novel materials)

2D Material

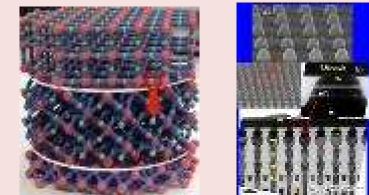


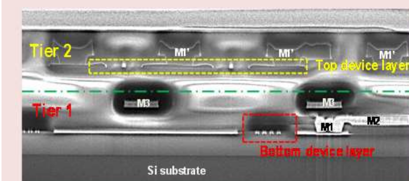
III-V

Ge、Ge(Sn)

High power devices

Memory
(RRAM、MRAM、IMC)





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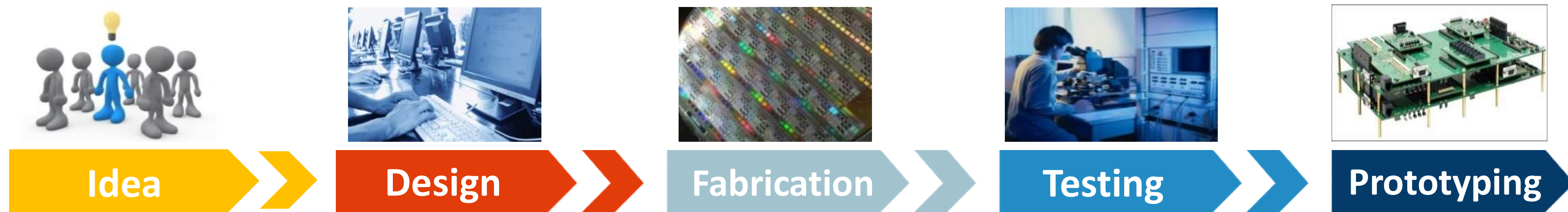
IC Design Service



- Provide IC/system design environments, design flows, and Silicon IPs
  - More than 90 commercial EDA tools from 13 vendors
  - EDA Cloud Service to optimize the investment and management
- Provide chip fabrication, packaging and PCB production
  - Standard / Advanced / Special-applications
  - Regular processes are available as below:

tsmc 0.35μm CMOS
tsmc 0.18μm CMOS
tsmc 90nm CMOS
tsmc 40nm CMOS
tsmc 28nm CMOS
tsmc 16nm CMOS
tsmc 7nm CMOS

tsmc 0.18um HV CMOS
tsmc 650V GaN

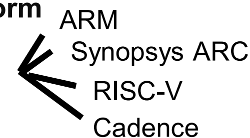
UMC 0.18μm CMOS MEMS
Multi-Optional MEMS

tsmc 0.18μm SiGe BiCMOS
WIN 0.15μm GaAs pHEMT
WIN 0.25μm GaN HEMT

Si-Photonic

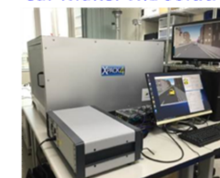
- 3 eco-system(Host CPU)
- FPGA platform

ARM
Synopsys ARC
RISC-V
Cadence



Zubu Palladium

Car Maker HIL solution



DGX

Drive PX2

HAPS

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Power GaN Application Fields

