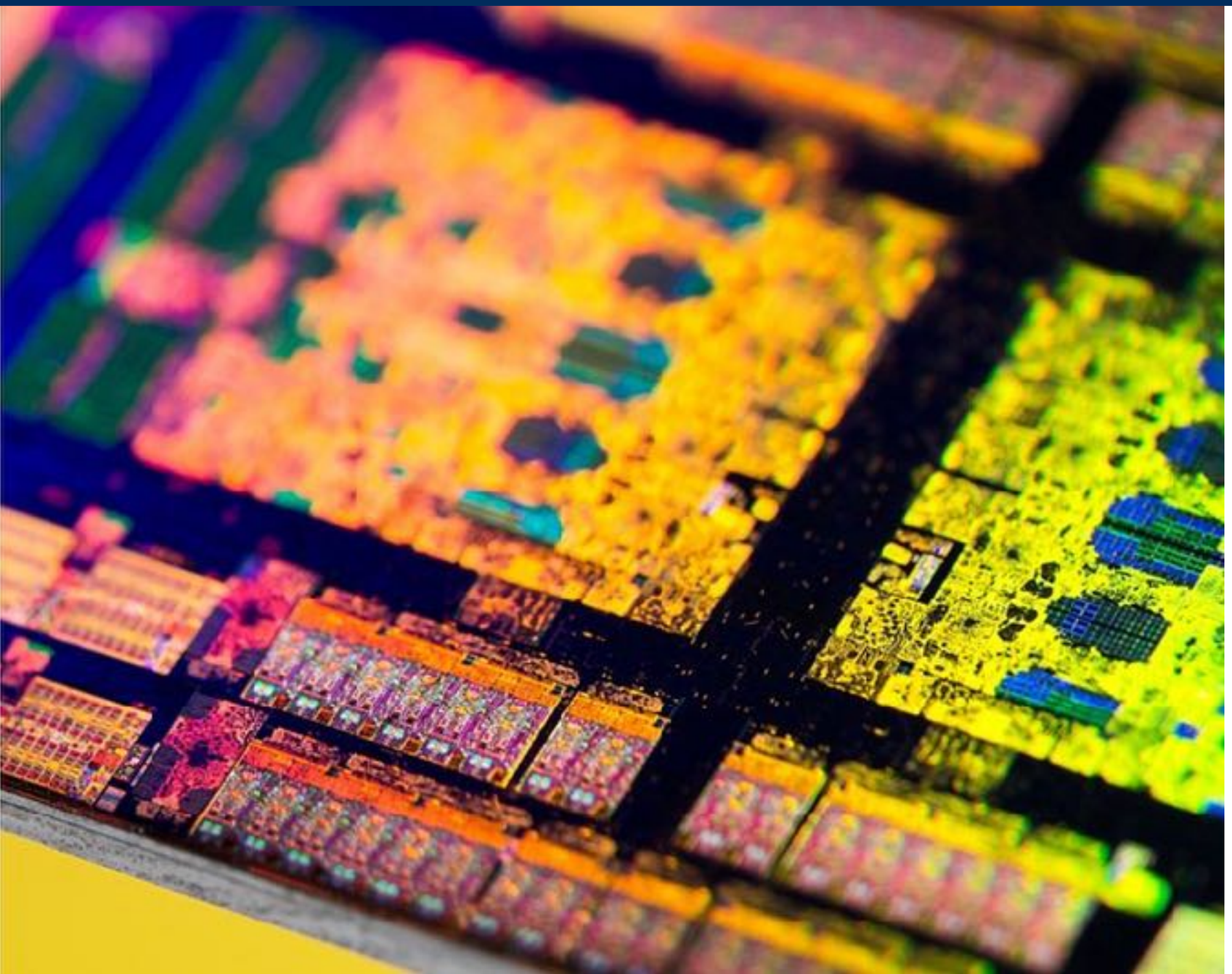
Wide Band Gap Semiconductors Pilot Line

a major boost for Europe’s innovation and competitiveness



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The growth of WBG semiconductors & the need for a PL

The <u>twin</u> green & digital transition

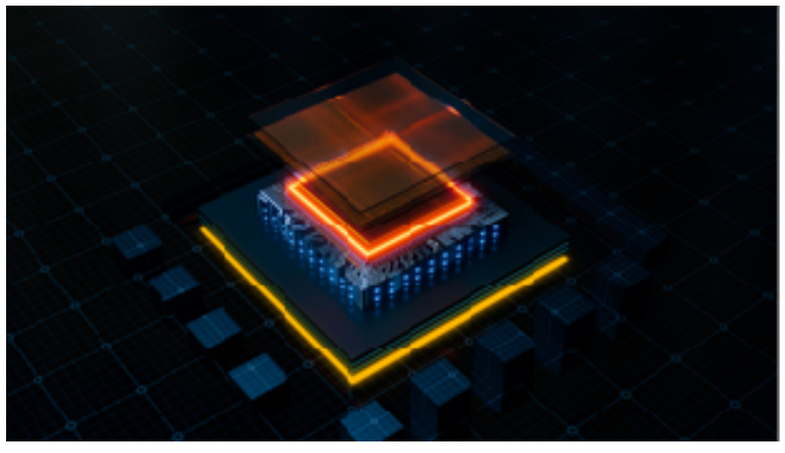
Digital technologies drive the green transition &
the digitalization process has to be sustainable

Large-scale electrification of industries and transport

moving away from carbon-rich energy resources

- Increase demand for electricity
- Increase supply to the energy grid

- Novel intensified voltages requires more versatile power systems and grids
- Increase connectivity and data volume



Breakthrough in power chip technologies

- Specific semiconductor device for power management and control applications (efficient energy conversion and regulation)
- Key role in the electrification of industry & transport

Overall value chain for power chips must focus on improving energy efficiency and reducing cost

