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Imec: A World-Leading Cooperative Research Center for Microelectronics

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Introduction

International competition for the most advanced semiconductors has highlighted the importance of cooperative research institutes. These centers, while diverse in their memberships and specialties, serve a critical role as aggregators of research and development (R&D) resources across firms—as well as shared infrastructure for de-risking emerging technologies throughout the semiconductor value chain and for driving the chip industry's uniquely rapid pace of innovation.

Located in the Flanders region of Belgium, imec is perhaps the foremost cooperative research organization for semiconductors, a status bolstered by the participation and support of the world's top semiconductor firms in its programs, with the exception of major Chinese entities.

Imec has pushed the concept of multinational, diverse research collaboration to achieve ambitious objectives. To this end, it works closely with other leading semiconductor research centers such as the Albany NanoTech Complex, the Alternative Energies and Atomic Energy Commission (CEA)'s Leti lab in France, and now Japan's Leading-Edge Semiconductor Technology Center.

This research institute's substantial physical assets, talented staff, reputation for neutrality, strong track record, and proven protocols make it ideally situated to advance leadership in semiconductor technology among like-minded countries. In fact, to a considerable degree, it is already performing this role. As such, the United States should collaborate closely with this research center in its efforts to regain technological leadership in chip manufacturing.

Imec holds major lessons for the development of the U.S. National Semiconductor Technology Center and its nonprofit purpose-built operator, Natcast. Imec' s ability to attract and retain leading companies to cooperatively develop cutting-edge semiconductor technologies in a fiercely competitive and unforgiving industry represents an outstanding model for international cooperative research. The following analysis highlights the unique strengths and approach of this research institute in Leuven, Belgium.

Imec's ability to attract and retain leading companies to cooperatively develop cutting-edge semiconductor technologies in a fiercely competitive and unforgiving industry represents an outstanding model for international cooperative research.

Imec's Origins

In 1982, the regional government of Flanders launched an "intense mobilisation of industrial and scientific actors for a 'Third Industrial Revolution'" in the area.[1] The most important expression of this effort was the government's establishment of the Interuniversity Micro-Electronics Center (imec) in Leuven in January 1984. Its mission was to promote microelectronics in Flanders through R&D projects with companies and universities that anticipated industry needs by 3-10 years.[2] Research themes eventually came to include microelectronics, nanotechnology, information and communications technology, semiconductor packaging, photovoltaics, and chip-design methods.

Imec was founded by Roger Van Overstraeten, a Flanders-born Stanford PhD graduate who returned to Belgium to pursue future-generation semiconductor technology with a group of colleagues at Catholic University Leuven (KU Leuven). His vision was to establish "an unparalleled research facility dedicated to microchip technology," which he pursued despite considerable skepticism at the time.[3] There was widespread recognition in government circles that while Flanders often excelled in research, its ability to support its practical applications was often lacking. Focusing on this challenge, Van Overstraeten sought to "drag European microelectronics excellence out of the laboratories and into the factories."[4]

When imec was established, policymakers intended for it to focus entirely on support for the Flanders region in collaboration with regional universities and companies. Given the lack of critical mass in the microelectronics space within the region, this initial concept was not feasible.

Fortunately, imec's leadership pivoted to a more international approach, establishing the organization as a neutral research center supporting companies and universities worldwide.[5]

Business Model

Most major microelectronics R&D centers around the world are located in jurisdictions that have one or more large semiconductor companies and where, for political and economic reasons, the centers tend to support those local producers, whether directly or indirectly. Belgium has no large chip firms—but in building a global network of industry partners, this has worked to imec's unique advantage. The center's current CEO, Luc Van den hove, explained in 2024 that because no one semiconductor company dominates imec's strategy, the organization has been able to build a "Switzerland of semiconductors" reputation.[6]

The center's broad membership includes companies that often compete with each other but are confident that their intellectual property (IP) will be respected. They recognize the value added from cooperation on common problems and the advantages of sharing the costs of cutting-edge facilities and equipment.[7]

The goal of neutrality has been reflected in practice. For example, in 2008, imec declared that it would not take part in any R&D projects organized under the auspices of the European Union's Eureka initiative, claiming such programs often serve as "a form of support for national champions" and are thus inconsistent with imec's practice of strictly neutral international collaboration.[8] In subsequent years, imec did participate in Eureka programs but to a limited degree.[9]

