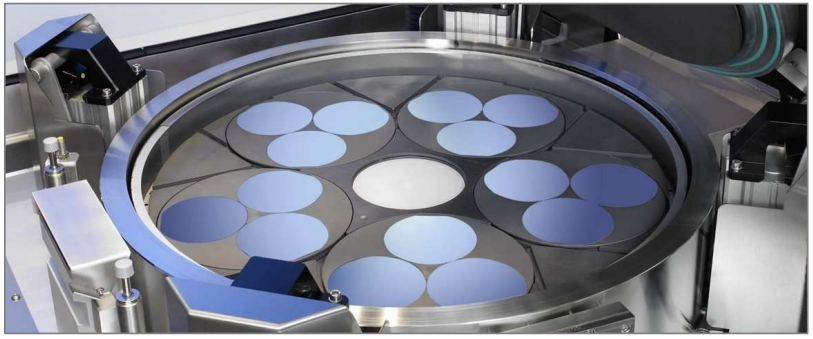
AIXTRON

40 years of innovation: lessons learned in epitaxial technology and related business

Prof. Dr.-Ing. Michael Heuken
AIXTRON SE and RWTH Aachen University

What we do

AIXTRON – a leading global Supplier of Deposition Equipment for the Compound Semiconductor Industry



1987 - The Horizontal Reactor Patent submitted

AIXTRON

(19) BUNDESREPUBLIK DEUTSCHLAND

DEUTSCHES PATENTAMT

(12) **Offenlegungsschrift**

(11) **DE 37 21 636 A1**

(51) Int. Cl. 4:
C 23 C 16/44
C 30 B 25/08
H 01 L 21/205
H 01 L 21/365
// C30B 29/40,29/48

(21) Aktenzeichen: P 37 21 636.8
(22) Anmeldetag: 30. 6. 87
(43) Offenlegungstag: 12. 1. 89

DE 3721636 A1

(71) Anmelder:
Aixtron GmbH, 5100 Aachen, DE

(74) Vertreter:
Münich, W., Dipl.-Phys. Dr.rer.nat., Pat.-Anw., 8000 München

(72) Erfinder:
Jürgensen, Holger, Dr.; Heyen, Meino, Dr., 5100 Aachen, DE

(54) Quarzglasreaktor für MOCVD-Anlagen

Beschrieben wird ein Reaktor für MOCVD-Anlagen, mit einem Reaktionsgefäß, das von dem bzw. den Reaktionsgasen durchströmt wird, und in dem die Substrate derart angeordnet sind, daß eine Hauptoberfläche in etwa parallel zur Strömungsrichtung ist.

Der erfindungsgemäße Reaktor zeichnet sich durch die Kombination folgender Merkmale aus:

- das Reaktionsgefäß (1) besteht in an sich bekannter Weise aus Quarzglas und weist wenigstens in dem Bereich, in dem die Reaktionsgase strömen, einen rechteckigen Querschnitt auf,
- am Gas-eintrittsseitigen Ende des Reaktionsgefäßes ist ein Flanschelement (3) vorgesehen,
- ein Schutzrohr (2) umgibt das Reaktionsgefäß,
- das Schutzrohr weist einen stirnseitigen Reaktionsgaseinlaß (5), der mit einem Flanschelement (4) verbunden ist, an das das Flanschelement (3) des Reaktionsgefäßes anflanschbar ist, und in der Mantelfläche einen Schutzgaseinlaß (6), der das Spülen des Raumes zwischen Reaktionsge-

