SAMPLE

Hybrid Bonding

Patent Landscape Analysis

August 2024

KnowMade
Patent & Technology Intelligence

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TABLE OF CONTENTS

SAMPLE

INTRODUCTION 5

- Context and objectives of the report
- Scope of the report
- Reading guide
- Excel database

EXECUTIVE SUMMARY 11

EXCEL DATABASE

Excel file that includes all patent selected for this study, along with the complete data by assignee from the statistical analyses.

PATENT LANDSCAPE OVERVIEW 20

Main trends and IP players 21

- Time evolution of patent publications
- Main patent assignees
- Timeline of IP players
- Typology of main IP players
- IP newcomers
- Current legal status of main players' patents
- IP leadership of patent assignees and evolution from 2019
- Geographical coverage of main players' patents

Main IP collaborations 34

- Co-owned IP
- IP transfers
- Licensing agreements

Patent segmentation 38

- Segments definition
- Type of claimed invention:
  - Hybrid bonding manufacturing process and interface engineering
  - Apparatus/Equipment for hybrid bonding
  - Semiconductor structure or device made using hybrid bonding interconnects
- Targeted applications
  - Image sensor (SPADs, CMOS image sensors, light sensing devices, etc.)
  - 2.5D/3D IC (assembly of any type of IC dies, excluding memory-on-memory)
  - 3D-stacked memory (memory-on-memory)
  - Other applications (RF, MEMS, Photonics, LEDs, etc.)
- Time evolution of patent publication by segment
- Main patent assignees by segment
- IP leadership of patent assignees for each segment

KEY PATENTS 48

- Most important patents in terms of prior-art, IP risks and technology
- Segments to which key patents belong
- Owners of key patents

IP PROFILE OF A SELECTION OF PATENT ASSIGNEES 52

TSMC, Adeia/Xperi, TongFu, ASE

For each player:

- Patent portfolio overview (IP dynamics, segments, legal status, geographic coverage, etc.)
- Description of key patents
- Description of recent patent applications

PATENT LITIGATION 67

ANNEX 70

- Methodology for patent search, selection and analysis
- Methodology to identify key patents
- Terminology

KNOWMADE PRESENTATION 76

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THE AUTHORS

SAMPLE

Dr. Pauline Calka

Pauline works for KnowMade as a patent analyst in the fields of semiconductor manufacturing and advanced packaging. She holds a PhD in Memory from the University of Grenoble Alpes (France), in partnership with the CEA-Leti (France). After an Alexander von Humboldt Postdoc fellowship position at the Technical University of Berlin (Germany) and the Leibniz Institute for High Performance Microelectronics on ReRAM development, Pauline worked five years at ASM International (Belgium) as Senior Process Engineer on thin film development for logic, memory and MEMS, and two years at CEA-Leti as Integration Engineer on imaging CMOS sensors.

Contact: pauline.calka@knowmade.fr

Dr. Nicolas Baron

Nicolas is CEO and co-founder of Knowmade. He manages the development and strategic orientations of the company and personally leads the Semiconductor department. He holds a PhD in Physics from the University of Nice Sophia-Antipolis, and a Master of Intellectual Property Strategies and Innovation from the European Institute for Enterprise and Intellectual Property (IEEPI Strasbourg), France.

Contact: nicolas.baron@knowmade.fr

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INTRODUCTION

Context and objectives of the report (1/2)

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The rapid growth of data-intensive applications, fueled by artificial intelligence (AI), Internet of Things (IoT), and 5G communications, is significantly impacting the semiconductor industry. This trend is accelerating the demand for computing capacity beyond the capabilities of current chip technologies. Nearly every sector of the global digital economy is expected to see a substantial increase in demand for high-performance semiconductor devices. However, even at the most sophisticated node, it is becoming more and more difficult to produce processor on a monolithic chip while the demand for computing performance rises. In this context, advanced semiconductor packaging offers several advantages that contribute to the performance, efficiency, and functionality of electronic devices and appears as a critical enabler of next generation semiconductor chips.