Partnerships with Industry: The Central Focus

The principal focus of imec's operations is joint R&D projects with industry partners to develop precompetitive technologies for applications in future generations of semiconductor products and processes. According to a science and technology counselor for the Flemish government, "This joint collaboration model accelerates innovation, by pooling resources and alleviating the ever-increasing development costs of new technologies."[10]

Reflecting its central position in advanced semiconductor manufacturing research, as of 2021 imec has over 600 industry partners who contribute their own resources to joint projects, including their knowledge base, experts, funding, and materials. They may share precompetitive intellectual property or use imec's fabrication services for their own proprietary research, including prototyping and low-volume manufacturing. Industry partners can sign up for individual imec projects and programs without committing to others—in contrast to the former U.S. chip research consortium Sematech, which required an all-or-nothing commitment from member companies.[11] Companies can also collaborate with imec bilaterally for private research, development, or services while securing their IP. For example, imec helped ASML fabricate high-quality sensor chips for their EUV lithography systems.[12]

Industry partners can also collaborate with imec to develop new research units and facilities within the consortium. In 2000, for example, imec and Philips Research (the R&D arm of Dutch chip and electronics firm Royal Philips Electronics) jointly created a permanent department within imec, with Philips signing onto all of imec's process-oriented industrial programs and gaining the ability to use the center's chip fabrication line for its own research on process technologies.[13] In 2003, Samsung, Intel, Infineon, Philips, and STMicroelectronics enabled imec to set up an R&D fab for 300-millimeter (mm) chips by joining imec as core partners in its sub-45-nanometer (nm) complementary metal-oxide-semiconductor (CMOS) program.[14] And in 2010, imec and Intel entered into an agreement to establish a new lab dedicated to exascale-class supercomputers, including the development of tools and applications.[15]

Imec's chip research strategy has two elements. The first, "More Moore," seeks to sustain the developmental path of established silicon-based technologies through incremental improvements, usually through scaling, to maintain Moore's Law into ever-deeper extremes of miniaturization.[16] On this front, imec has created the world's largest ecosystem for CMOS technology, bringing together most of the world's major chip foundries, fabless firms, tool and materials suppliers, electronic design automation firms, and application developers.[17] CMOS is the chip technology currently used to produce most of the world's integrated circuits, offering advantages such as low power consumption, simple structure, high noise tolerance, and strong temperature stability.[18] In addition, imec's longstanding commitment to developing extreme ultraviolet (EUV) lithography with Dutch chip toolmaker ASML has been instrumental in the industry's ability to scale beyond the 14 nm node level (as discussed further below).

Meanwhile, "More Than Moore" pursues innovation that could lead to the emergence of new micro- and nanoelectronics technologies and markets. Imec's long-term assumption is that this branch of its research effort will eventually eclipse More Moore. Pursuant to More Than Moore, the center has explored specialties such as organic electronics, hybrid semiconductors, organic photovoltaics, and biomedical electronics. These projects often involve collaboration with imec's Dutch affiliate, the Holst Center, which it cofounded in 2006.[19]

Within the constellation of imec industry partners, a handful of companies are "core partners." The center's management may identify research programs of interest, then reach out to interested firms from their pool of core partners and provide them the shared facilities to conduct collaborative research.[20] In 2003, imec recruited several major chipmakers to pursue process technology for 45 nm and smaller semiconductors—then the next generation of semiconductor technology.[21] Core partner status meant that the firms involved could participate in all seven of the 45 nm programs that comprised imec's platform at the time and would receive "certain advantages over companies that remain outside the core," according to then-CEO Gilbert Declerck.[22]

Substantial and Sustained Public Support

The imec research center was founded in 1984 with an initial investment of around $72 million by the government of Flanders.[23] Although the regional government continued to make the annual contributions crucial for a sustainable research program, it set a target from the outset for imec to eventually receive 50 percent of its revenues from nongovernment sources, which it achieved in the mid-1990s and has exceeded in every subsequent year. In 2023, imec's annual revenue totaled 941 million euros: 75 percent came from industry partners, 16 percent from the regional government of Flanders, 6 percent from the European Union, and 3 percent from other government programs.[24] This long-term commitment by the regional government to support and grow the institution is one of the keys to imec's success.