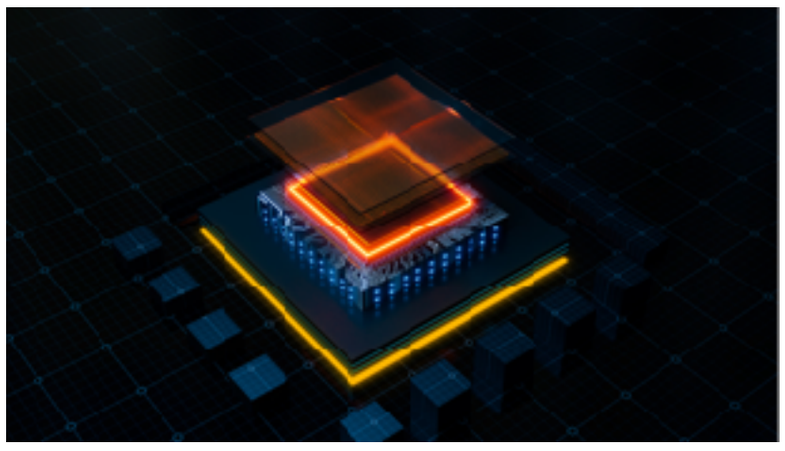
Future power chip technologies: a quest for new materials

Wide & Ultra wide bandgap semiconductors

- Ideal for applications requiring high breakdown voltages
- Compared to silicon, WBG materials can handle higher voltages and frequencies,
- Suitable for the power electronics driving digital & green twin transition + other application areas like telecommunication and radar

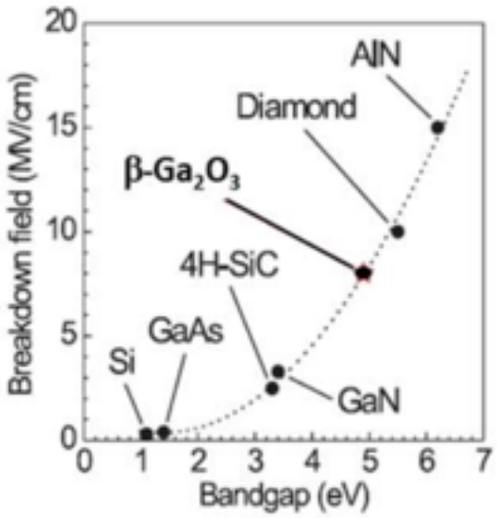
The growth projections of industry & automotive market segments outperform the growth of the semiconductor industry as a whole

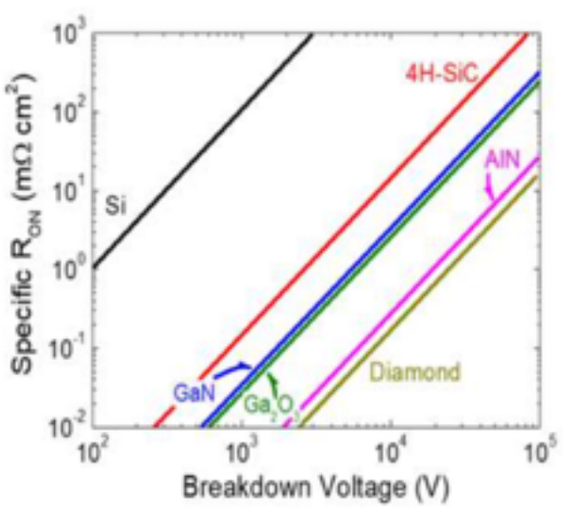
Addressing the needs of the growing market of power electronics requires a breakthrough in materials



- Power transistors
- High frequency / high voltage devices such as HEMTs, MISHEMTs, FinFETs, SBDs, PNDs, JBSDs and bipolar transistors
- Power integrated circuits including active and passive components
- High–frequency devices (HETs, barristors, etc.) operating up to the THz
- Light Emitting Diodes (LEDs), photodetectors, solar cells, based on III nitrides and 2D semiconductors and transition metal oxides
- Solid state detectors for different radiation types (X-Ray, particles, neutron, …)
- High frequency or high sensible MEMS

Materials challenges for future power devices





Now

- Present WBG semiconductors represent the frontier of materials that satisfy these criteria (e.g. SiC, GaN, ZnO …)

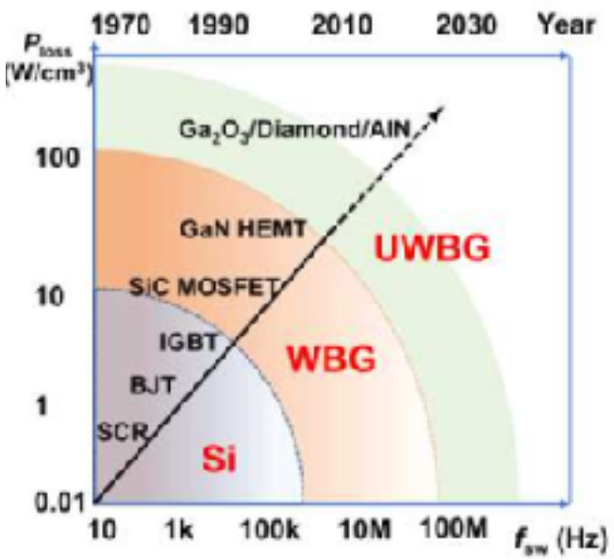
The future 5 year roadmap

- Ultrawide bandgap (>4 eV) semiconductors (e.g. AlN, BN, AlGaN, Ga2O3 and (Al,Ga)2O3

Lack of fundamental understanding

controlled growth, phase engineering, materials properties (electronic and ionic contributions to conductivity and formation of a depleted region; Electrical properties; electron emission mechanisms; effects of thermal annealing on electrical properties; optical phonon modes, the high-frequency dielectric constant, and the effective electron mass

Realistic solutions should be provided in terms of operational characteristics like voltage, current level and sensitivity or switching frequencies