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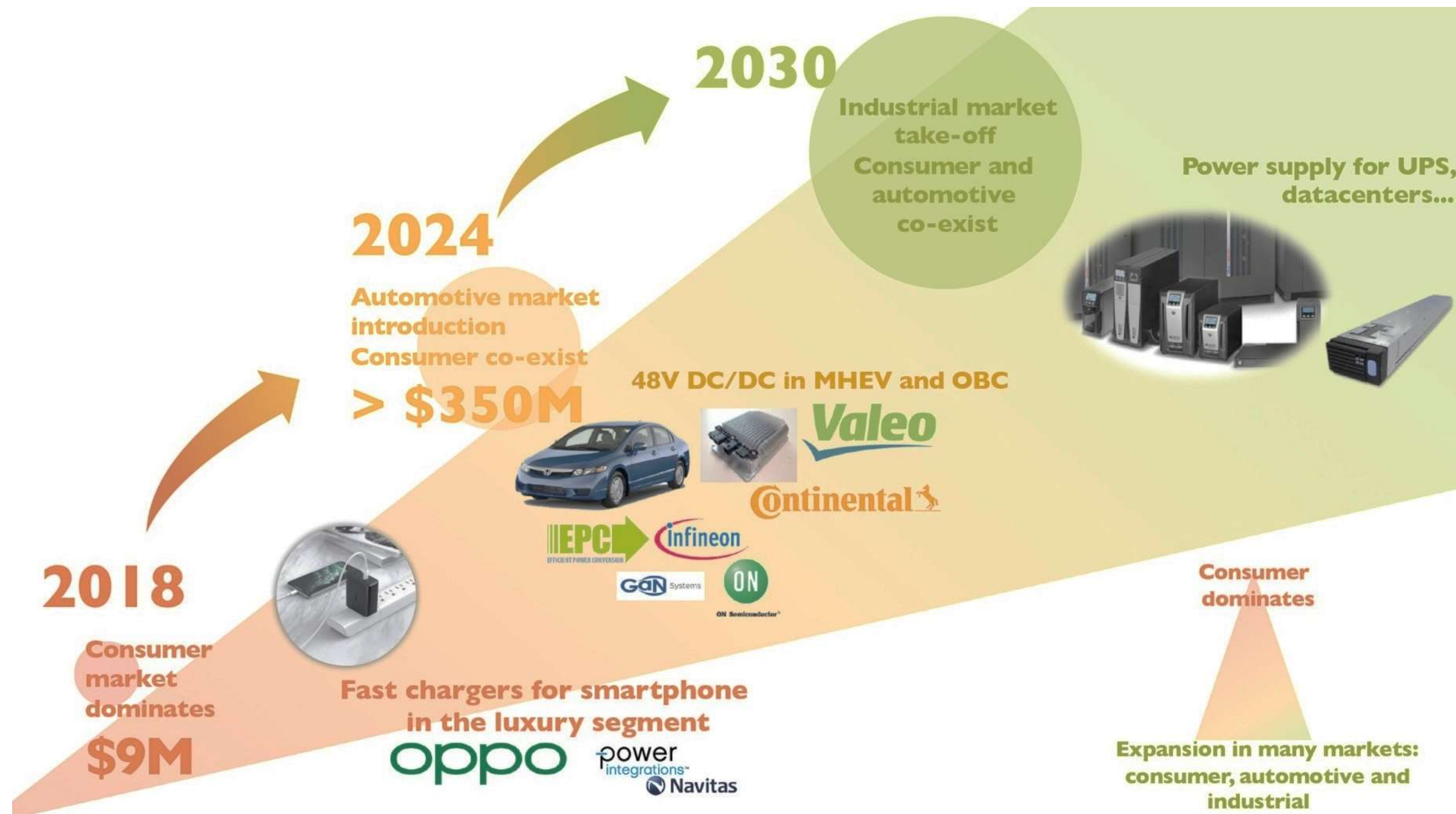
- **Fast charger applications → industrial & automotive market**



Source: Yole

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TSMC 650V GaN Process

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- **Process name:**
  TSMC 0.5UM GAN WBG E-HEMT USG AL 0P3M HKMG 650V
  - 650 V power cell
  - 12 V control circuit
- **Suttle service**
  - 2 shuttles/year, 6” full wafer
- **Process advantages**
  - Integration of power device and circuit
  - Low cost of GaN-on-Si

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Features of TSMC 650V GaN Process

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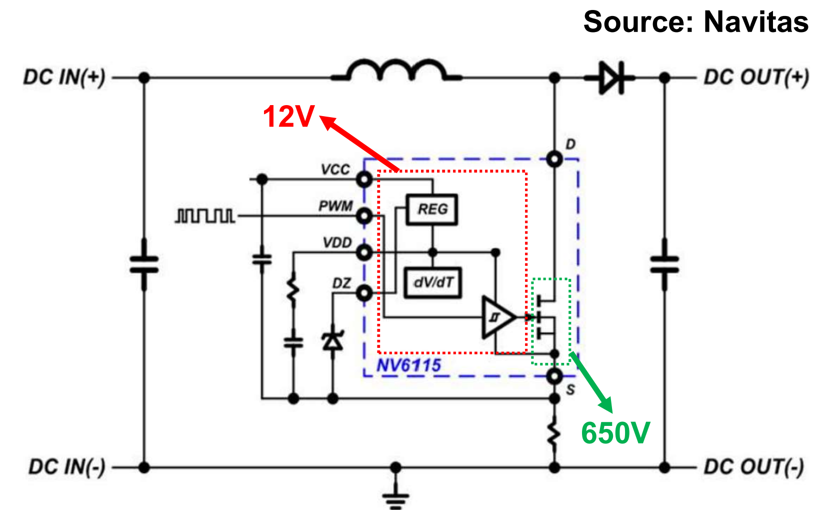
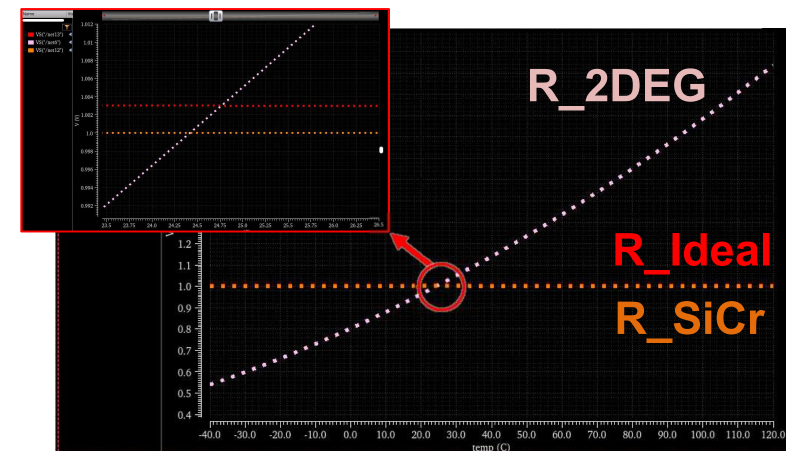
- **Active devices**
  - 650V E-HEMT NMOS
  - 12V E-HEMT NMOS
  - 12V D-HEMT NMOS
  - 12V Rectifier
- **Passive devices**
  - P-GaN varactor
  - MIM Capacitor
  - 2DEG Resistor
  - SiCr Resistor