Although Flanders is a relatively small political jurisdiction with a population of about 6.8 million, its government wields substantial power to drive internal economic development and plays a strong role in supporting imec. A 2012 Japanese study observed that the "strength of the Flemish government's authority in industrial development is equivalent to that of the Japanese federal government."[25] This regional thrust comes as Belgium has shifted from a unitary state to a federal state in phases since the 1960s, with central government powers devolving progressively onto the regional governments of Dutch-speaking Flanders, French-speaking Wallonia, and the Brussels Capital Region, each with its own executive and parliament.[26] Although the central government retains authority in areas such as foreign relations and national defense, regional authorities lead industrial development. Devolution gave the government of Flanders the autonomy to significantly increase its investments in innovation, enabling it to more than double outlays on R&D from what had been below-average levels relative to the European Union prior to devolution to far above the EU average by 1995.[27]

In a 2024 interview at CSIS, imec CEO Van den hove emphasized the importance of continued public funding despite its diminished percentage of total revenue:

> We believe that we've been able to realize a phenomenal growth over those 40 years. And this has been realized through a growing commitment from industry. But at the same time, this commitment from industry was leveraged on top of very strong and stable support from the local government. And this, we believe, is important because it allows us to invest in new programs which today are probably too early for industry to finance but allow us to make sure that we can develop a long-term strategy. . . . Our role is to kind of set the

> roadmap for the next 10-20 years. So we have to pre-invest a lot in some of these [emerging technology areas].[28]

In addition, Flanders and the European Union have also made significant one-time contributions to imec for special projects. For instance, Flanders provided imec 35.7 million euros for a new research facility that allowed it, among other things, to build a machine to clean silicon plates of minute dust particles in 2004.[29] In 2009, Flanders gave imec 35 million euros to help finance 75 million euros that it used to construct a new 2,800-square-meter (0.7-acre) cleanroom to support research on 22 nm and smaller CMOS chips and on organic solar cells and biomedical electronics.[30] In 2012, Flanders indicated it would invest in the cost of building cleanroom facilities at imec to enable the pursuit of 450 mm wafer technology, estimated at 100 million euros.[31] The project was shifted to expand the existing 300 mm facility, as the industry did not coalesce around 450 mm technology.[32]

In 2016, imec added a second 4,000 square meter 300 mm cleanroom. This new cleanroom expansion (including building and equipment) entailed a total investment of more than 1 billion euros, one-tenth of which was supplied by the Flemish government. Importantly, more than 900 million euros in investment were derived from joint R&D with more than 90 industrial partners from across the entire semiconductor industry.[33] Imec's semiconductor research cleanrooms now total more than 13,000 square meters (nearly 140,000 square feet).[34]

Most recently, it was announced in May 2024 that imec will receive 1.4 billion euros in combined funding from the European Chips Act and the Flanders government–complemented by 1.1 billion euros from industry partners–to extend its NanoIC pilot line, a leading technology platform for companies to explore new technologies before they are introduced into large-scale production. Aiming to accelerate commercialization of sub-2 nm semiconductor technologies, the NanoIC pilot line will support a broad range of industries–including automotive, telecommunications, and health–to develop products that leverage the latest chip innovations.[35] This will include a new 4,000 square meter 300 mm Fab 4, bringing total cleanroom space to 17,000 square meters (182,000 square feet).[36] These ambitious projects feed into what European Commission president Ursula von der Leyen has described as an "essential" role for imec in the context of the European Chips Act:

> The role imec plays in the European Union's ambitions will be particularly significant. . . To be less dependent on East Asia, we need to scale up our production here in Europe: imec is essential for our economic security. For investors who need to research and test their innovations before moving to mass production, it is an important place.[37]

While imec is strongly supported by Flanders, it enjoys operational autonomy. It is run by an executive board and a senior leadership team that plan and execute strategy. The center's R&D targets are set forth in 5-year business plans that are reviewed by both the government of Flanders and technical advisory boards comprised of global experts in the various thematic areas in which imec is active.[38] imec is further overseen by a board of directors, which has four members drawn from the faculty of Flemish universities, two from Flemish industry, two designated by the Ministry of Economic Affairs, and one picked by the Ministry of Education. In addition, university professors and industry researchers drawn from among core partners conduct a critical review twice a year of each research project and suggest actions the center could take.[39] The relative autonomy of the imec leadership enables it to follow the technology—and indeed lead it—without undue political constraints.

