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Orchestrating Innovation Ecosystems_IMEC

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Abstract

Building on recent contributions on the role of orchestrators in ecosystems, this study illustrates the IP model that an experienced orchestrator of innovation ecosystems in the nano-electronics industry adopts. The governance of IP is instrumental for the success of innovation ecosystems as it determines: (1) the ability of the orchestrator to ensure value appropriation for all partners; (2) the ability of the orchestrator to define valuable (new) ecosystems; (3) the ability of the orchestrator to offer partners crucial technological expertise. The organization under study is IMEC, a research institute

in nano-electronics, which has orchestrated numerous innovation ecosystems in semiconductor technologies.

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Introduction

The purpose of this paper is to add to ecosystem thinking by illustrating the important role the ecosystem orchestrator can play in the success of ecosystems. Several authors have mentioned that in most industries the competitive pressures, technological uncertainties, and costs associated with innovation have made it attractive for companies to organize themselves in fluid structures such as ecosystems. A prime example is the semiconductor industry where the costs of developing new generations of semiconductors have increased strongly with each successive attempt to miniaturize the features used to make an integrated circuit. This is mainly due to exponentially increasing costs of tools and equipment used in the production processes of integrated circuits.[1] Depending on the innovation needs ecosystems can be made up of different sets of partners at different times where companies collaborate and pool their resources on a temporary basis to achieve joint innovative goals while sharing associated costs and risks. Afterwards partners separate and pursue their own research agendas until a new opportunity to collaborate in ecosystems arises. This important benefit of ecosystems is referred to as dynamic re-configuration.[2] Considering the challenges that many industries face these days ecosystems may well be the preferred way of organizing in the near future.

Ecosystem thinking is by no means new; while originating from biological research its application in economic thinking goes back as far as Alfred Marshall's writings. Several terms have been used to refer to what we now consider to be an ecosystem: national systems of innovation[3], clusters [4], platforms[5] are but a few. The first one to propose a definition of the ecosystem concept was James Moore in his 1993 contribution: "A network of organizations and individuals that co-evolve their capabilities and roles and align their investments so as to create additional value and/or improve efficiency".[6] In more recent years researchers have studied ecosystems that are specifically targeted towards joint research for the purpose of innovation or *innovation ecosystems*.[7] An innovation ecosystem generates value for its partners by reducing development costs and risks and by combining complementary knowledge that enables partners to address problems with a high complexity and provides them with multiple technological routes to a solution. The purpose of innovation ecosystems is to create knowledge that is protected by Intellectual Property (IP) and which the ecosystem partners can, at least to some extent, appropriate to support their own businesses.

While many authors within the ecosystem literature refer to the self-organizing characteristics of ecosystems a number of publications stress the important role of the leading firm or ecosystem orchestrator in the success of ecosystems.[8] In fact authors have pointed out that the particular role the orchestrator plays in shaping the innovation ecosystem, stimulating cooperation amongst research partners, setting the research agenda, and adding value through its own capacities can be an important determinant of ecosystem success as well an important source of competitive advantage for the orchestrator. An ecosystem orchestrator can influence ecosystem success if it is able to create a structure, including an IP model, that ensures value appropriation for all ecosystem partners and if it is able to keep on attracting partners based on its specific technological expertise.[9] In this respect, more recent contributions on innovation ecosystems build strongly on the platform literature where the role of the technology leader and the structure this firm puts in place to orchestrate ecosystems are considered as important factors in platform success.[10] These studies emphasize the need for additional case-based research illustrating how ecosystem orchestrators design, stimulate, and direct their ecosystems. To address this need we have chosen to study a case[11] where an ecosystem orchestrator with strong technological capabilities manages a set of innovation ecosystems on the basis of an elaborate IP model. The orchestrator is IMEC, a Belgian research institute in the field of nano-electronics. IMEC orchestrates innovation ecosystems around specific nano-electronics technologies through multi-party research collaborations. These joint research activities are organized in *Industrial Affiliation Programs* (IAPs), which create their own innovation ecosystems around IMEC and partners that hold different positions in the semiconductor value chain. In an IAP industrial partners cooperate with IMEC researchers at the research facilities of IMEC within the context of common research platform programs. The technologies explored within an IAP are costly and have a high risk-factor and complexity[12] justifying the cost, risk, and talent sharing across multiple partners. The research conducted within an IAP is pre-competitive in nature, which induces companies to collaborate within an innovation ecosystem (IAP).