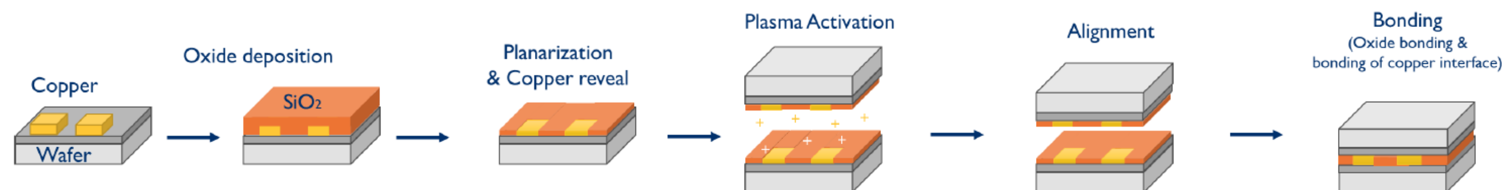
There is a growing interest in the industry to use hybrid bonding technology for manufacturing the logic and memory modules needed for high performance computing

Hybrid bonding combines dielectric-to-dielectric and metal-to-metal bonds to interconnect wafer-to-wafer, die-to-wafer, or die-to-die without the need for solder or other adhesives. A first step toward a new way of 3D stacking was **ZiBond®** developed by **Ziptronix** (founded in 2000 as a spin-out of Research Triangle Institute - RTI), an enhanced version of direct oxide bond that involves wafer-to-wafer processing at low temperatures (150-300degC) to initiate high bond strength rivaling silicon. The next vision was to combine the dielectric bond with embedded metal to simultaneously bond wafers (or die-to-wafer) and form the interconnects. **ZiBond®** is the dielectric bond that forms the basis for **direct bonding interconnects (DBI®)** technology developed in 2005. **Tessera** (now **Adeia/Xperi**) acquired **Ziptronix** in 2015 and **ZiBond®** and **DBI®** were integrated in **Invensas**' portfolio.

Hybrid bonding technology is enabling finer pitch (<10µm, or even <1µm) with significant benefits for interconnect density and device performance. The direct metal-to-metal contact facilitates efficient heat dissipation and reduces the parasitic delay. The dielectric insulates each metal pad so that there is no signal interference between the pads. Moreover, **hybrid bonding** enables the stacking of multiple dies in 3D IC architectures, offering greater design flexibility and enabling the integration of different functions (e.g., logic, memory, analog, sensors) within a single package. **Hybrid bonding** is used for the vertical stacking of chips, enabling seamless integration and interoperability of different types of chips (3D heterogeneous integration). **Adeia/Xperi**'s **DBI®** technology entered the market in 2016 through Sony's CMOS image sensor (CIS) in Samsung's Galaxy S7 mobile phone. Following its entry into the image sensor market, **hybrid bonding** technology began to be explored in various semiconductor applications, including memory, logic, RF, and photonics.

Bumpless direct metal-metal/dielectric-dielectric hybrid bonding

(e.g., Adeia/Xperi's DBI, TSMC's SoIC, Intel's Foveros Direct, YMTC's Xtacking, etc.)



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INTRODUCTION

Context and objectives of the report (2/2)

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The patenting activity related to hybrid bonding has been blooming

In 2019, **Knowmade** released its first Hybrid Bonding Patent Landscape report and has been monitoring the IP evolution since then. The patent landscape was led by **TSMC** and **Xperi** (now Adeia). **TSMC** led the IP landscape due to its high number of patented inventions that claim both the hybrid bonding process itself and devices made using hybrid bonding. Meanwhile, **Xperi**'s IP portfolio was highly blocking thanks to key generic patents on critical hybrid bonding process steps that are difficult to bypass. **Adeia/Xperi** has been pioneering and remains at the forefront of enhancing hybrid bonding technology. The company has adopted an aggressive strategy to assert its patents and license its hybrid bonding IP portfolio to various semiconductor markets, including image sensors, memory, logic, and RF. Despite **Adeia/Xperi**'s historically strong IP position, other players like **TSMC**, **Intel**, **YMTC**, and **Samsung** have been developing their own patent portfolios related to hybrid bonding processes or die stacking using hybrid bonding technology. **The number of hybrid bonding related patents has increased more than fourfold since 2019, while new entrants have joined the IP landscape.**

Understanding the IP landscape has become key to evaluate the risks and opportunities that go with the development and the use of hybrid bonding

In this context, the new **Hybrid Bonding Patent Landscape report 2024** aims to clarify the current positions of IP players and the market applications targeted by patent applicants. By extracting data from the patent database, the report aims to answer the following questions:

- Who are the key patent owners, the most active patent applicants and the new entrants?
- What are the applications targeted in patents?
- What type of inventions are protected (method, devices, equipment) and who own the key patents?
- How is the patent portfolio strength of the main IP players? Any evolution since 2019 Knowmade report?