Source: Navitas





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TSRI Developing Techniques

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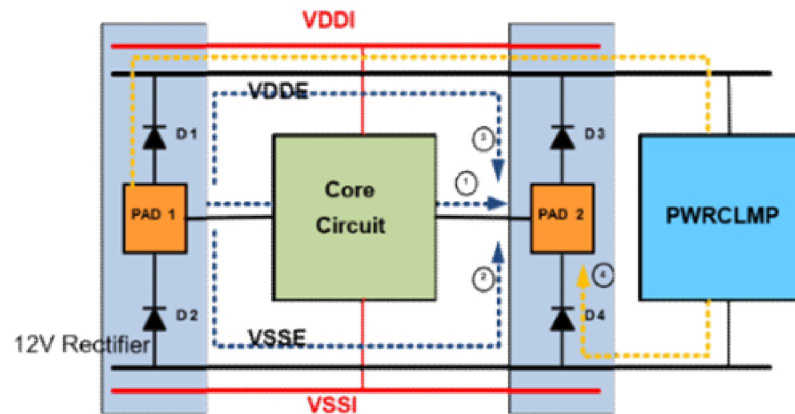
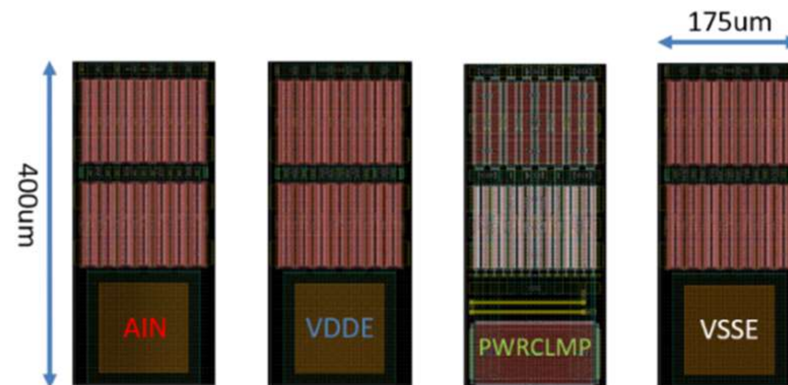
- **ESD protection I/O**
  - VDDE/VSSE/AIN/PWRCLMP
  - 400 μm x 175 μm





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TSRI Developing Techniques cont.

