ELTE Conference 2023 in Poland

Exploring Wide Bandgap Semiconductor Research Collaboration Opportunities in Poland

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IEEE Fellow, Member of U.S. National Academy of Engineering

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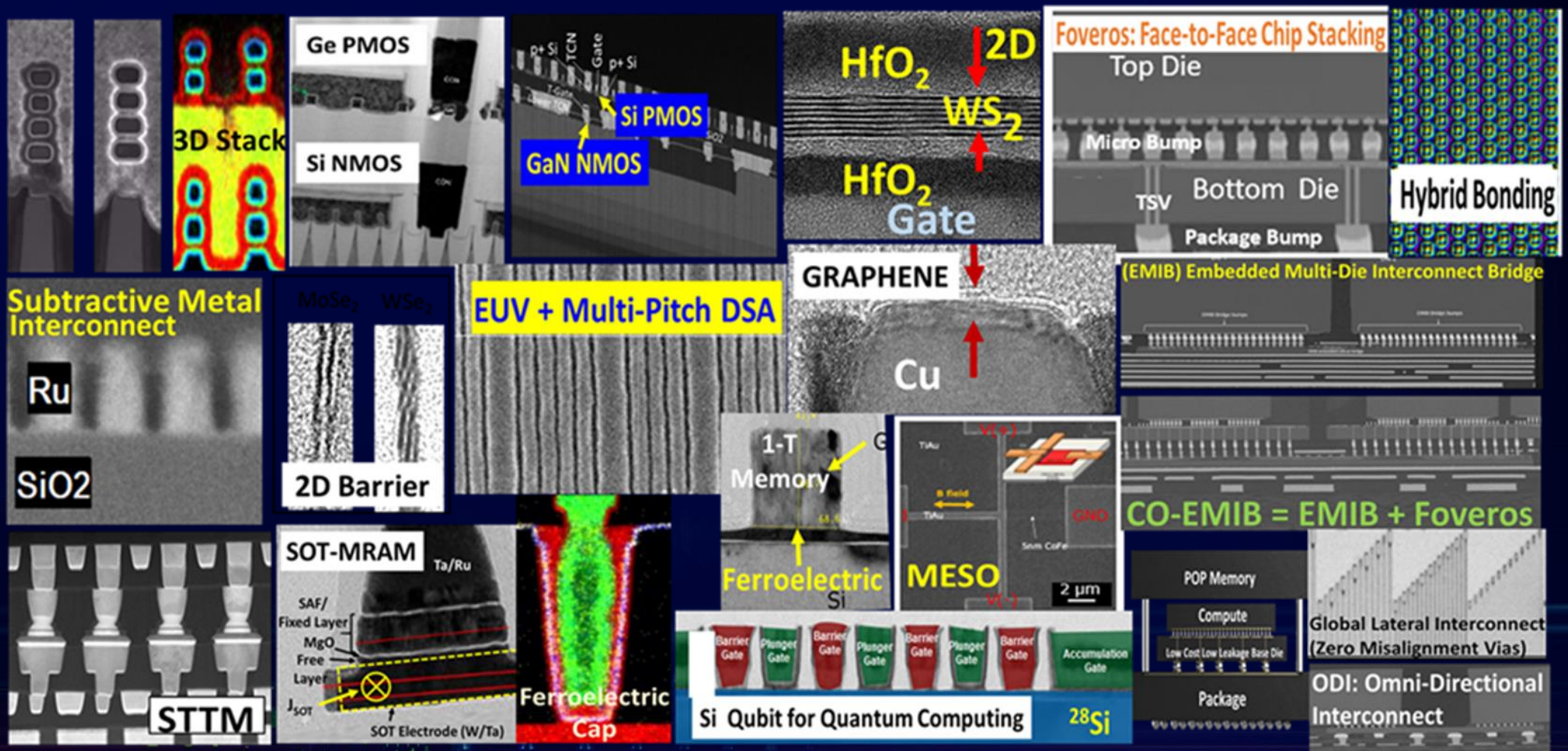
Robert Chau, Director of Intel Europe Research

- 35 years with Intel.
- Intel Senior Fellow since 2005.
- General Manager of Intel Components Research organization 2014-2022.
- Director of Intel Europe Research 2022 - present (relocated from U.S. to Brussels in 2022).
- 2012 IEEE Jun-ichi Nishizawa Medal for Strained-Si and High-k/Metal-Gate technologies.
- 2015 Intel Inventor of the Year Award for Intel's FinFET technology.
- Holds >480 U.S. patents.
- IEEE Fellow.
- Elected Member, U.S. National Academy of Engineering.