The Leuven Technology Cluster

Imec is the main hub of a local technology cluster, which reflects decades of investment by Flanders, local governments, the private sector, and imec itself. In addition to five excellent nearby research universities, Leuven hosts numerous other world-leading research entities.[40]

Applying the imec model to similar national efforts around the world has led critics to claim that subsidizing the research activities of multinational firms without a local footprint will not help the local economy. However, imec's benefits to the Flemish region have been significant and measurable over the past four decades. Young company representatives doing research at imec are likely to move up in their own companies, then consider Flanders when later making decisions about where to locate research centers or other activities. Hundreds of PhD candidates pursuing their research at imec provide a growing talent pool with ties to the region. In addition, imec subcontracts many tasks to local companies, helping to strengthen the industrial ecosystem; some of these firms have gone on to become "very fast growers."[41] An independent analysis of imec's economic benefits to the region concluded in 2020 that for each euro of Flemish government investment, imec creates 7 euros of value added to the Belgian economy and 3.7 euros of return on the subsidy through taxes. Each million euros invested in imec creates 23 jobs at imec and 67 elsewhere in the Belgian economy.[42]

Intellectual Property

Given its large pool of researchers and expertise, imec brings very substantial knowledge—some of it patented—to any research collaboration, known as "relevant background IP." Industry partners can pay a fee to join one or more of imec's Industrial Affiliation Programs, and imec will share its background IP applicable to their particular research area. Imec holds the "foreground IP" that is developed during the collaboration and licenses it out to all industry partners who participated; this becomes part of its background IP for use in future collaborations.[43]

Industrial partners can take away as little or as much of the IP generated by the joint effort as they would like, with the terms being negotiated on a case-by-case basis, usually involving costs to the industrial partner, particularly for an exclusive license. These bilateral negotiations are overseen by imec lawyers and valuation experts. Imec may seek terms such as payment of the royalties on subsequent sales if the industry partner takes the technology to market.[44]

Infrastructure

From imec's inception, companies and academic researchers have been attracted to its research partnerships because of its ability to make available the advanced equipment needed to pursue cutting-edge research. Imec benefits in this respect since partners "can provide tools, equipment and materials for free and that can be provided and tested by other partners when conducting R&D at the facility." The center also offers other forms of support, including design, prototyping, testing, and consulting services, which are particularly important for start-ups and small- to medium-sized enterprises.[45]

In an event at CSIS, imec CEO Van den hove observed that the center's success is attributable to the fact that it has invested in the infrastructure needed to achieve its objectives: "Over those 40 years, we probably built out what is. . . the world's most advanced, independent R&D pilot line. We've invested more than $5 billion in that facility. And it's really run as one integrated facility, with a very strong focus on operational excellence so that we can deliver value in a very effective way to our partners."[46]

Imec currently has 8,000 square meters (1.98 acres) of 300 mm cleanroom space and 5,200 square meters (1.28 acres) of 200 mm cleanroom space. Its class 1,000 300 mm cleanroom has all the equipment needed to pursue sub-2 nm CMOS R&D, including advanced lithography based on ASML's newest EUV equipment. It has a vast array of specialized labs pursuing silicon and organic photovoltaics, packaging and testing equipment, photonics, gallium-nitride processing, design methodology, biosensors, DNA research, imaging, and many other topics.[47]

Workforce: A Melting Pot

From about 70 employees at its inception, imec's workforce has grown to over 5,500, with roughly 10 percent holding PhDs.[48] In November 2023, imec forecast that its workforce would add nearly 2,000 new hires by 2035.[49] Research staff are drawn from university partners in Belgium and many other countries, and staff are allowed to hold dual appointments at their institutions. An important strength of the model is that it allows industry partners to assign their own employees to work on site, which brings in cutting-edge, commercially relevant perspectives and the tacit knowledge garnered through familiarity with actual production.[50]

This inclusive approach results in imec having one of the most diverse workforces of any major microelectronics center in the world. As CEO Van den hove observed, "We've been attracting people from all over the world, close to 100 nationalities, and 5,500 of the most advanced, top-notch researchers. Many of them have experience of more than twenty years either in imec or the industry."[51] One Indian-Finnish employee at imec remarked that the staff is so multinational in character that "the Flemish culture does not prevail. . . . You can never see the difference between people's national backgrounds."[52]

An important strength of the model is that it allows industry partners to assign their own employees to work on site, which brings in cutting-edge, commercially relevant perspectives and the tacit knowledge garnered through familiarity with actual production.