Improved properties of materials

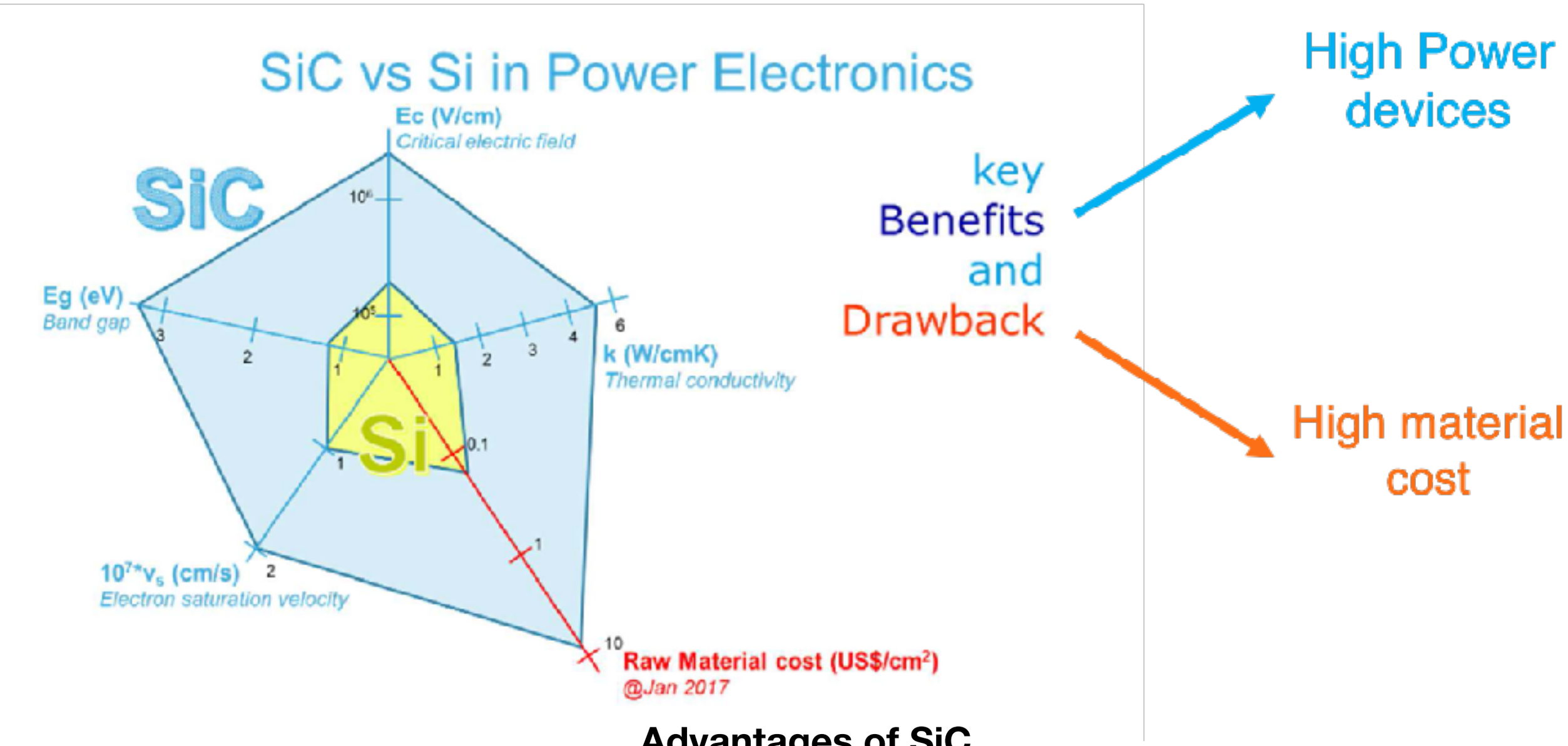
Improvement of the operation of power-electronics devices