Microelectronics Advancement Requires Semiconductor and Packaging R&D

Moore's Law Scaling + New Functions



Transistor, Interconnect, Patterning, Memory, Packaging, 3D Integration, New Materials, New Functions

Source: Robert Chau, Intel, IEDM 2019 Keynote

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Intel Europe Research (Robert Chau): Intel-European RTOs R&D collaborations in 1) accelerating semiconductor process and packaging R&D advancement in Europe and 2) driving Moore's Law and beyond.

IMEC

Talent and Research Pipelines

Moore's Law Innovations

Talent & Research Pipelines

Fraunhofer

Intel Europe Research Robert Chau

Leti

Semiconductor Innovations

Talent and Research Pipelines

European Academic & University Research CEZAMAT (Poland)

Lukasiewicz (Poland)

Intel Europe Initiatives

Intel Global Government Affairs
EU Chips Act
U.S. Chips Act

intel

Intel Europe Research and Poland RTOs

- Intel established its presence in Poland 24 years ago.
- Intel has established a large software R&D center in Gdansk with ~2400 employees.
- Intel Europe Research (Robert Chau) visited CEZAMAT in Oct 2022 and gave keynote speech at the 2022/2023 academic year inauguration:

- Piotr Dardzinski (former Lukasiewicz president) and Robert Chau (Intel) met in Brussels Nov 2022 to discuss R&D landscapes in Poland and Intel-Lukasiewicz research collaboration opportunities.
- Intel's Robert Chau and IMEC's Luc Van den hove (CEO) co-hosted Lukasiewicz at IMEC Leuven in Feb 2023 to discuss joint Intel/Lukasiewicz/IMEC research collaboration opportunities.
- Lukasiewicz (Jakub Kaczmarski) and Intel (Robert Chau) are organizing a joint technical workshop in Poland in 2023 on wide bandgap semiconductors R&D (contact: Jakub Kaczmarski @Lukasiewicz)
  - ❖ To stimulate discussions on wide bandgap semiconductors and explore joint R&D opportunities

Wide Bandgap Semiconductors for RF and Power Applications

	Ge	Si	SiC	GaN (AlGaN)	Diamond	hBN
Eg (eV)	0.67	1.1	3.26	3.39	5.45	6.4
electron mobility (cm2/Vs)	3900	1350	700	1900	1900	200
hole mobility (cm2/Vs)	1900	450	20	20	2000	?
electron charge density (e20 cm^{-2})	>10	>10	**0.5**	**5**	**~1**	**?**
v_{peak} (10^7 cm/s)	1	0.7	2	2.5	2.7	?
$E_{Critical}$ (MV/cm)	0.15	0.3	3	3.3	5.6	15
Thermal conductivity (W/cm K)	0.6	1.5	3.3-4.5	2	20	21
RF Johnson's FOM = $E_{Critical}$*v_{peak}	0.7	1.0	**29**	**39**	**72**	?
Power Baliga's FOM = μ_n* $E_{Critical}$^3	0.5	1.0	**443**	**1441**	**4460**	**5698**

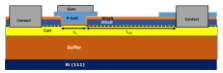
SiC most mature; GaN higher performance (higher mobility, higher charge density and higher FOMs) than SiC but requires more R&D; Diamond and hBN in research/exploration phase

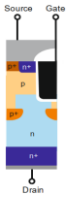
Source: Han Wui Then, Intel, IEDM 2019, 2012, 2022.

Wide Bandgap Semiconductor Opportunities

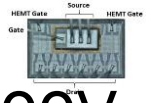
5-48V GaN

600V GaN, SiC





1200V GaN, SiC



1V 12V 48V 600V 1200V ...higher

Si (1.1eV)

Emerging LV GaN

GaN (3.4eV)

Emerging HV GaN

GaN FoM >3x better than SiC

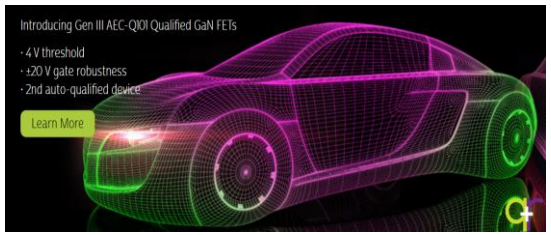
SiC (3.3eV)

Ga2O3, Diamond, hBN in research/exploration

Datacenter

Fast Chargers

- **RF Base Station**
- **5G/6G Small Cells**
- **Mobile Handsets**



Automotive

Defense, Space

Aerospace

- SiC most mature and dominates at >1000V (but lower performance than GaN)
- GaN opportunities in < ~600V (higher performance than SiC) but requires more R&D.
- More discussions at the upcoming 2023 Lukasiewicz-Intel technical WS in Poland (contact: Jakub Kaczmarski @Lukasiewicz)