More in details, this patent landscape report provides an overview of **hybrid bonding technology**:

- To present global **IP trends** (time evolution of patent filings, geographical evolution of patent filings, etc.).
- To highlight the **main IP players** and **newcomers** and analyze the **global IP competition**.
- To evaluate the current state of players' **patenting activity** and determine their **IP strategies**.
- To identify **key patents** and targeted **applications**.
- To reveal **IP collaborations** (co-owned patents, patent transfers, IP licences).

In addition, the report includes the **IP profile of most relevant IP players**: **Adeia/Xperi**, **TSMC**, **TongFu Microelectronics**, and **ASE**. Each player's patent portfolio related to hybrid bonding is analyzed to provide an overview of its strengths, potential for reinforcement, level of IP activity, main IP collaborations, recent patenting activity, and inventions that stand out.

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INTRODUCTION
Scope of the report

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We have selected and analyzed more than **5,800 patents and patent applications** published worldwide up to January 2024, representing more than **1,600 patent families** (inventions) relevant to the scope of this report.

The patent search strategy has been implemented using advanced search equations in the patent database and by a cautious patent selection performed by the analyst to get the most out of the corpus.

More details are available in METHODOLOGY part.

Inventions related to **hybrid bonding** have been selected as follows:

	Included	Excluded
Patents related to hybrid bonding process or interface engineering	X	
Patent related to apparatus/equipment for hybrid bonding technology	X	
Patents related to semiconductor structures or devices made using hybrid bonding interconnects	X	
Patents describing specific example or embodiment where hybrid bonding is used	X	
Patents related to dielectric-to-dielectric bonding (e.g., ZiBond)		X
Patents related to metal-to-metal direct bonding		X
Patents related to any bonding process using solder balls or other adhesives		X

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INTRODUCTION

Reading guide: find the right information in the report

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Report sections

Your concern →

Information you get

Report sections	TECHNOLOGY *For R&D teams, engineers, scientists*	IP *For IP teams, patent attorneys*	MARKET *For executives, business developers*	PLAYER *Zoom in a competitor / partner*
PATENT LANDSCAPE OVERVIEW • **Ranking of players** (enforceability, current activity, geo/tech coverage, prior-art contribution, etc.) • **Patent filings dynamics per player** • **IP collaborations** (co-filings, IPR transfers) • **Patent litigation/oppositions**	Innovators	Main patent owners IP risks/opportunities	Ecosystem (competitors, newcomers, partners, clients) Main trends IP vs Market	IP position vs Market position Player relationships (collaborations/ dependencies)
SEGMENTS ANALYSIS • **Patent filings dynamics per segment** • **IP leaders per segment** (enforceability, current activity, blocking potential) • **Key patents per segment** • **Recent patenting activity per segment**	Technology trends Technology mapping	Blocking players IP risks/opportunities in each segment (FTO, litigation, licensing)	Benchmarking Markets of interest Future developments	IP position and level of investment in each segment Key IP developments
IP PROFILE OF KEY PLAYERS • **Patent portfolio summary** (portfolio size, IP activity evolution, patents legal status, geo/tech coverage, strengths/weaknesses, etc.) • **Key patents** • **Recent patenting activity**	Current R&D activities Technology roadmap	Blocking patents Geo/Tech coverage Link between patents and products	Future products Potential partners Potential targets	R&D investment level Key inventions Current IP activities Strengths / Weaknesses

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INTRODUCTION
Excel database

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With this report, an **Excel file** is provided that includes all **1,600+ patent families** (inventions) selected and analyzed in this study, along with the **complete data by assignee** from the statistical analyses.

- In the first tab, you will find a **useful patent database** that allows for **multi-criteria searching** and includes patent publication numbers, **hyperlinks to an updated online database** (original documents, legal status, etc.), priority date, title, abstract, patent assignees, **segments** (bonding process and interface engineering, apparatus/equipment, 2.5D/3D IC, 3D-stacked memory, image sensor, etc.), and **key patents**.
- In the second tab, you will find a **comprehensive statistical data table for all the patent assignees**, including the number of patent families, timeline of patenting activity, number of granted patents and pending patent applications, and geographical coverage of patent portfolio.