design architectures, heat dissipation, processesing, …

Control over the whole pipeline

Material -> Component + Module + System level

Materials challenges for future power devices: Si vs. SiC



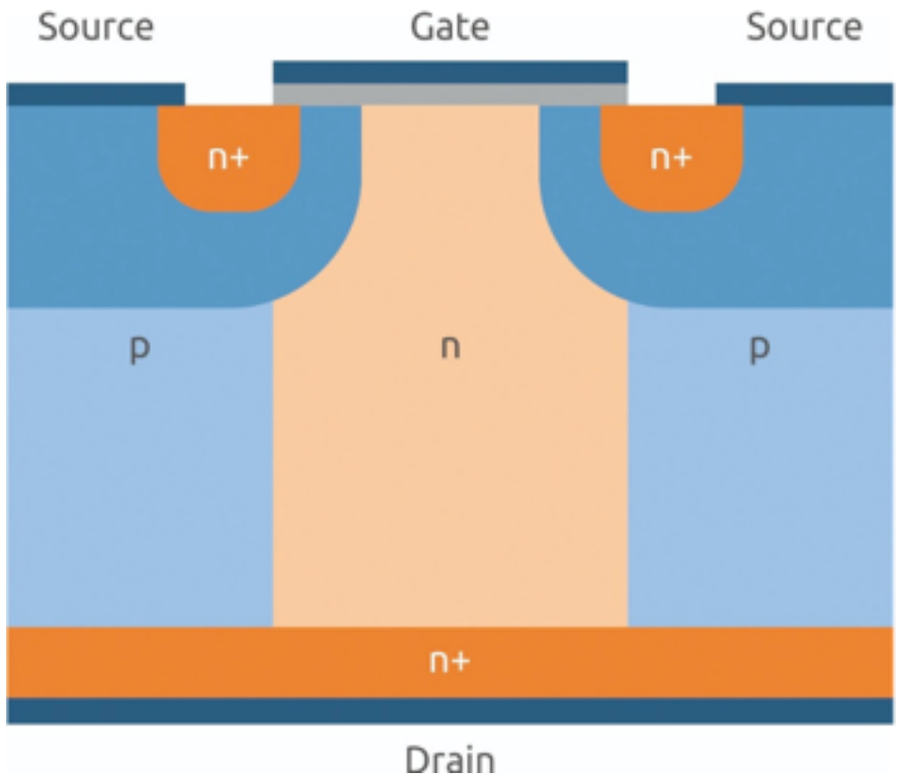
Advantages of SiC

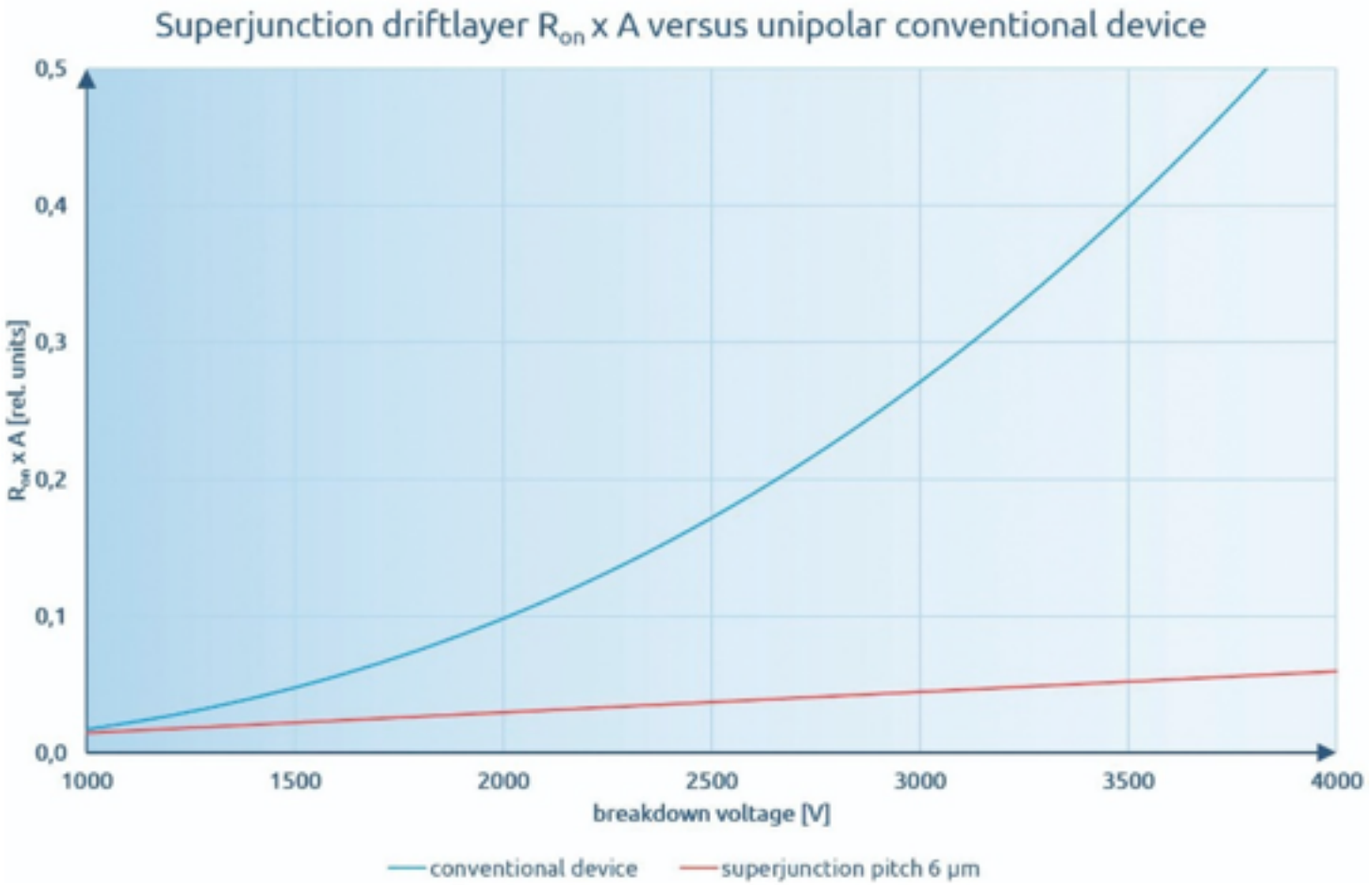
- SiC is the leading WBG material for power devices due to its superior properties: Critical electric field, Thermal conductivity, Bandgap, Electron saturation velocity.
- These properties make SiC ideal for power applications.

costs are decreasing rapidly with increased production

Primary drawback: cost of raw materials, which is nearly 100 times higher than silicon