Intel's GaN research has been focusing on low-voltage (5-48V) applications and large-wafer processing

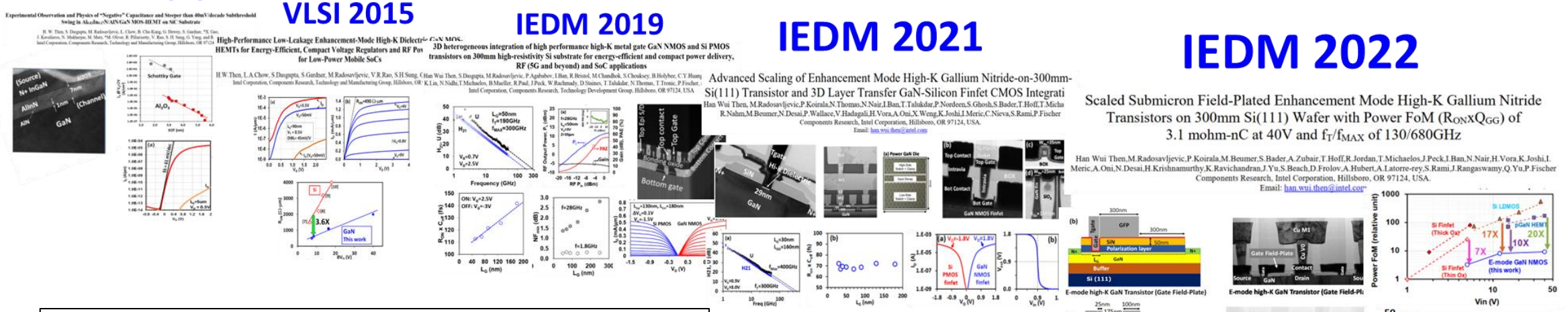
IEDM 2013

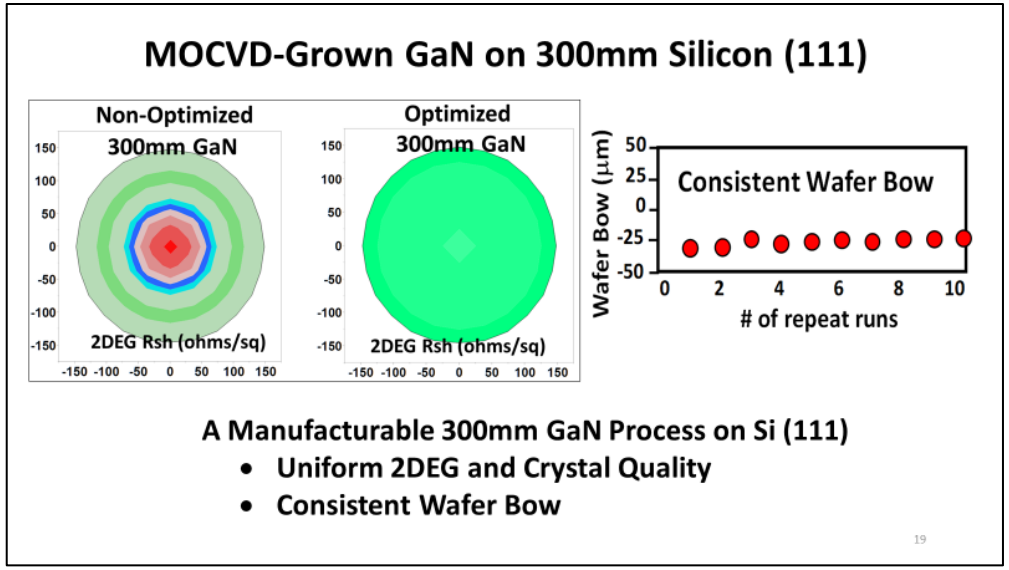
VLSI 2015

IEDM 2019

IEDM 2021

IEDM 2022





Source: Robert Chau, Intel, IEDM 2019 Keynote

Han Wui Then, Intel, IEDM 2019, 2021, 2022

Closing Remarks

- Strong research collaborations between Intel Europe Research, Poland's RTOs (Lukasiewicz, CEZAMAT) and Polish universities will accelerate semiconductor R&D advancement in Poland and Europe.

- Joint Lukasiewicz-Intel 2023 technical workshop in Poland on wide band-gap semiconductors R&D (contact: Jakub Kaczmarski @Lukasiewicz)