The IP model of IMEC is designed to guarantee value appropriation by IMEC and its ecosystem partners. The basic premise is that IP-protected knowledge, which is developed in the IAPs, is made largely available to the ecosystem partners. Although the goal is to generate generic IP that is of interest to all partners, for each partner there are also possibilities to limit IP sharing and to conduct additional proprietary research with IMEC to acquire exclusively owned IP. The combination of shared and exclusively owned IP allows each partner to build up a unique *IP fingerprint* in a cost effective and speedy way. Furthermore, the IP model enables IMEC to build up a strong technological base which puts it in a good position to repeatedly define and initiate new innovation ecosystems as it is able to offer partners ecosystem-specific technological expertise.

The remainder of the paper is organized as follows. The next section introduces IMEC and its IAPs. After that, we explain the IAP-IP model and discuss how it enables IMEC and its ecosystem partners to appropriate value. Finally, we compare the IAP-IP model with the one adopted by IBM in its ecosystem and discuss how IMEC adapts its IP model to leverage new applications of its ecosystem orchestration model to other settings.

Background – IMEC and the IAP

IMEC is a European research institute in the field of nano-electronics that is headquartered in Leuven[13], Belgium. IMEC was founded in 1984 by the Flemish government[14] as a research institute in micro-electronics. Though IMEC started off in micro-electronics, it later expanded its research into nano-electronics and its applications in chips and systems design, energy, healthcare and life sciences, wireless communication, imaging and sensor systems. At foundation, IMEC received more than 90% of its operating revenues in public grants. This percentage has shrunk to 15% in 2011 while revenues have increased from 6.5 M€ in 1984 to 300 M€ in 2011. In 2011 IMEC had a staff close to 2000, including 600 industrial residents, PhD students, and guest researchers. In 2011 IMEC produced 1773 publications, was granted 132 patents, and applied for 133 patents. Since 1984 IMEC has launched 35 spin-offs. In 2011 IMEC received the prestigious IEEE corporate innovation award for its contribution to CMOS technologies (i.e. scaling research) and its innovative ecosystem orchestration model.

Research at IMEC is conducted in three phases, i.e. basic, applied, and developmental research (see Figure 1). The stage of development of the technology determines the type of collaborations that IMEC undertakes. Basic research is 8-15 years ahead of market applications and most companies are reluctant to invest in this type of research because of the high degree of uncertainty, long time frames to bear fruit, and value appropriation difficulties.[15] This research phase is the domain of universities where researchers examine the basic characteristics of materials and explore different paths to achieve technological goals. IMEC collaborates with universities in this phase and attracts PhD students from 200 local and international universities by providing an academic-like environment (with opportunities to publish research findings), access to funds, and state-of-the-art infrastructure (e.g. clean rooms). The research output of PhD theses is selectively patented. In congruence with ecosystem thinking IMEC uses the research output of basic research as ecosystem-specific technological expertise to initiate new ecosystems and ensures its orchestration role is grounded in the technological expertise it has on offer for future partners.[16]

Insert Figure 1

The second phase is applied research. Applied research focuses on topics that are 3-8 years ahead of market needs. It is pre-competitive research, which facilitates collaboration amongst industrial partners. In this phase IMEC defines and initiates innovation ecosystems by bringing together partners in IAPs to advance research on particular technologies in the field of nano-electronics. The existing ecosystems literature defines the set-up and initiation of ecosystems on the basis of ecosystem-specific expertise and orchestrating capabilities as an important role to be played by the ecosystem orchestrator.[17] This is also the case for non-player orchestrators such as IMEC. IMEC can be considered as a non-player orchestrator as it is not active in end markets and therefore does not constitute a competitive threat to its partners. IMEC's neutrality in this respect helps in playing an orchestrator role as it creates an environment where partners are willing to openly discuss R&D roadmaps enabling IMEC to initiate valuable research programs that correspond to partners' needs.

IMEC's IAP, the basic concept of which was developed in the early 90s by Johan Van Helleputte, acting at that time as Vice President in charge of business development, is a partnership formula for joint R&D by industrial researchers and IMEC research teams focused on a specific technology. An IAP enables industrial researchers to join IMEC's research teams via well-defined R&D programs. Each industrial partner joins an IAP on the basis of a *bilateral contract* with clearly defined technical scope and deliverables. As such

IMEC ensures the value appropriation potential for all partners, which is considered to be an important orchestrating task for ecosystem success in the ecosystem literature.[18] Partners send employees to IMEC to be part of the research teams as industrial residents. In an IAP, R&D actors that take different positions in the semiconductor value chain cooperate in a common platform program, thereby establishing an innovation ecosystem. An IAP addresses the challenges of applied platform R&D in a technical domain. By collaborating in an IAP, companies reduce the costs and risks of applied research. IAP participation also offers companies the option to experiment with alternative routes to those followed by in-house applied research. Although IMEC initiates the IAPs, partners are consulted while the technology R&D roadmap is composed and adapted over time.