Superjunction SiC Devices

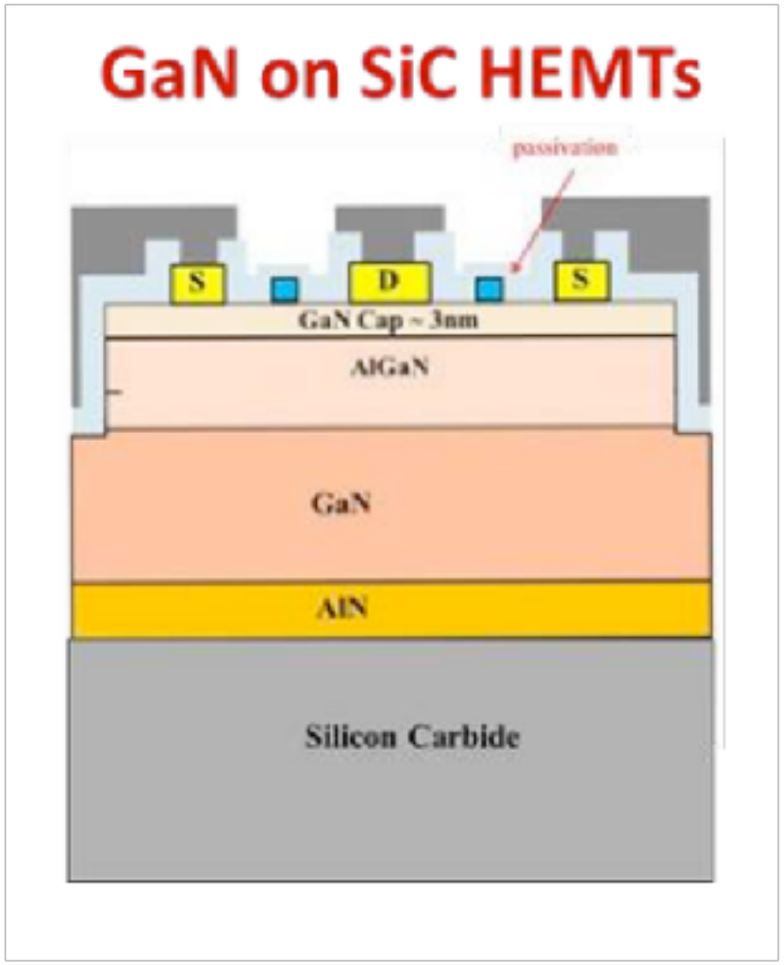


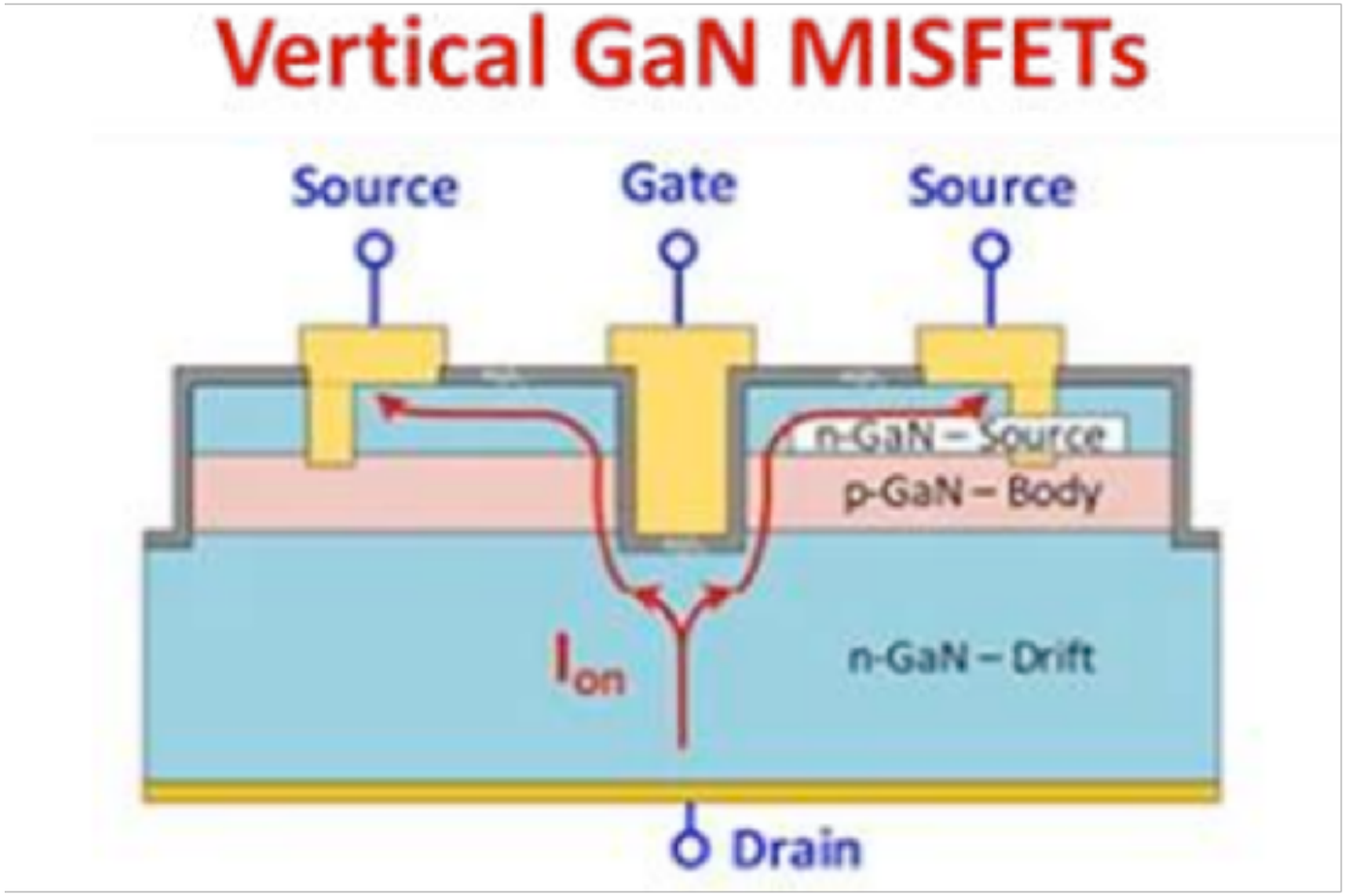


- Performance improvements can be achieved with superjunction structures -> requiring deep junctions.
- Deep junctions: challenging to produce in SiC due to the absence of doping diffusion, even at high temperatures.
- **<u>The WBG Pilot Line</u>** will explore innovative approaches to overcome this limitation

These advancements could significantly enhance device performance for breakdown voltages starting at 1 kV