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PATENT LANDSCAPE OVERVIEW

General trends, main patent assignees and new entrants

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Typology of main IP players
The value chain spreads from

Foundry/IDM | Memory maker | NPE (non-practicing entity) | OSAT

IP dynamics
A strong acceleration of patenting activity over the last 5 years

Time evolution of patent publications
5,800+ patent applications grouped in 1,600+ patent families

Early innovators
Activity takes-off
Strong acceleration

Time evolution of patent publications by company headquarters
The current patenting activity is driven by Chinese, American and Taiwanese players

All patent publications

Timeline of main IP players
Historical IP players and new entrants

Patent publication year 2015 2020 2023

Early innovators
IP players with increasing IP activity
IP newcomers

- The patenting activity is relatively recent.
- Historical IP players are the licensing firm

Main patent assignees
Ranking of patent assignees according to the number of their patent families

IP newcomers
What are their patent topics?

Main IP players and current legal status of their patents

Current legal status of patents

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PATENT LANDSCAPE OVERVIEW

IP leaders, IP strategies, IP collaborations, licensing agreement, litigations

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Geographic coverage of alive patents

IP strategy of main patent assignees

IP leadership of patent assignees

Snapshot from 2023 with evolution from 2019

Main co-owned IP

Main actors mutualizing R&D strength through collaborations

Main licensing agreements

Adeia as a key licensing firm

LITIGATION & OPPOSTION

Main IP transfers

Main actors acquiring patented technologies

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PATENT SEGMENTATION

Categorizing patents according to type of claimed invention and targeted applications

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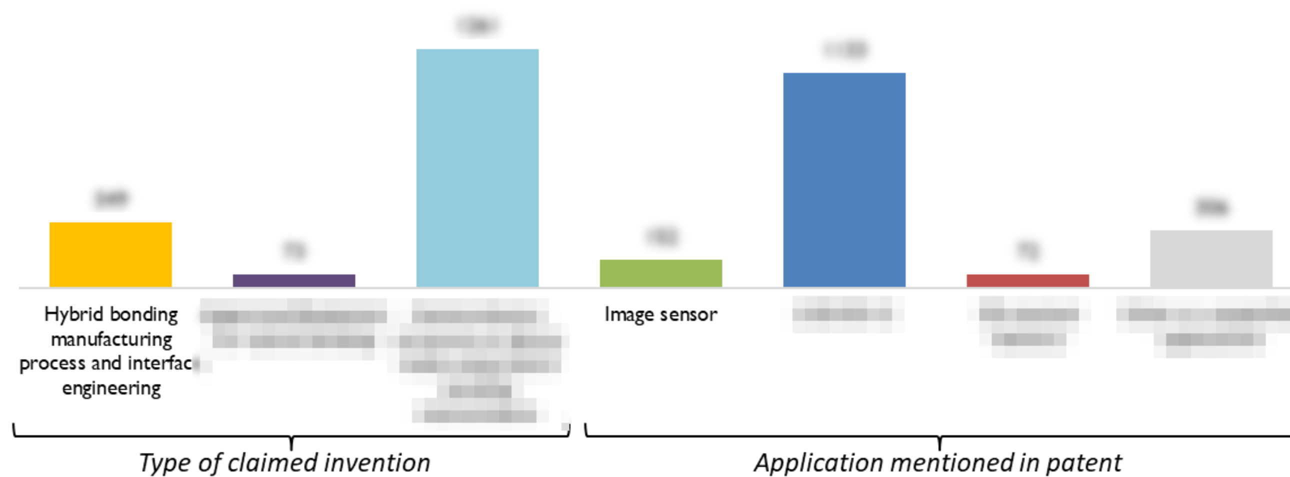
The patents have been **categorized** according to the **type of invention** they claim and the **application** they explicitly mention in the description of the invention.

Type of claimed invention:

- Hybrid bonding **manufacturing process** and **interface engineering**.
- **Apparatus/Equipment** for hybrid bonding.
- Semiconductor **structure or device** made using hybrid bonding interconnects.

Application explicitly mentioned in patents:

- **Image sensor** (SPADs, CMOS image sensors, light sensing devices, photo detectors, IR detectors, TOF sensors, etc.)
- **2.5D/3D IC** (assembly of any type of IC dies, excluding memory-on-memory)
- **3D-stacked memory** (memory-on-memory)
- **Other applications** (RF, MEMS, Photonics, LEDs, etc.) or **unspecified applications**



Note: A patent can belong to multiple segments.