Imec's facilities are colocated with KU Leuven, and its CEOs have all been professors there.[53] For instance, Luc Van den hove is a member of KU Leuven's Faculty of Engineering Sciences and received his PhD in electrical engineering from the institution while conducting research at imec.[54] When the center was starting up, faculty from various Flemish universities—particularly a group of KU Leuven professors who wanted to pursue microprocessor research—served as experts to help build its knowledge base.[55] This partnership has contributed to Thompson-Reuters rating KU Leuven as Europe's most innovative university in recent years, while the university-based leadership has enabled imec to develop a global network of formal and informal relationships with other institutions of higher learning. At present, it has collaborations with over 200 universities and myriad "non-formal collaborations through a network of scientists, engineers and PhD students."[56]

Critical Bilateral Partnerships

ASML

Imec's costly, risky, but successful three-decade research partnership with the Dutch chip toolmaker ASML is an important illustration of its capabilities. This collaboration has created an ecosystem for proving, testing, and debugging newly developed ASML tools and integrating them into manufacturing lines.[57] With imec's support, ASML has produced technological breakthroughs such as the development of EUV lithography tools used to produce the chips needed to support cutting-edge applications, including artificial intelligence (AI).[58]

Prior versions of photolithography for chips utilized deep ultraviolet (DUV) light, but shorter wavelengths were needed to continue to make circuit patterns smaller and advance Moore's Law.[59] EUV uses light with a wavelength of 13.5 nm, which does not occur in nature but can be created by zapping drops of molten tin with a carbon dioxide laser until they become plasma. The light emitted by this process is collected and passed through a mask with the pattern of the circuitry on it, then the pattern is shrunk down to the size of a semiconductor die with a system of ultra-flat mirrors and projected onto a silicon wafer. This must all be done in a vacuum.[60]

Developing and refining this technology into workable lithography tools was a challenge so daunting that during the several-decade-long developmental effort, various observers declared that the process was a failure, would never work, or could not become reality in the reasonably foreseeable future.[61] Nevertheless, ASML and imec persevered in a protracted, multi-billion-euro effort, a demonstration of how big R&D risks and a long-term focus sometimes pay off in spectacular fashion.

ASML enjoys a monopoly on the manufacture of the world's most advanced lithography equipment, EUV—representing a major strategic asset for Western powers in their technological competition with China. EUV lithography enables the high-volume production of chips with advanced AI applications, underpinning advances in a vast array of other critical technology areas that have the potential to shape the outcome of future conflicts. Many in the West have underestimated Chinese capabilities in adapting and improving complex technologies such as high-speed rail, aircraft, and telecommunications. Nonetheless, given the enormous complexity of EUV lithography, China is unlikely to possess a comparable capability for many years, especially given U.S. semiconductor export controls.

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While other players made major contributions to the EUV effort—including Intel, IBM, the Taiwan Semiconductor Manufacturing Company (TSMC), and ASML's German optics partner, Carl Zeiss—imec's role was crucial. Before the first EUV-based lithography tool was available, imec conducted EUV tests at Switzerland's Paul Scherrer Institute and collaborated with six makers of photoresist. In 2006, imec received one of the first full-field EUV lithography tools, the Alpha Demo Tool—jointly created by engineers at ASML and the College of Nanotechnology, Science, and Engineering (CNSE) at the University of Albany, SUNY—so it could assess its commercial viability and identify operational challenges on pilot lines in a real factory environment. Since then, imec has worked with ASML to prove and test every subsequent generation of EUV tools.[62]

Summarizing imec's "very close partnership" with ASML, CEO Luc Van den hove has said "ASML focuses on the machine. We develop the process. We develop the ecosystem around the machine."[63] This dynamic continues today. In June 2023, imec signed a Memorandum of Understanding (MoU) with ASML to install and service its "full suite of advanced lithography and metrology equipment in the imec pilot line in Leuven," such as the new 0.55 and 0.33 numerical-aperture (NA) EUV machines.[64] The high-NA lithography EXE-series machines enable much faster wafer throughput than the previous-generation NXE systems introduced in 2010, and can be used to produce 2 nm and below semiconductors.[65] Imec has secured commitments of 750 million euros each from the European Union and the Flanders government to support this project.[66]