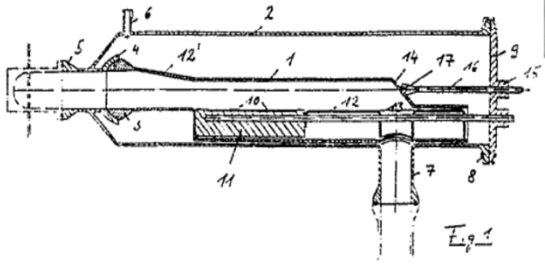
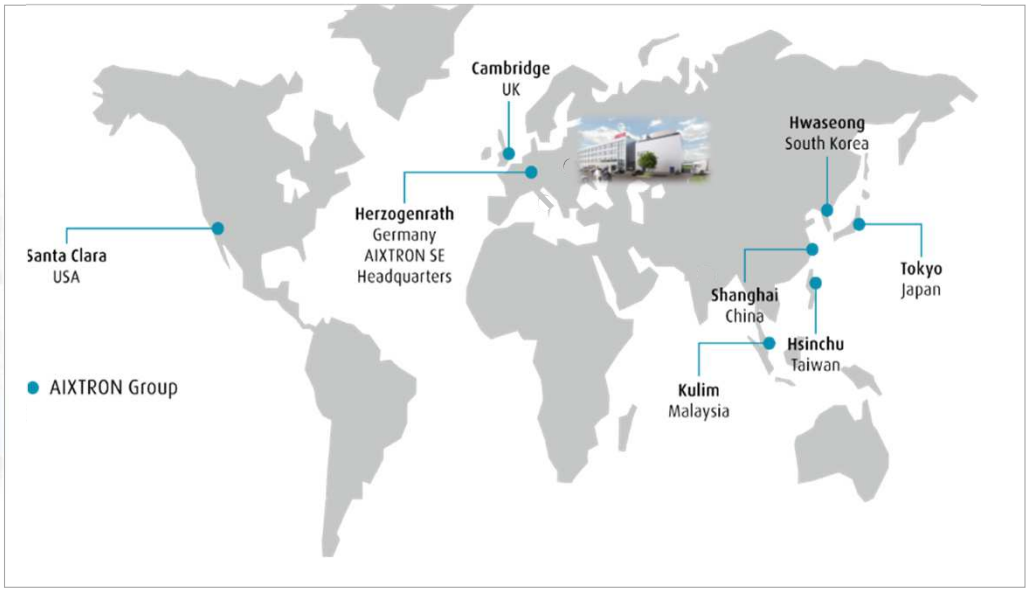


Fig. 1

AEG Ulm	1101
WF	1102
SEL in Stuttgart	1103
Philips in Eindhoven	1104
Universität Duisburg	1105
Fraunhofer IAF Freiburg	1106
TU Berlin	1107

We are leading MOCVD Innovation for 40 Years



- **Founded 1983** next to Aachen University – evolved to be the Global Market and Technology Leader for MOCVD
- We are a **Pure Play** MOCVD Equipment Manufacturer
- **Strong Collaboration Partner -** designing Solutions together with Partners to enable most demanding Compound Semiconductor materials

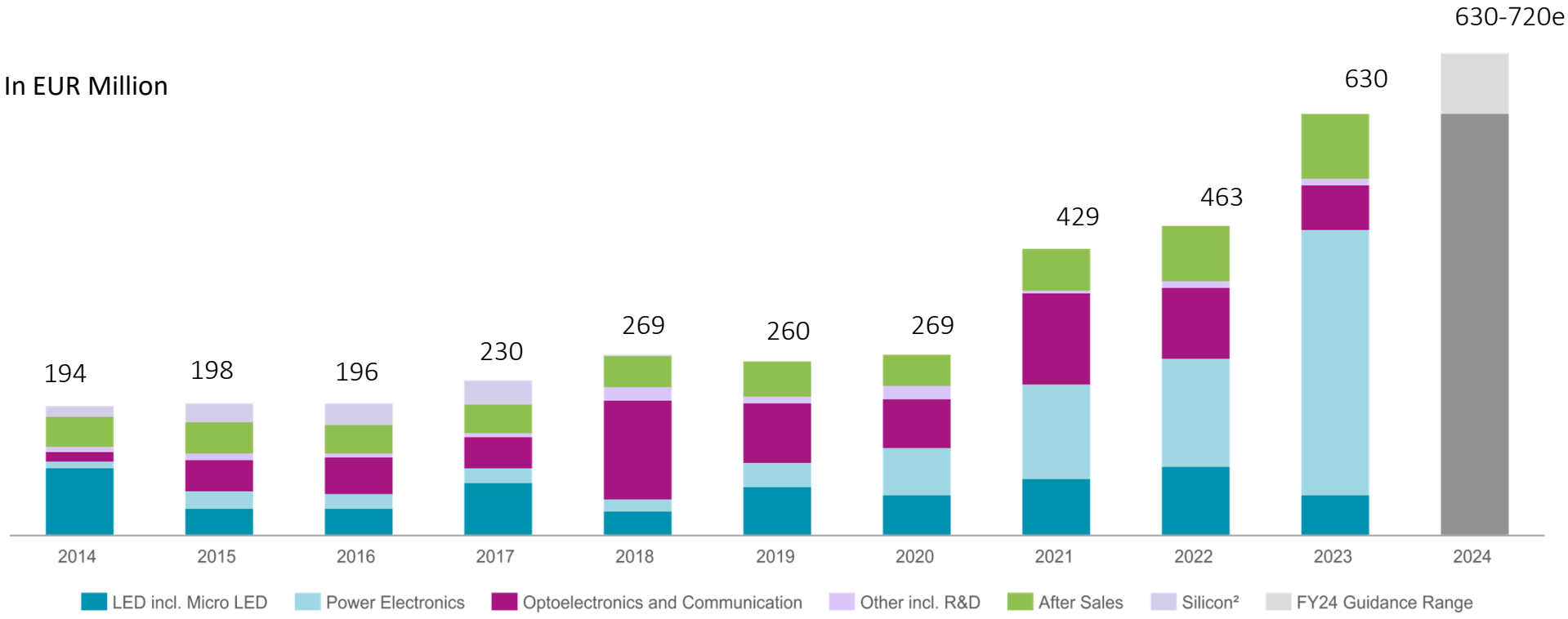
NEW: Kick-off new AIXTRON Innovation Center - Move-in 2024