The categories to which each patent belongs are available in the Excel file provided with the report

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PATENT SEGMENTATION

IP dynamics, main patent assignees, IP leaders, and key patents by segment

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Main patent assignees
Main patent assignees for hybrid bonding process and target applications

IP leadership of patent assignees

IP dynamics
Time evolution of patent publications for hybrid bonding process and target applications

3D-stacked memory

Inventions focused on hybrid bonding process and apparatus
Bonding process, interface engineering, bonding apparatus/equipment

Key patents
Which are the most important patents in terms of prior-art, IP risks and technology?

Targeted applications
Definitions

Key patents

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IP PROFILE OF PLAYERS

IP portfolio summary, IP strategy, key patents and recent patenting activity

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A focus on **a selection of IP players and newcomers** is provided in a dedicated section. For each player, the **hybrid bonding patent portfolio** is analyzed to provide an overview of its **level of IP activity**, **geographical coverage**, **strengths**, **potential for reinforcement**, and to highlight **key patents** and **recent IP activity**.

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Patent Landscape Analysis – August 2024

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KnowMade
Patent & Technology Intelligence

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KNOWMADE PURPOSE

Turning **patent information** and **scientific literature** into actionable insights, providing high value-added reports for **decision-makers** working in **R&D**, **Intellectual Property**, **Innovation Strategy**, and **Marketing**

Competitive landscape | Technology trends | Opportunities / Risks | R&D and IP strategy

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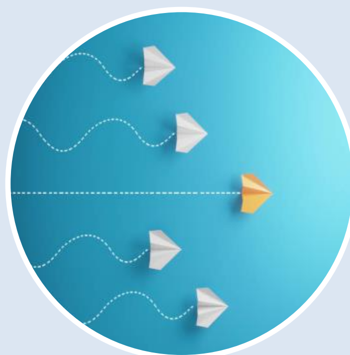
WHAT INFORMATION CAN YOU GET ?

INTELLECTUAL PROPERTY

For IP teams,
patent attorneys

- Risks and opportunities (FTO, litigations, licensing)
- Key patents
- Link between patents and products



TECHNOLOGY

For R&D teams,
engineers, scientists

- R&D activities
- Technological roadmap
- Position on the supply chain

MARKET

For executives,
business developers

- Identify competitors
- Compare IP with market position
- Evaluate the level of investment
- Future products & target markets

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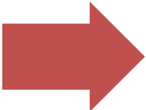
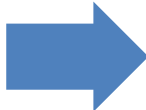
KNOWMADE ADDED VALUE

Search



- ✓ **Strong technical expertise of our analysts with PhD degree**
  - Best-in-class databases (e.g., Orbit Intelligence by Questel)
  - Comprehensive search queries and keywords
  - Manual selection of relevant and related patents/sci papers
  - Manual segmentation by technology & application

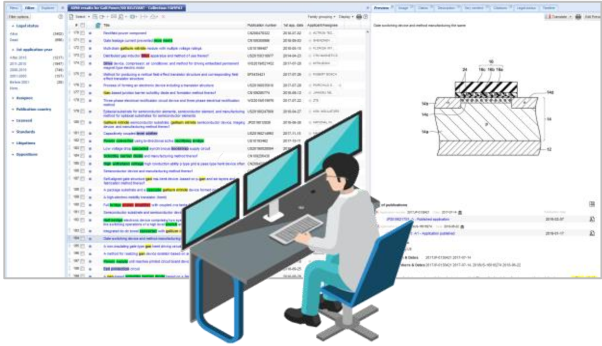
Analytics

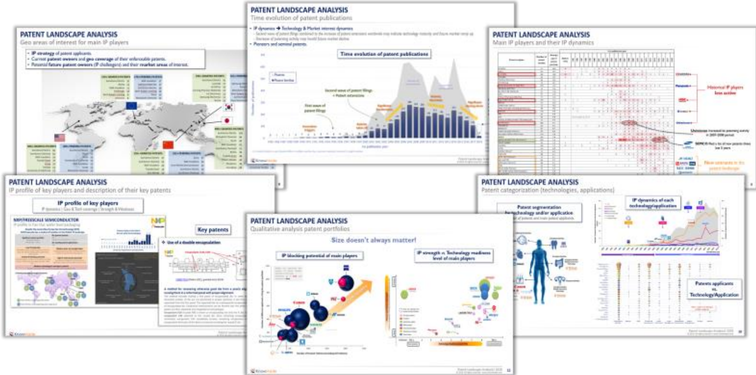


- ✓ **Statistical analysis** (main trends)
- ✓ **Qualitative analysis** (key players, key patents, key scientific findings)
- ✓ **Innovative methodologies** to deliver relevant analysis (metrics)
- ✓ **Business-oriented** data representation and graphics