Taiwan Semiconductor Manufacturing Company

Over time, imec has come to engage deeply with TSMC.[67] A core partner of imec since 2005, TSMC dispatched a researcher to Leuven in 2006 to work with the prototype Alpha Demo Tool and prepare the technology for high-volume manufacturing; after its work at imec, it eventually ordered a development EUV tool from ASML for delivery in 2013, concluding that the technology could be refined and used successfully.[68] TSMC subsequently deployed its EUV machines in high-volume manufacturing in 2019 for use in its N7+ process.[69]

In the meantime, the imec-TSMC relationship became more symbiotic. One 2010 partnership between them was designed to resolve a chicken-and-egg conundrum facing the Taiwanese foundry. TSMC could not safely develop manufacturing processes for certain application-specific technologies until it was sure that volume demand would exist, but volume demand would not emerge until the process existed. To break the impasse, imec promised to pass on certain new technologies to TSMC, which would ramp up their production once imec had demonstrated their viability.[70]

Rapidus

Reflecting its international approach, in late 2022 imec entered into a collaboration with Rapidus, a collective of eight Japanese companies that aims to restore an internationally competitive chip industry in Japan.[71] In 2023, the conglomerate became one of imec's core partners, gaining access to its "advanced technologies, system solutions, state-of-the-art 300 mm pilot line, and extensive partner network."[72] This cooperation complements the partnership at SUNY-Albany's CNSE between IBM and Rapidus, which hopes to gain the ability to manufacture 2 nm chips. The Japanese government is committed to this ambitious effort, as reflected in its announcement in April 2024 that it would contribute $3.9 billion to Rapidus.[73]

Start-up Support and Investment Arms

Today, over 300 high-tech companies are now located in Leuven, many of which are spinoffs from KU Leuven and imec. This situation underscores imec's dynamic effects on the region (in the view of Chairman Antoon de Proft) and highlights how imec not only serves established high-tech companies but also creates new firms in significant numbers.[74]

Notably, imec conducts venturing activities that focus on "deep tech"—fundamental technologies that require an extended phase of R&D to commercialize but promise major payoffs, transforming "disruptive technologies into disruptive companies."[75] Imec encourages this dynamic in several ways: through spinoffs led by its own researchers; through its technology accelerator, imec.istart; and through venture capital investments in its independently managed imec.xpand fund.[76]

Spinoffs

In the view of imec's director of venture development, Olivier Rousseaux, spinoffs in particular represent a way for imec to help commercialize IP it has developed and capture "a share of the upside potential of our innovation." He suggests this activity could be expanded further, noting, "Today, imec gets paid typical research project fees for innovation that goes into the market and generates billions of Euros. We make good money, but peanuts compared to what we could make."[77]

These spinoff ventures continue to grow. Imec's website lists 72 companies spun off by the consortium between 1986 and 2023, most of which are still operating or have been acquired by other firms. Another 68 companies were spun off from iMinds before that organization merged with imec in 2016.[78] As one would expect with high-tech start-ups, a few of these new companies have been liquidated, but the majority have survived and thrived. This is in no small part because imec contributes the deep-tech expertise of over 5,000 "highly skilled and dedicated researchers"; access to exceptional facilities, particularly cleanroom space and 3.5 billion euros worth of equipment; and support through a vibrant regional ecosystem of established partners, "which creates opportunities for young spinoffs to collaborate."[79]

The Imec.istart Accelerator

The 12 to 18-month imec.istart program complements imec's venture activity. Launched in 2011, imec.istart is a digital technology business accelerator for supporting start-ups that present a working proof of concept, providing access to imec facilities, early-stage financing, mentoring, free office space, and introductions to tech communities, among other benefits.[80] Participation in imec.istart is limited to companies that are less than two years old, based in Belgium, and focus on digital products or nanotechnologies.[81]

Imec.istart invests a minimum of 100,000 euros in pre-seed funding for each selected start-up, split 50-50 between equity and a convertible loan, and may choose to award an additional 150,000 euros at its discretion once the start-up is "up-and-running." The initial 100,000 euros can be used for any business costs, but only up to 30,000 of it can be spent on product development, and none of it on salaries.[82]