The first two IAPs were launched during the period 1992-1994 and focused on the reduction of chemicals (cleaning IAP) and the development of advanced equipment to produce chips (lithography IAP). Since 2000 IMEC has coordinated more than 25 IAPs on topics such as high-k dielectrics and metal gates in scaled planar devices, cleaning and contamination control for sub-32nm process technology, carbon nanotubes and semiconducting nanowires, low-k Cu interconnect, photovoltaic energy, body area networks and 3D systems integration. Anno 2013, 12 IAPs are operative. Since the beginning of the 1990s, 587 different companies have signed contracts with IMEC and participated in at least one IAP. Some of these companies can be labeled as core IAP partners as they participate simultaneously in multiple IAPs. Exhibit 1 gives a detailed account of the innovation ecosystem (IAP) on 3D systems integration that IMEC orchestrates, as an example.

Insert Exhibit 1

The third research phase is developmental research. This type of research focuses on topics that are 2-3 years ahead of market applications and is based on bilateral collaborations.

The IAP-IP Model

In this section we describe the core principles underlying the IAP-IP model and we explain how this model enables IMEC and the IAP partners to appropriate value from their participation in innovation ecosystems. Value appropriation by IMEC is discussed from both a static and dynamic point of view.

IP Model Principles

Ownership of, and access to, the IP-protected knowledge in an IAP is determined beforehand and is part of bilateral agreements between IMEC and its partners. Several principles underlie the IAP-IP model (see Figure 2). First, IMEC's IP that is available at the start of an IAP is labelled *IAP background*. It is IMEC's existing IP, preferably on fundamental technologies that are relevant for the IAP research. Upon payment of an entrance fee, IAP partners receive a non-exclusive, non-transferable license necessary for the exploitation of the foreground IP generated within the scope of the IAP, discussed later-on. The scope of the license depends on the contributions and technology needs of ecosystem partners. Several researchers within the ecosystem and platform literature stress that this type of platform-specific knowledge or ecosystem-specific technological expertise contributed by the ecosystem orchestrator is crucial for ecosystem success. Not only does it allow the orchestrator to shape the direction of the ecosystem but it also enables the orchestrator to repeatedly initiate and design new ecosystems and attract future partners based on its valuable expertise and its dynamically expanding background IP.[19] Second, IP that is generated during the course of an IAP is termed *IAP foreground*. Foreground IP consists of all the IP that is generated by IMEC researchers and/or residents of IAP partners at IMEC facilities and which falls within the scope of the IAP. The following foreground IP categories can be distinguished:

- $\underline{R_0}$ IMEC researchers generate R_0 during the course of an IAP without the collaboration of industrial residents. This IP is owned exclusively by IMEC and industrial partners have no (ownership) rights to it; IP access for an IAP partner consists of a non-exclusive, non-transferable license.
- $\underline{R_1}$ IAP partners generate R_1 possibly in collaboration with IMEC researchers. R_1 is co-owned[20] by IMEC and the industrial partner(s) that has (have) contributed to the invention. Each co-owner can use this IP as it wishes. A partner can get access to (some of the) IP that IMEC and other partners have developed within the IAP without contributing to it. The access is regulated in the bilateral contract with IMEC and depends on the technological needs of the partner. For example, chip manufacturers need process technologies, while fabless partners rely on manufacturers to produce their chips in silicon and are more interested in design and application technologies or the impact of next generation process technologies on their future design strategy. They do not need access to (most of the) manufacturing and process IP. IP access for a non-contributing partner consists of a non-exclusive, non-transferable license;
- $\underline{R_1*}$ This IP category refers to knowledge that is not shared among all IAP partners because the partner that (co-)developed the technology does not want to share it with some others. In this case, restrictions (indicated by the star) are added to the knowledge that can be shared among partners. For example, the purpose of the low-K IAP was to generate knowledge on the operation and efficiency of low-K materials as isolation materials in transistors. Besides chip manufacturers, several providers of equipment to

deposit low-K materials on transistors, each with a different material composition, participated in the IAP. Not all partners received access to the full equipment or materials related knowledge that was created. While all partners received access to general knowledge on the operation of low-K materials, knowledge on the performance of specific materials was only shared with the material owning company and not with other equipment companies. The general knowledge is labelled R_1 and the specific knowledge is categorized as R_1*;