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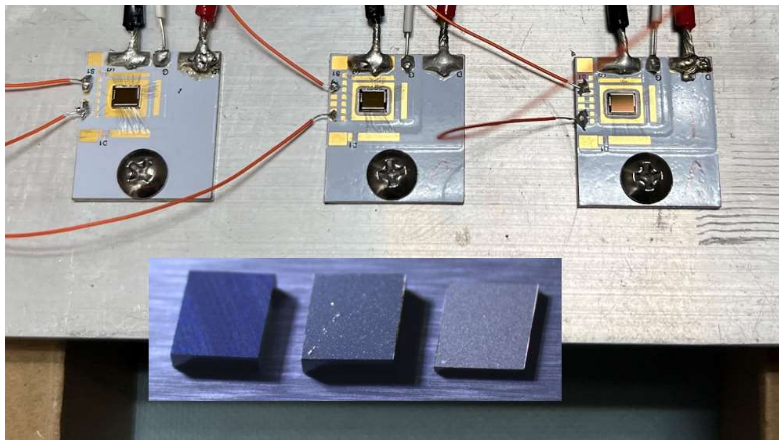
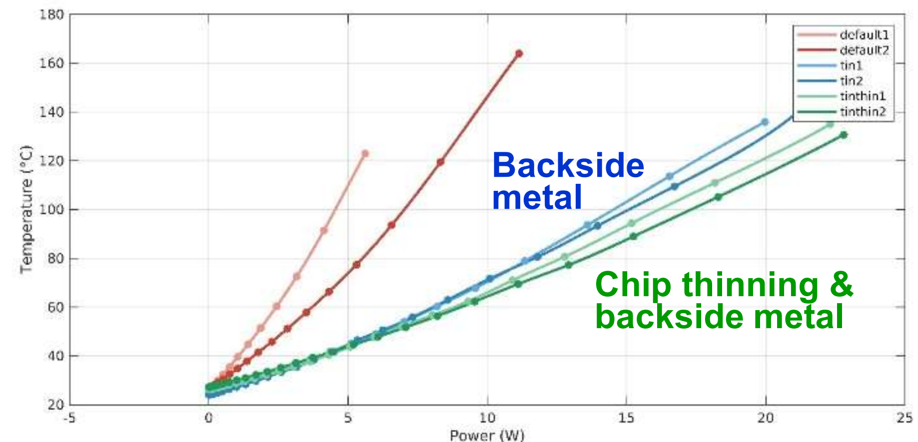
- **Thermal dissipation improvement**
  - Chip thinning
  - Backside metal
  - Chip thinning & backside metal





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GaN Research Topics by TSRI Customers

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- **Device development/improvement**
  - ESD protection device
  - Schottky diode
  - GaN transistor characterization
  - Temperature effect
- **High integration circuits of T50GaN**
  - High switching frequency
    - DC/DC converter
    - gate driver
  - High power density
    - power amplifier
    - power switch
  - Oscillator
  - ESD protection circuit

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Prospective Research Competitiveness

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- TSRI is **ONLY** the institute provided TSMC GaN process to academia in the world
- Regular GaN session in **ISSCC from 2017**

ISSCC 2017

25 GaN Drivers and Galvanic Isolators....................................426

ISSCC 2018

24 GaN Drivers and Converters..380

ISSCC 2019

15 Power for 5G, Wireless Power, and GaN Converters.............236

ISSCC 2020

18 GaN & Isolated Power Conversion..284

ISSCC 2021

33 High-Voltage, GaN and Wireless Power................................458

ISSCC 2022

14 GaN, High-Voltage and Wireless Power................................226

ISSCC 2023

20 GaN Power Conversion...300

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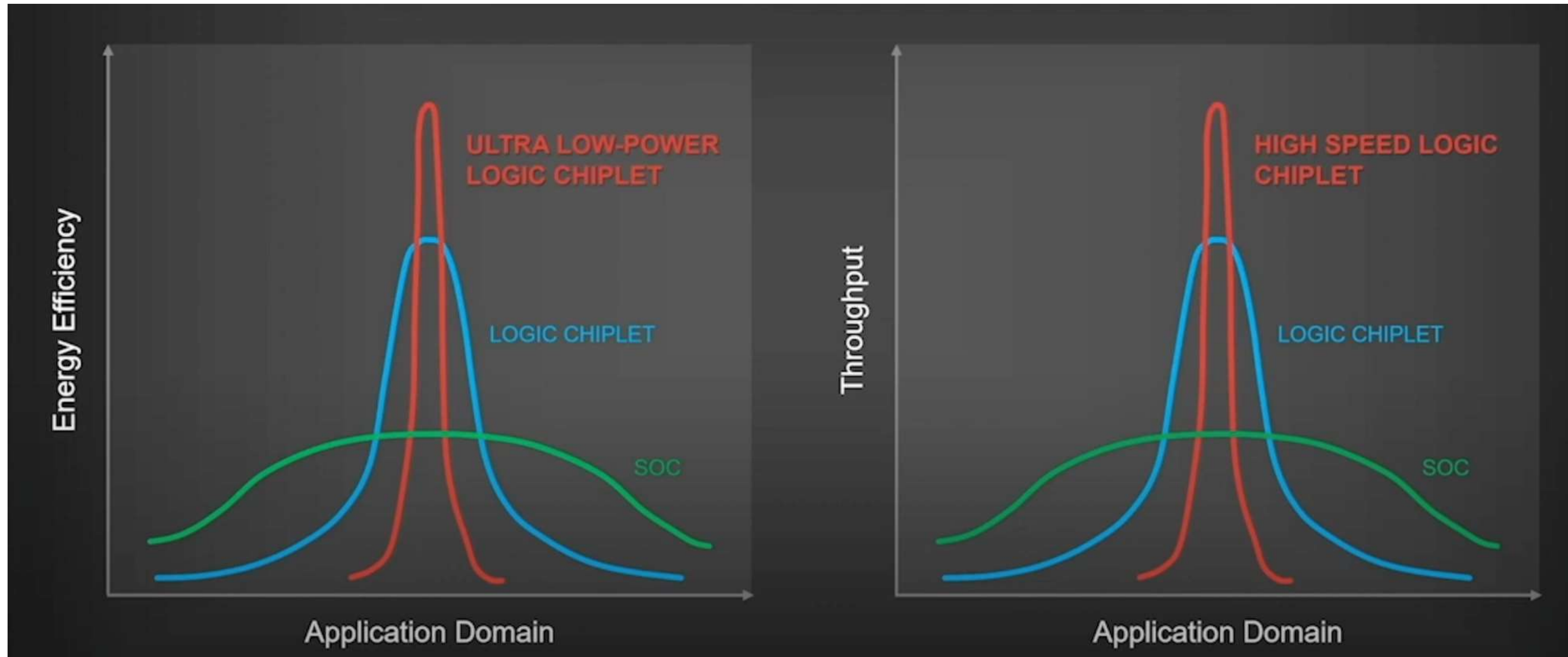
Go Beyond Individual Chips