Analysis

- ✓ **Technical expertise**
  - Highly specialized analysts (PhD)
  - Benefit from knowledge capitalization
- ✓ **In-depth IP analysis compared with market**
- ✓ **Capability to work with market research firms and IP law firms**





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KNOWMADE OFFER

CUSTOM SERVICES
(Tailor-made analysis)

To meet your needs and budget/lead time constraints

- Specific and dedicated report.
- Prior-art search, freedom-to-operate, patent landscape, patent valuation, technology scouting, monitoring service, etc.

Format
- PDF file with analyses.
- Excel file with data.
- Access to the analyst.

REPORTS
(multi-client product)

To understand the competitive landscape and explore the emerging ecosystems and new technologies

- Stand alone report
- Patent landscape.
- Overview on IP dynamics, trends and players.
- Competitor, technology and strategy analysis.
- Benchmark of patent portfolios.
- Key IP players & key patents.

Format
- PDF file with analyses.
- Excel file with patent data.

MONITORS
(multi-client product)

To track the latest R&D developments and IP activities, and to be sensitive to weak signals

- Annual subscription
- Patent monitoring service.
- Quarterly updated patent data and technology trends.
- Current R&D and IP activities.
- Early detect weak signals, opportunities and risks.
- Open discussion with analyst.

Format
- PDF file with analyses.
- Excel file with patent data.
- Direct access to the analyst.

INSIGHTS
(free article & webinar)

To get unique information about industry and technology

- Analyst point of view about industry news (product release, M&A, start-up, fund-raising, etc.) from a patent perspective.

Format
- Knowmade website

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MAIN FIELDS OF EXPERTISE

SEMICONDUCTORS

- Materials & Substrates
- Power electronics
- RF & Wireless datacom
- MEMS, Sensing & Imaging
- Photonics, Lighting & Display
- Memory
- Packaging

HEALTHCARE

- New therapeutic tools
- Medical diagnostics
- Medical devices and imaging
- Drug discovery and delivery

ENERGY

- Batteries
- Fuel-cells
- Solar PV
- Power management

AGRI-FOOD

- Food processing & formulation
- Vegan food
- Next-gen packaging
- Microbiology

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SEMICONDUCTORS

Expertise

Power electronics

- Wide bandgap semiconductors
- Power devices and IC
- Power modules
- Power applications

RF & Wireless communications

- RF substrate & epiwafers
- RF devices (SAW, BAW, PA/LNA, etc.), RFIC, MMIC
- RF front-end module, RF packaging
- MIMO, beamforming, carrier aggregation
- 5G & 6G networks, Radar, mm-waves, microwaves, THz

MEMS, Sensing & Imaging

- MEMS sensors and actuators
- 3D imaging and sensing (ToF, CIS, thermal imaging, LiDAR, imaging Radar, event-based camera, etc.)
- AI/ML, sensor data fusion

SEMICONDUCTORS
from materials and devices to circuits, packaging and modules/systems

Memory

- SRAM, DRAM, flash
- 3D-stacked memories
- Emerging non-volatile memories (MRAM, PCM, RRAM, etc.)
- Embedded NVM

Photonics, Lighting & Display

- Optoelectronics & optical components (LED, OLED, laser, optical transceivers, waveguides, metasurfaces, etc.)
- Photonic crystal, photonic IC, silicon photonics
- Optical communications, AR/VR, quantum

Advanced packaging

- Fan-Out WLP/PLP, 2.5D/3D IC
- SiP, SoC, Chiplets
- TSV, µbumps, interposer, interconnect bridge, hybrid bonding

Materials & Substrates

- Compound semiconductors
- Engineered substrates
- Epiwafers

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KnowMade SARL
2405 route des Dolines
06560 Sophia Antipolis, France

www.knowmade.com
contact@knowmade.fr