We are building the largest Innovation Center for Compounds Semiconductor MOCVD

for its 40th Anniversary AIXTRON is investing ~ EUR 100 Million into Future:

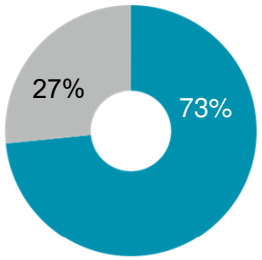
- 1.000 m^2 Clean Room, Class ISO 6 , expandable to ISO 4 , + Facilities – full Si-Style Fab Layout
- Move-in starting from H2 2024, official Handover scheduled for early 2025

Annual Total Revenues by Application (including After Sales)



1 includes Applications in Consumer Optoelectronics, Solar and Telecom/Datacom
2 Silicon: ALD/CVD Product Line sold in 2017

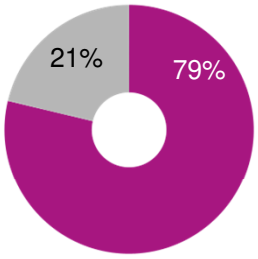
EU Taxonomy Alignment and ESG Ratings



FY/2023: Revenues[1]

Taxonomy Aligned

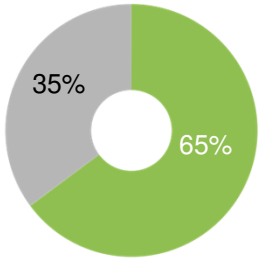
Taxonomy Non-Aligned



FY/2023: CapEx[1]

Taxonomy Aligned

Taxonomy Non-Aligned



FY/2023: OpEx[1]