GaN Devices



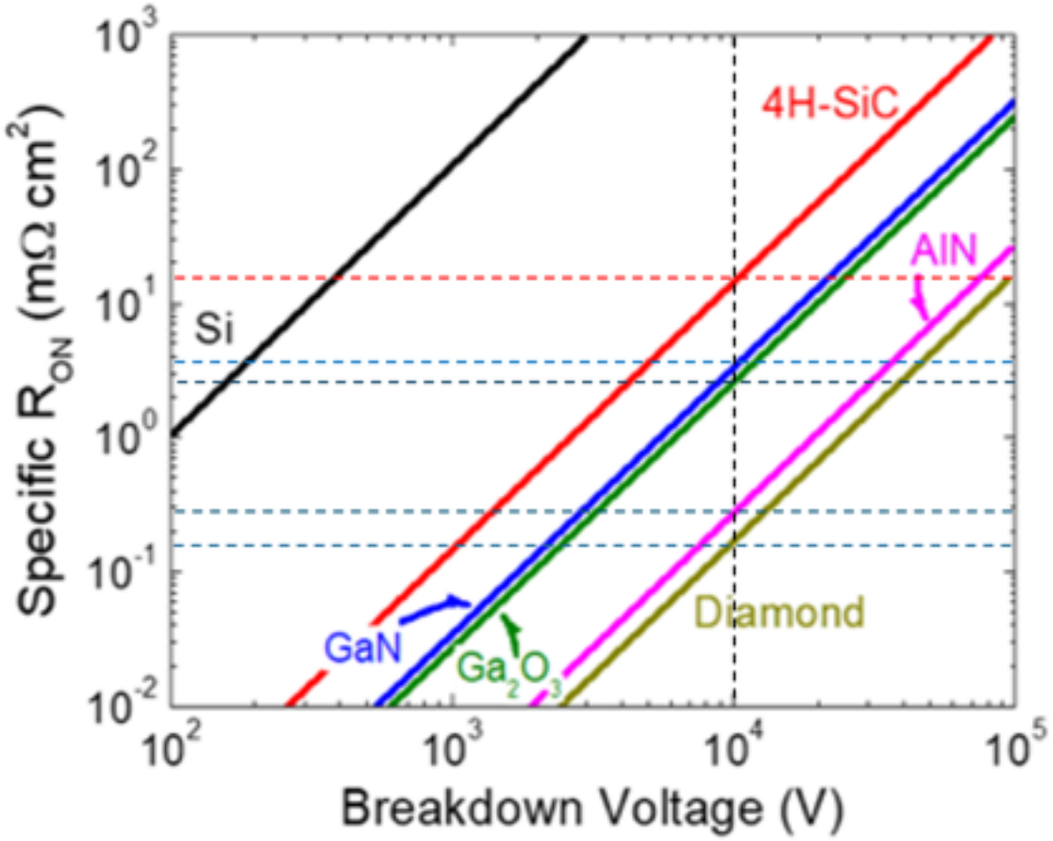


- Today, all GaN devices are produced on Si or SiC substrates, resulting in horizontal structures with limited scalability and low current capacity.
- Hetero-epitaxy introduces defects that reduce performance and reliability.

The WBG Pilot Line will develop processes for bulk GaN wafers, enabling vertical devices

Lower defect densities; Higher current-carrying capacity; Enhanced scalability and performance