In January 2024, imec.istart announced the launch of a new, independently managed future fund to enable longer-term and larger-scale investments in promising imec.istart start-ups beyond the initial 100,000 euros of seed funding. The investments are expected to average 1 million euros per qualifying start-up, totaling an estimated 25 million euros over the first five years. Investors include imec, PMV (the Flanders government's wholly owned investment fund), ING Belgium, and private parties such as angel investors and the founders of imec.istart alumni companies.[83]

About two-thirds of imec.istart's portfolio consists of software firms, which have the advantage of lower capital costs than hardware developers and can go to market more quickly, making them much more attractive to investors. Some of the accelerator's notable successes include the Ghent-based food-delivery company Deliverect, data companies Datacamp and PieSync, and medical-software developer Ugentec.[84] Imec.istart now has a portfolio of over 300 start-ups, and in 2023 UBI Global named it the world's top business incubator linked to a university.[85]

Venture Investment: Imec.xpand

Established in 2017, imec.xpand operates as a venture capital fund, investing in nanotechnology hardware start-ups and spinoffs in which "imec knowledge, expertise and infrastructure will be the differentiating factor for success."[86] The fund is independently managed and cofinanced by imec, government entities, and private firms (some of which are imec members), who together contributed 120 million euros in its first round of investment.[87] In May 2024, imec.xpand announced the launch of a second, 300-million-euro fund for "accelerating the growth of transformative semiconductor and nanotechnology innovations."[88] According to imec, imec.xpand has invested in 23 companies to date—including two unicorns—which have collectively raised close to 1.5 billion euros in funding.[89]

International Partnerships and Footprint

Imec in the United States

In addition to its research partnerships with many U.S. firms, imec operates three centers of excellence in the United States at sites where it can collaborate easily with local research universities. Notable centers and partnerships include:[90]

- imec USA-Florida, located near Orlando, which focuses on cryogenic and superconducting computing, as well as advanced semiconductor packaging;
- imec USA-Berkeley, which focuses on innovative AI architectures and the co-optimization (redesigning) of system technology;
- imec USA-San José, which provides design services, multi-project wafer runs, and application-specific integrated circuit development;
- joint research by imec and Purdue University to develop and demonstrate novel semiconductor materials, laying the foundation for "the next wave of high-performance compute and packaging materials" and aiming to make them more sustainable; and
- an MoU signed by imec, the University of Michigan, Washtenaw Community College, General Motors, the semiconductor firm KLA, and the Michigan Economic Development Corporation to pursue semiconductor technologies for the automotive industry.

Imec has proposed further partnerships with U.S. research organizations and companies to advance the competitiveness and self-sufficiency of semiconductor production in the two regions. Along with partners, imec has expressed its willingness to help CHIPS Act entities ramp up U.S.

semiconductor programs. As CEO Van den hove has pointed out, the center is well-positioned to expand upon its ties with major U.S. chipmaking firms by providing access to its expertise, IP, and other complementary operational capabilities. Imec also hopes to work with the newly established U.S. National Semiconductor Technology Center on earlier-stage technology research that may take seven to ten years before going to market and has proposed assigning imec engineers to the Albany NanoTech Complex.[91]

Europe's PREVAIL Consortium

In late 2022, Europe's four leading public research organizations–imec, France's CEA-Leti, Germany's Fraunhofer Gesellschaft, and Finland's Technical Research Center (VTT)–established a consortium to coordinate their respective 300 mm research facilities to design, evaluate, test, and fabricate the advanced chips needed to enable artificial intelligence.[92]

The consortium, the Partnership for Realization and Validation of AI-hardware Leadership (PREVAIL), will initially operate for 42 months and has a budget of 156 million euros–half of which is coming from the European Union and half from the host governments of the four organizations involved. Most of this budget (86 percent) is allocated to capital outlays, and only 6 percent funds the manufacture of demonstration circuits. By February 2024, the consortium announced it was finishing up installing cleanroom tools and was almost ready to design and test prototypes from across Europe.[93] The aim is for the consortium to open up their new, shared pilot lines to smaller chipmakers, start-ups, and research institutions by May 2026, allowing them to manufacture, assemble, and test AI-embedded devices.[94]