Taxonomy Aligned

Taxonomy Non-Aligned

[1] In line with EU Taxonomy Regulation

EU Taxonomy Aligned Technologies

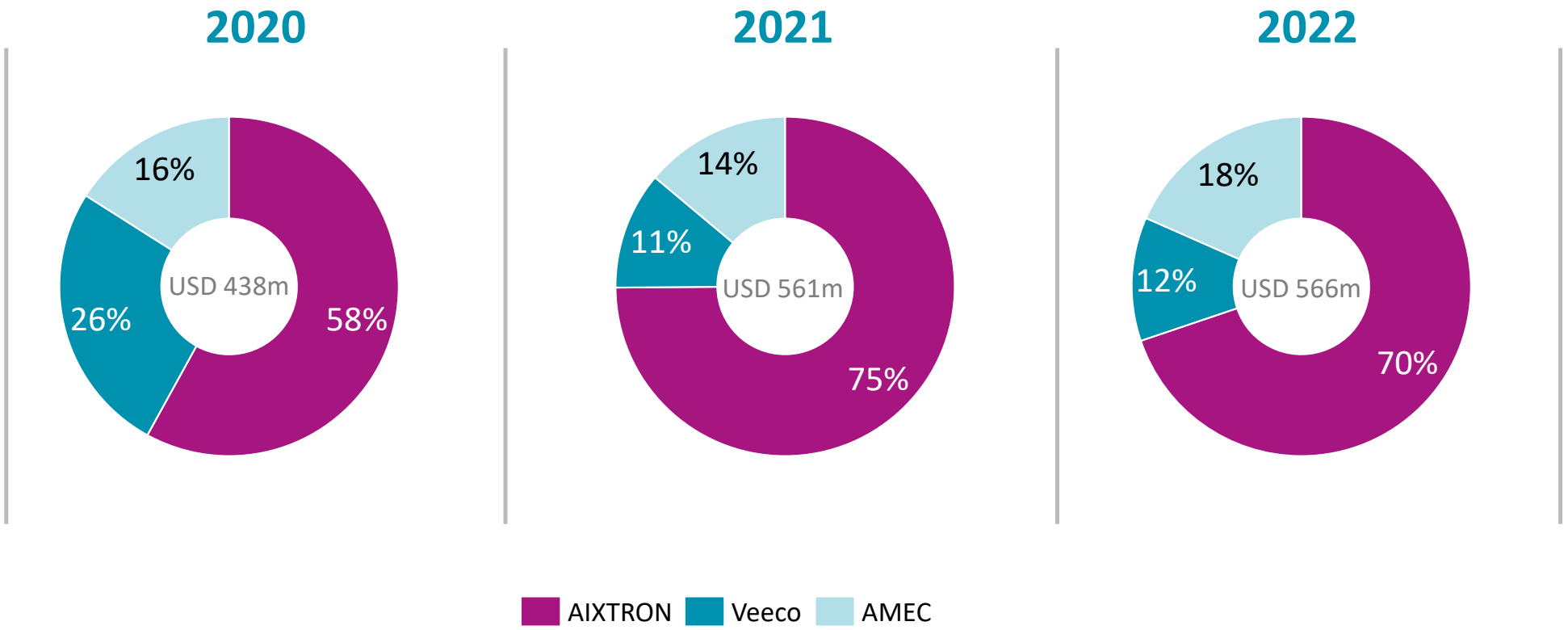
- **Wide Band Gap (WBG) Power Semiconductors** based on:
  - **Gallium Nitride (GaN) and**
  - **Silicon Carbide (SiC)**

  Key Technologies for energy-efficient Power Electronics
- **Micro LEDs:**
  For the next Generation of Displays
- **Laser Diodes for Data Communication:**
  Key Technology for the Digitalization of our World
- **Photovoltaics based on Compound Semiconductors:**
  for High-Tech-Applications (e.g.,Space Applications)
- **Quantum Technologies:**
  for neuromorphic Computing and quantum Sensing

ESG-Ratings

- **CDP (Europe):**
  - 2023: D (B)
  - 2022: C (B)
- **MSCI:**
  - 2023: AA
  - 2022: AA
- **Sustainalytics:**
  - 2023: 19.6 - Low Risk
  - 2022: 19.2 - Low Risk
- **ISS Oekom:**
  - 2023: C-
  - 2022: C-

AIXTRON is the Market Leader for MOCVD - large Investment needed to keep Technology Leadership



Source: Gartner

The Solution – Multi-Wafer Production MOCVD Reactor

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United States Patent [19]

Frijlink

[54] **EPITAXIAL GROWTH REACTOR PROVIDED WITH A PLANETARY SUPPORT**

[75] Inventor: **Peter M. Frijlink**, Crosne, France

[73] Assignee: **U.S. Philips Corporation**, New York, N.Y.