Source: TSMC

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Chiplets in Power Module

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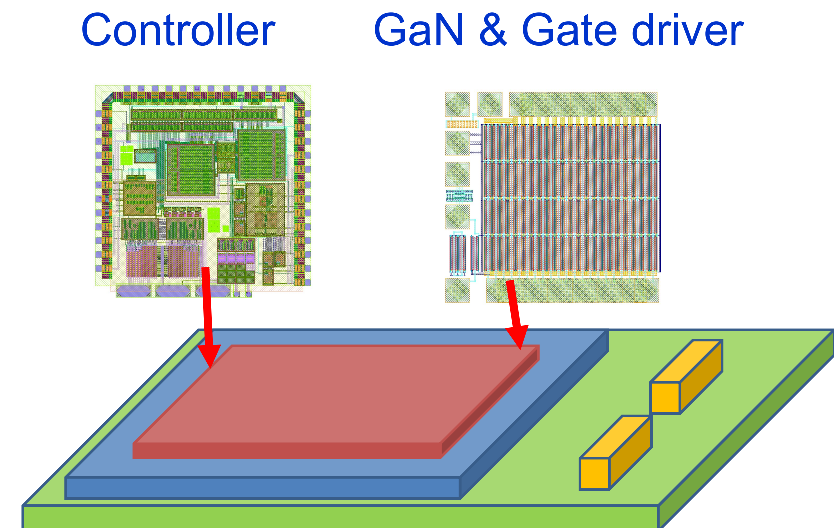
- **Combined advantages of Silicon and GaN**
  - Si
    - CMOS/BCD
    - Complicate control capability
    - Low static loss
  - GaN
    - High switching frequency
    - High power density