Imec Research Center in Spain

In March 2024, imec, the Spanish government, and the regional government of Andalusia signed an MoU to establish a public-private partnership to establish a 300 mm R&D facility in Málaga called Fab 5. Imec will manage operations, provide the necessary technology and operations, and grant access to its global partner network. The two government parties have agreed to finance the construction of Fab 5, including equipment for a pilot line, and will provide additional long-term support for its operation. However, as the parties are reportedly still negotiating on the level of public support, there is no timetable or budget available yet. Complementing the existing imec fab in Leuven, which is focusing on CMOS and sub-1 nm fabrication, the Málaga fab will concentrate on "process developments and the introduction of materials that are difficult to combine with standard CMOS processes," as well as R&D of devices with applications to healthcare, photonics, sensing, and augmented and virtual reality.[95]

Conclusion

As one of the world's premier cooperative research institutions, imec has made remarkable contributions to today's semiconductor ecosystem. These contributions are reflected most clearly in the continued active participation of major chip manufacturers, system companies, and equipment, materials, and design software suppliers in imec programs, as well as the sustained support of the Flanders regional authorities. In addition to its outstanding research facilities and staff, the flexibility of the imec structure–allowing for different degrees of cooperation–and the independence of its leadership have made it a central node in the global semiconductor supply chain. Critically, the center is a major source of the next-generation manufacturing technologies needed to keep the Western chip industry continuing along its rapid trajectory, with all the economic and social benefits that entails.

For the United States, expanded collaboration with imec is an opportunity to accelerate the progress of U.S. semiconductor research programs, strengthen the transatlantic alliance, and minimize needlessly duplicative, costly investments in semiconductor research programs and infrastructure.

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Charles Wessner is currently an adjunct professor at Georgetown University, where he teaches global innovation policy. He is active as a speaker, researcher, and writer with a global lens on innovation policy and frequently advises technology agencies, universities, and governments on effective innovation policies. He served for two decades at the National Academy of Sciences, where he achieved the distinguished position of National Academies scholar. He founded and directed the National Academies Technology, Innovation, and Entrepreneurship Program and its Innovation Forum and directed research addressing the importance of the semiconductor industry for innovation and national security. In collaboration with Gordon Moore of Intel and Sematech CEO William Spencer, he produced a series of influential reports, including *Securing the Future: Regional and National Programs to Support the Semiconductor Industry* (National Academies Press, 2003) and *Innovative Flanders: Innovation Policies for the 21st Century* (National Academies Press, 2008), which reviewed the role of imec. His most recent publication, *Regional Renaissance: How New York's Capital Region Became a Nanotechnology Powerhouse* (Springer Nature, 2020) documents how state and private-sector investments in universities, institutions, and infrastructure created a vibrant semiconductor cluster that drove regional growth. He is also a leading U.S. expert on Sematech, the U.S. semiconductor consortium; the Manufacturing Extension Partnership; and the Small Business Innovation Research (SBIR) program, which provides awards to promising small businesses and start-ups. Reflecting his commitment to transatlantic cooperation, he was awarded the Order of

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Thomas Howell is an international trade attorney (currently in solo practice) serving as a consultant to CSIS Renewing American Innovation. During the course of his 40-plus year legal career, he has represented U.S.-based semiconductor companies and organizations in matters such as the U.S.-Japan trade disputes and litigation of the 1980s, the formation of Sematech in 1986–87, trade disputes with China (including the first WTO dispute settlement challenge to that country in 2003), and numerous other public policy initiatives. He served as a member of the Defense Science Board on Secure Microchip Supply in 2004. He has also represented U.S.-based industries in trade disputes and litigation in telecommunications equipment, soda ash, photographic film and paper, flat-rolled steel, and renewable energy equipment. In conjunction with his legal work, he developed a specialization in field research in Asia and Europe to produce analytic studies for clients. His subjects include industrial, research, and science and innovation policies outside the United States and foreign market barriers to U.S. exports and investment. The National Academy of Sciences has commissioned and published many of his works, and he has contributed to the academy as a contract writer/researcher producing numerous peer-reviewed chapters and book-length studies. He has published numerous articles and books, the most recent of which was co-authored with Charles Wessner, *Regional Renaissance: How New York's Capital Region Became a Nanotechnology Powerhouse* (Springer Nature, 2020). He is a graduate of Harvard College (1971) and the Boston University School of Law (1977).

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