[21] Appl. No.: **323,468**

[22] Filed: **Mar. 14, 1989**

[30] **Foreign Application Priority Data**

Mar. 22, 1988 [FR] France 88 03688

[51] **Int. Cl.**[5] **C23C 16/00**

[52] **U.S. Cl.** **118/730**; 118/715; 118/725; 156/611

[58] **Field of Search** 118/715, 719, 725, 730; 156/610, 611, 614; 427/255.5

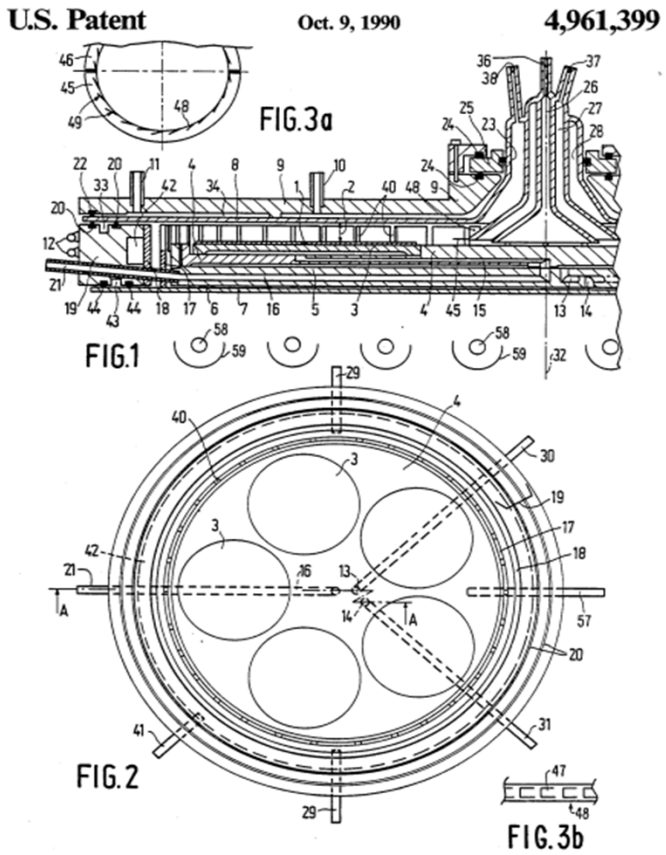
[56] **References Cited**

U.S. PATENT DOCUMENTS

4,047,496	9/1977	McNeilly et al.	118/730

FOREIGN PATENT DOCUMENTS

56-49518	5/1981	Japan	118/730
60-74509	4/1985	Japan	118/715
61-86498	5/1986	Japan	118/730



first Ideas presented at ICMOVPE IV in Hakone Japan, 1988

1988 - The Founders Dr. Meino Heyen und Dr. Holger Jürgensen

AIXTRON

Dr. Meino Heyen und Dr. Holger Jürgensen

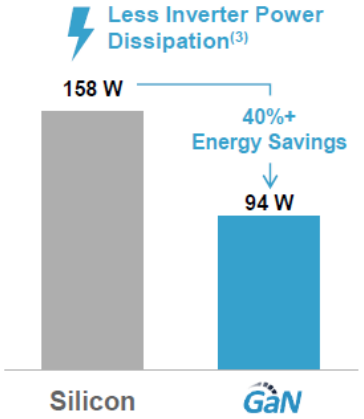
Dr. Heyen, Prof. Heime, Dr. Heuken

Hakone/Japan ICMOVPE

Important Milestones after 1995

- 1995 Start R&D on Wide Gap Semiconductor, e.g. Gallium Nitride
- 1996 first SiC System sold to Westinghaus (8x4 Inch)
- 1997 going public at Frankfurt Stock Exchange
- 1999 Thomas Swan, TSSEL (Thomas Swan Semiconductor Limited)
- Akquisition of Epigress as Experts for Silicon Carbide
- Akquisition of Genus in Sunnyvale CA, Oxide Materials
- 2000 Start working on organic Materials and Gallium Nitride on Silicon
- 2000 Move to Kaiserstrasse, Herzogenrath
- 2009 Extension of R&D Capacity in Dornkaulstrasse, Herzogenrath
- 2016 no Take-over by Chinese Investor, USA refused
- 2023 Increase R&D Capacity in Dornkaulstrasse, Herzogenrath

GaN Switches used in Applications seeking high Energy Efficiency in low/mid Power