Beyond SiC and GaN: Ultra Wide Band-Gap

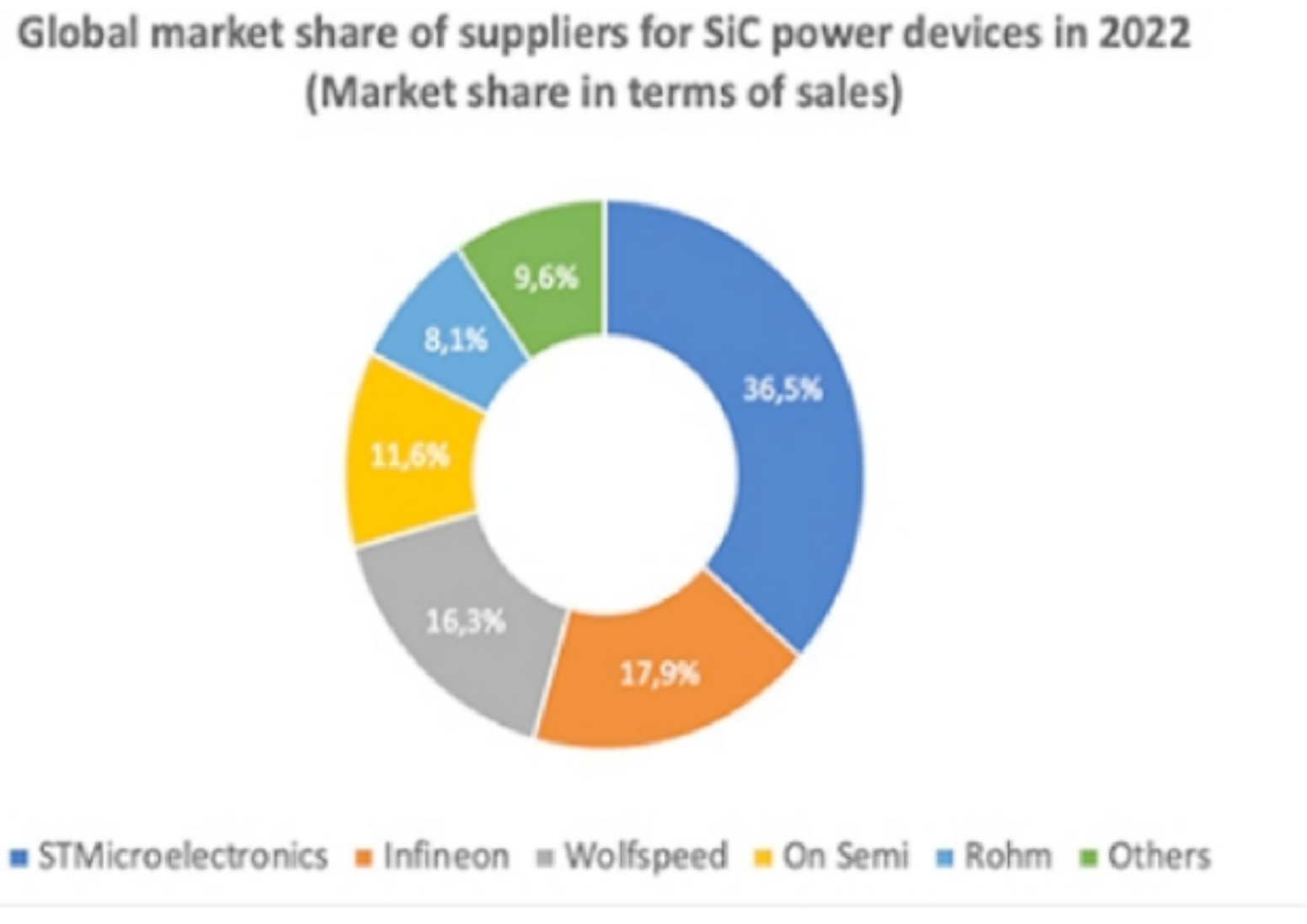


Material	Specific Ron (mOhm/cm2) @10 kV
SiC	15
GaN	4
Ga2O3	2.5
AlN	0.3
Diamond	0.15

- Further advancements are possible with materials featuring even wider bandgaps: Ga2O3, AlN, Diamond
- New UWBG materials could drastically lower theoretical Ron values for the same breakdown voltage.

Developing these materials and their associated processes will be a key focus of the WBG Pilot Line.

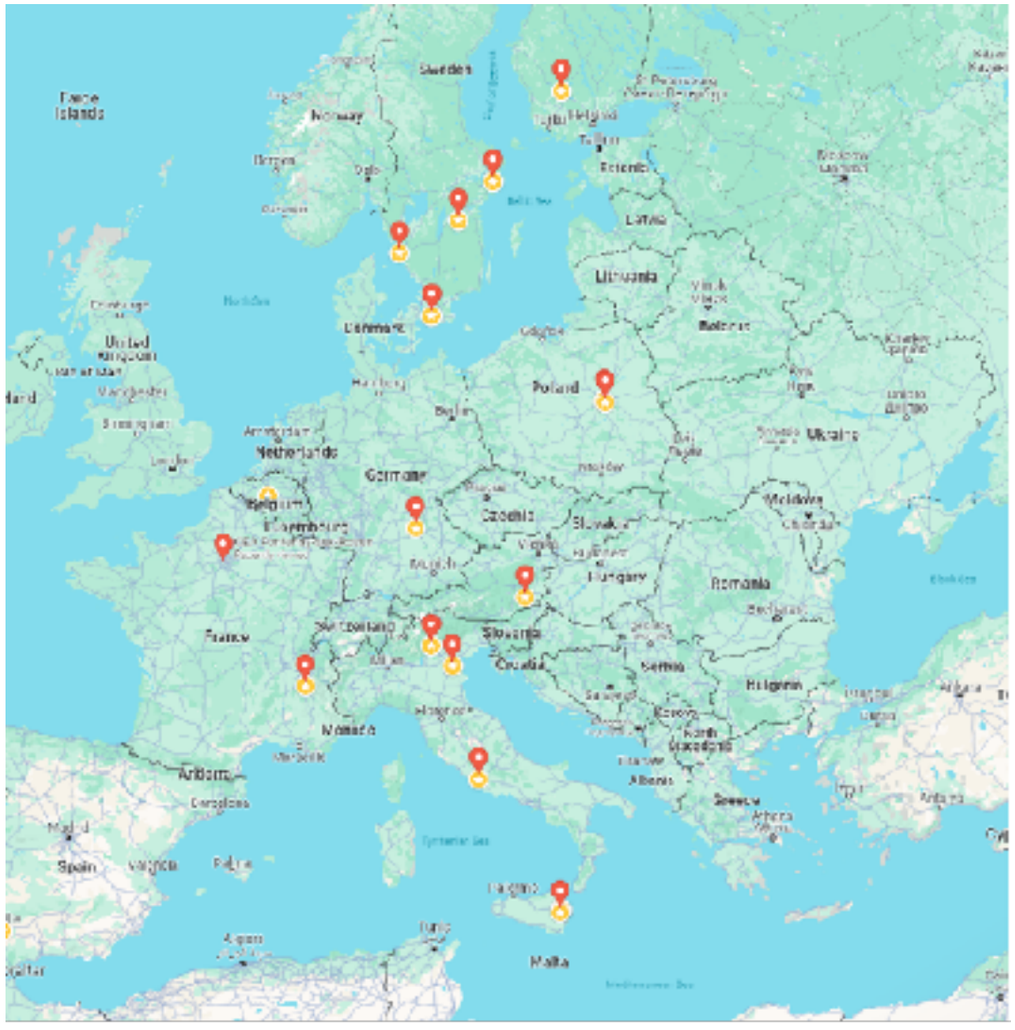
Europe is the market leader



- Europe, led by companies like STMicroelectronics and Infineon, holds over 50% of the global WBG device market
- It is crucial to support EU+ companies in maintaining their leadership as the market evolves with technological advancements.

The WBG Pilot Line will play a pivotal role in this effort, benefiting not only large corporations but also startups and SMEs within the value chain.

The WBG Pilot Line



	Material Growth & EPI	Device Processing	MEMS and detectors Processing	Advance char. and Reliability	M&S - PDK	Packaging & Integration
SiC	CNR	CNR, KTH	FBK	IUNET, KTH	I&C	FBK
GaN	IHPP, CNR, LUND	CNR, IMiF, CHAL		IUNET, IMiF, CHALM	I&C	
Ga_2O_3	LUND	IMiF, CNR		IUNET, IMiF	I&C	
AlN		CHALM	FBK	UNET	I&C	
Diamond				UNET	I&C	

- Establish a distributed pilot line across seven nations with 14 partners. The pilot line will focus on:
  - Materials: SiC, GaN, GaO, AlN, and diamond.
  - Technologies: Substrate and epitaxy growth, power device processing, MEMS and detector processing, characterization and reliability, PDK development, and packaging.