Competitive in small and high-power density

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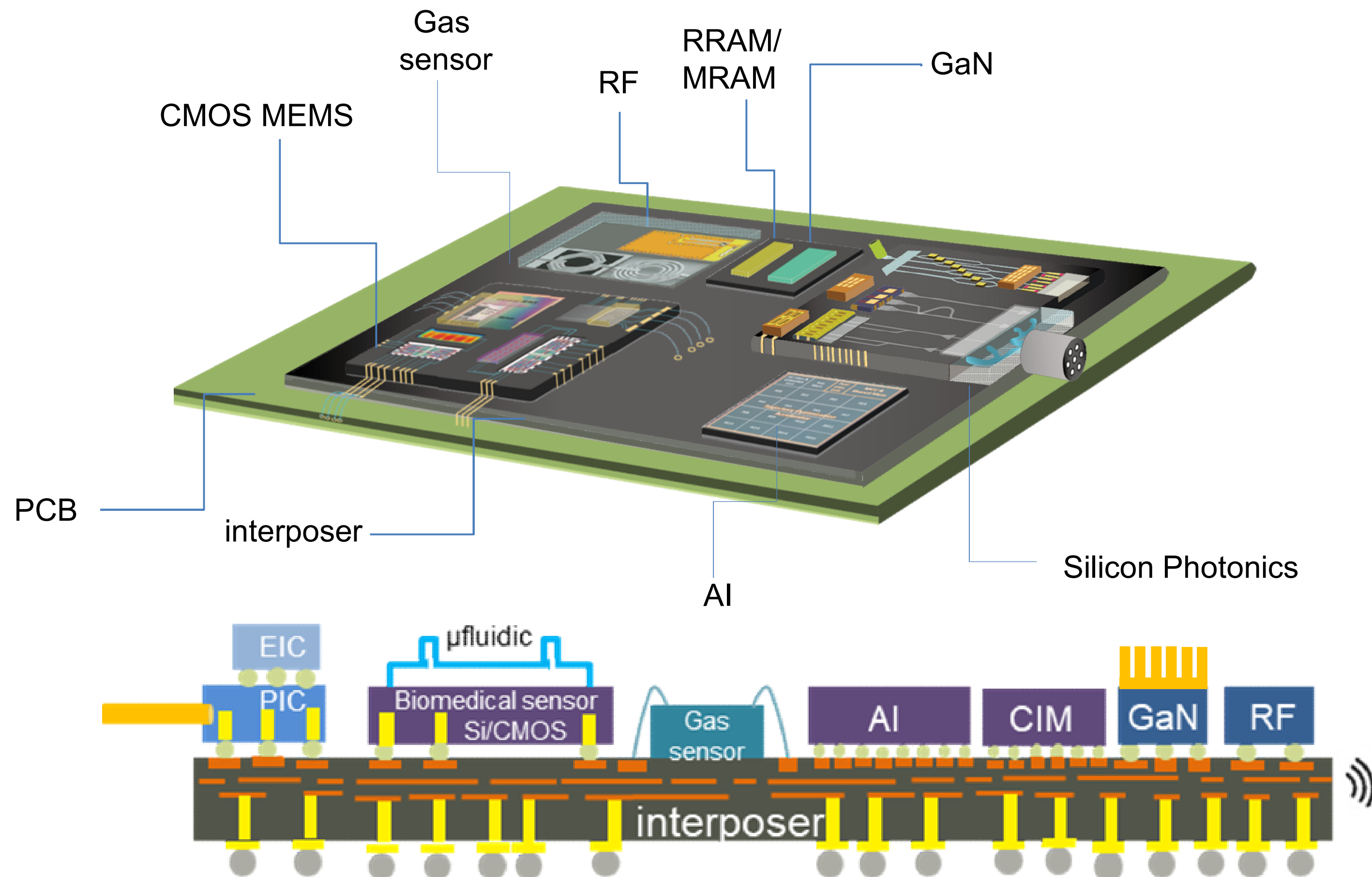
TSRI 2.5D/3D Heterogeneous Integration

- **Integrate advanced ICs, Optoelectronics/MEMS/biomedical sensors, CIM, power managements, wireless/photonic communications**
- **A platform for academia and startups to verify their prototypes**



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Key Technologies

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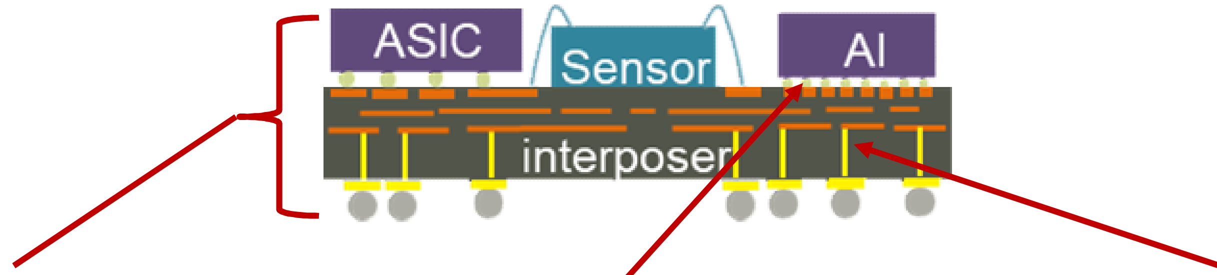
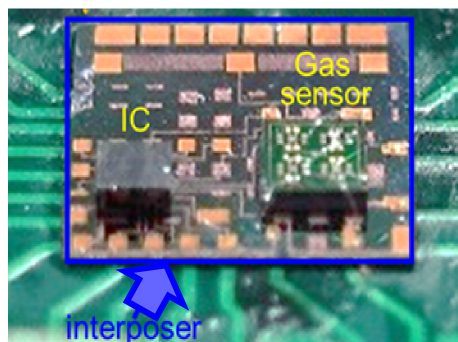