GaN reduces switching losses by up to 40%

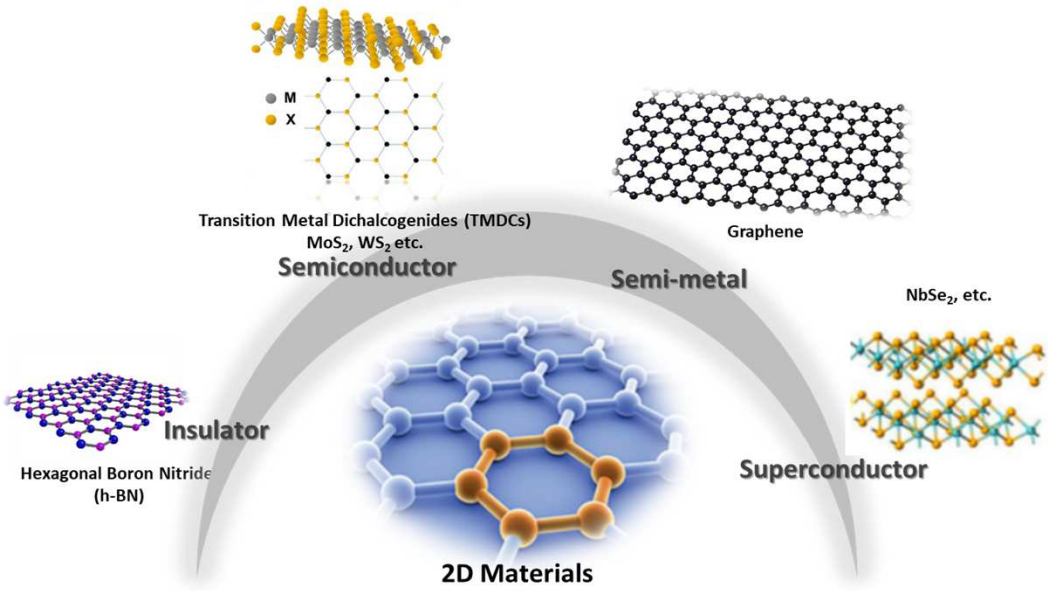
Data Center

Solar Inverter (Residential Scale)

EV Fast Charger

Source: Navitas IPO Presentation, 2021

Miniaturization is reaching physical Limit – a new Class of Materials needed for tomorrow's Performance Chips: 2D Materials



Structures become too small – parasitic Quantum Effect limits Developments

2D Materials ultra-thin Layers (1-3 Atoms thick) that have the smallest possible Length Scale for Electronics → desired Candidates to replace Silicon in current Transistors Channel

We have just launched the G10 Series – the most productive MOCVD Solutions to date for most advanced Material

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G10-SiC

- 9x150 mm (6“) or 6x20 0mm (8“)
- New Hardware und Process surpassing Single Wafer Reactor Uniformities
- +50% Productivity per Fab Area with large Batch Technology & small Footprint
- **End Markets/Products:** EV Inverters and Charging Infrastructure

G10-GaN

- 8x150 mm (6“) or 5x200 mm (8“)
- 1st fully automated compact GaN MOCVD Cluster designed 100% for Si Power Fabs
- novel Hardware Solution for unmatched Barrier Uniformities and Device Yields
- **End Markets/Products:** Power Electronics and wireless Communication

G10-AsP

- 8x150 mm (6“) or 5x200 mm (8“)
- 1st fully automated AsP MOCVD System enabling 10x lower Defect Density
- unmatched Wavelength Uniformity on all Wafer Sizes
- **End Markets/Products:** Micro LED, optical Data Communication, 3D-Sensing and LiDAR

Summary

- MOVPE has become a mature and versatile Volume Production Method.
- Multi-Wafer Planetary Reactors® combine Economies of Scale with uncompromised Growth Performance and Process Control.
- Novel Applications and Productivity Improvement demand tighter Specifications and enhanced Process Control.
- Emerging Applications with large Potential predicted in the Field of Power Conversion, High Frequency Microelectronics, 3D Sensing and Display Technology.

We see a bright Future and more Fun to come……

11x2“ Year 2000

AIXTRON

Our technology. Your future.

AIXTRON SE
Dornkaulstr. 2
52134 Herzogenrath, Germany

Phone +49 (2407) 9030-0
Fax +49 (2407) 9030-40
E-Mai info@aixtron.com

Prof Dr.-Ing. Michael Heuken