Lab-to-fab key concept

The WBG Pilot Line

	RF devices Lateral	Power Lateral devices unipolar	Vertical devices unipolar	BJT
SiC			CNR	KTH
GaN	CNR CHAL	CNR CHAL IMiF	CNR IMiF	
Ga_2O_3			CNR IMiF	
AlN	CHAL	LUND		

Materials	Processing	Devices	Applications
ST Life.augmented SiCrystal A ROHM Group Company soitec KISAB OMMIC innovating with III-V'S	ASM AIXTRON APPLIED MATERIALS axcelis COHERENT	ST Life.augmented Infineon onsemi NXP STLAB SENSIC	Valeo

- Specific device technologies to be developed include:
  - SiC: MOSFETs, diodes, and BJTs.
  - GaN: RF and power lateral devices, as well as vertical devices.
  - GaO: Vertical devices.
  - AlN: RF and power lateral devices.

All these technologies could be of large interest for several companies

Several companies have already contacted the pilot line to develop their product

Present status & Conclusions

April 10th - PAB to approve the Hosting Agreement
April - signature of the HA, and grant agreements
May - start of the WPG Pilot Line project

- The European semiconductor industry excels in markets driven by WBG materials: automotive, industrial, and telecommunications.

- To maintain its leadership, Europe must foster the growth and maturation of WBG platforms.

- The WBG Pilot Line will:
  - Drive process, architecture, and material innovations from lab to fab.
  - Strengthen the entire value chain.
  - Enable the fast adoption of advanced WBG technologies in high-value applications.

The WBG PL represents a crucial step in strengthening Europe's technological leadership in the strategic sector of power electronics

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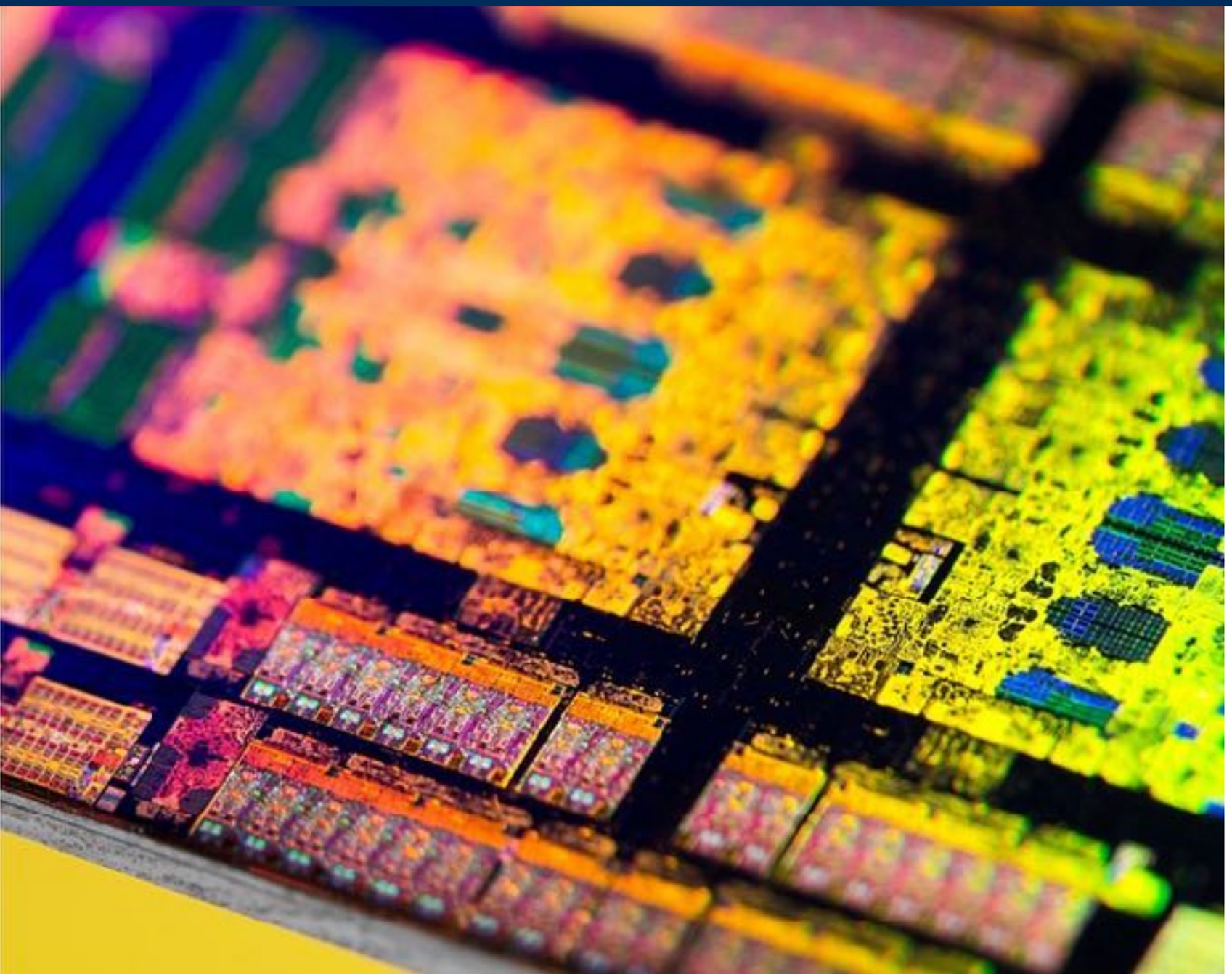

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