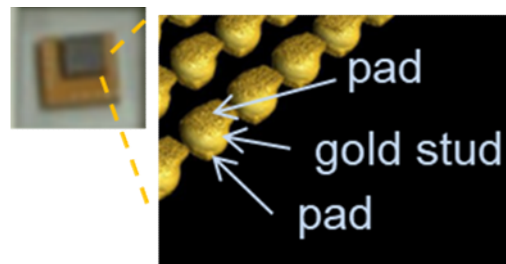
CoCoP

- Now providing services to academia



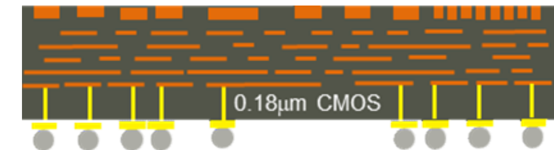
Die-level 50 μm-pitch microbump

- 2023: Verification
- 2024: Start servicing



CMOS BS TSV

- 2023~2024: Development and verification
- 2025: Start servicing



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Die-level μbump Technology

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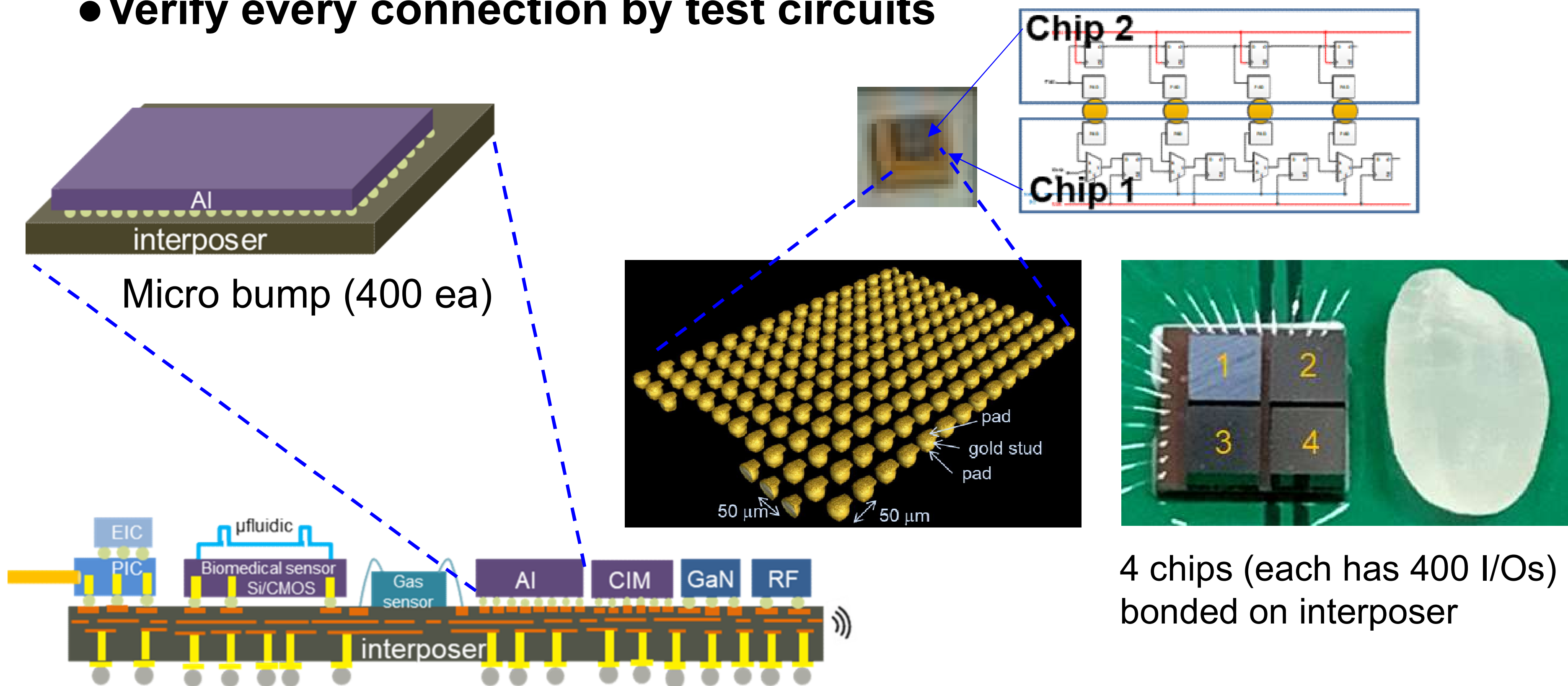
- Motivation: High cost to have 16/28 nm wafers with micro bumps
- Goal: Realize the 50 μm pitch micro bump in the AI chiplet with >100 I/Os
- Verify every connection by test circuits



4 chips (each has 400 I/Os) bonded on interposer

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Demonstration of GaN Chip

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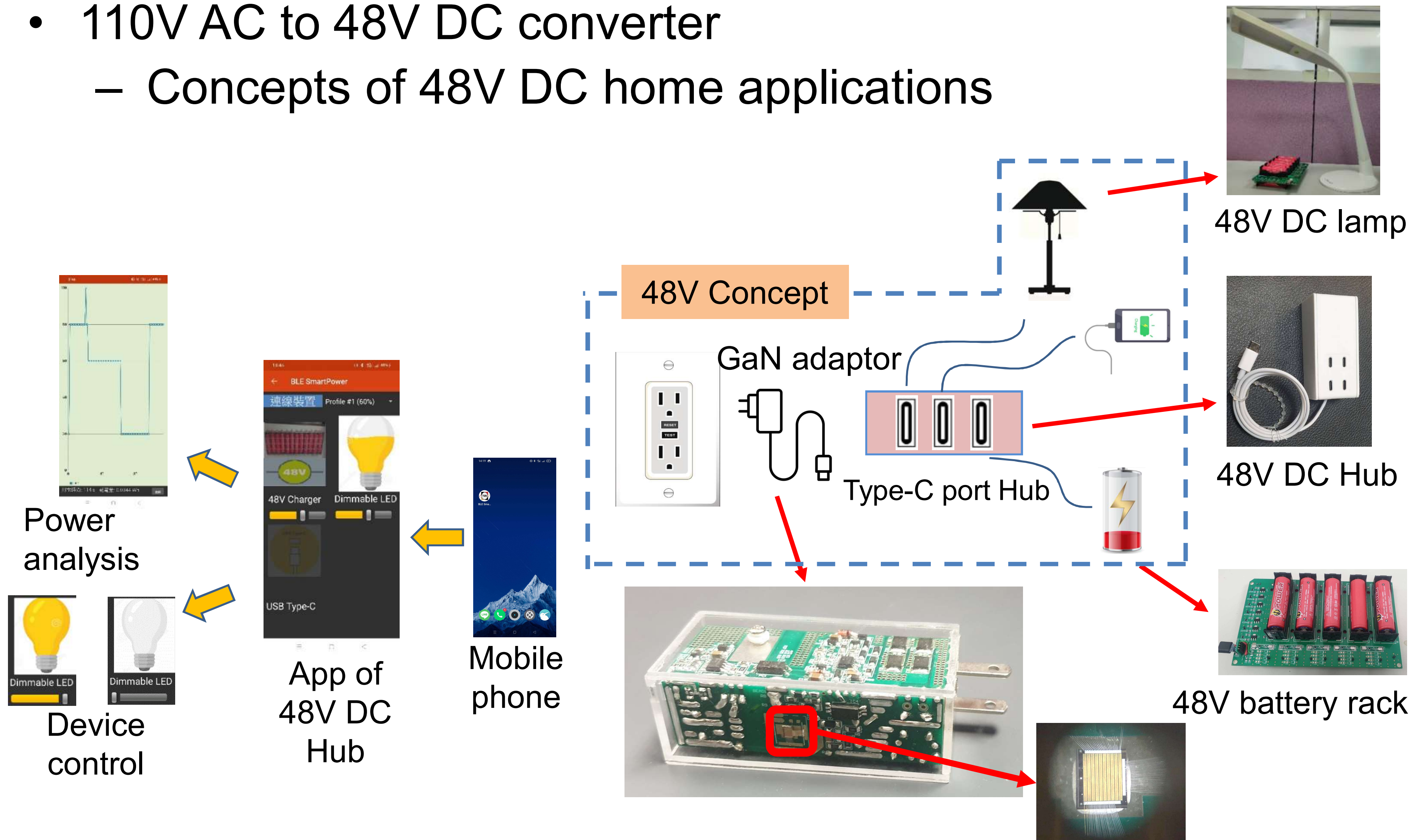
- 110V AC to 48V DC converter
  - Concepts of 48V DC home applications



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Summary

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- Make innovative GaN devices in TSRI
- Design unique GaN ICs in TSRI
- Realize smart GaN power modules by TSRI HI Technology
- Welcome international collaborations!

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Thanks for your attention!

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