- $\underline{R_2}$ An IAP partner can request to perform *limited proprietary research* with IMEC researchers in the margin of and in parallel with the IAP. For example, the 3D systems integration IAP (see exhibit 1) resulted in an IP-protected TSV technology to make an interconnection between chips. To learn more about this technology, some IAP partners asked for additional proprietary ($\underline{R_2}$) research to apply the TSV technology to their own processes and wafers. The content and conditions of such research are agreed on upfront between IMEC and the partner. The costs for R_2 results are to be fully borne by the partner and the IP that is generated is exclusively owned by the partner and is not shared with IMEC or others.

Insert Figure 2

Value Appropriation by IAP Partners

There are different ways through which the above described IP model allows the IAP partners to appropriate value from their investment and participation in an IAP.

First, IAP partners obtain access to valuable IMEC background knowledge (IP) at an early stage. Background information is scientific knowledge resulting from PhD research and basic research collaborations with academic partners or research conducted by IMEC and its industrial partners in prior IAPs. It is hard to access this knowledge outside the IAP as IMEC only selectively provide licenses on important background technologies.

Second, the majority (R_1) of foreground knowledge is shared among partners. As such, partners obtain access to most of the program outputs while paying for only part of total R&D costs. This is interesting as the costs of semiconductor research have soared during the last two decades. Today only the largest companies, such as TSMC, Intel, and Samsung can afford long-term internal applied research. Through participation in IAPs, semiconductor firms can share the costs of long-term applied research, and can explore different technological options in cases where there is no clear up-front winner known (yet).

Third, the IP model allows IAP partners to conduct limited proprietary research to match individual needs (R_2) and to protect the confidentiality of company-specific information (R_1*). In this way, partners can combine generic IAP results with company-specific applications that they developed in parallel with/tangential to the IAP and to which they have exclusive rights (R_2). Partners are able to build on the foreground knowledge, combine it with internal knowledge, and improve the quality of their own innovations.[21] The fact of having bilateral contracts between IMEC and each of its program partners allows for a high degree of flexibility in IP-modulation (unlike with consortium approaches).

The combination of different types of IP enables IAP partners to build up a unique IP fingerprint in a cost effective and fast way (see Figure 3). Such an IP fingerprint consists of a mix of background IP, foreground IP that is shared (partly) with others (some R_0, R_1 and R_1*), and foreground IP that is solely owned (R_2) by each partner. This unique IP fingerprint enables IAP partners to differentiate themselves from other companies in an IAP and to provide ex-post a unique offer to the market hence appropriating economic value.

Insert Figure 3

Value Appropriation by the IAP Orchestrator

There are different ways through which IMEC appropriates value from orchestrating innovation ecosystems. From a static point of view, IMEC appropriates value from its IAPs via the program fees that are paid by the IAP partners and (co-)ownership without any accounting on foreground (R1) IP. From a dynamic perspective, IMEC appropriates value from the orchestration of innovation ecosystems by using the foreground IP of IAPs as background information (IP) to initiate new IAPs.

Program fees (a one-time entrance fee and a yearly program affiliation fee) compensate IMEC for the background IP that is brought into the IAP, the provision of research facilities and researchers, the execution of the R&D program in mixed research teams and the orchestration tasks. Exhibit 2 discusses the key orchestration tasks that IMEC conducts within each of the IAPs and which are considered to be important determinants of ecosystem success by several authors in the platform and ecosystem literature.[22]

Insert Exhibit 2

IMEC obtains rights to most (R_1) of the foreground IP irrespective of whether it contributed. These rights can be IP ownership, co-ownership or a non-exclusive license with sublicensing rights. There are two ways through which IMEC appropriates value from the foreground IP. First, and most importantly, IMEC uses such IP as background IP to launch new IAPs. IP from prior IAPs, together with IP from internal basic research, is used dynamically as background IP in new IAPs (see Figure 4). Second, IMEC occasionally directly valorises IP by licensing/transferring/selling technologies, and creating spin-offs.

Insert Figure 4

The choice between direct valorisation of IP and the safeguarding of IP rights for future IAPs is an important one for IMEC. The future success of the IAP-IP model hinges on the access of IMEC to IP that can be used as background IP in new IAPs. Studies within the platform literature emphasize that platform leaders need to prepare for the future in order not to lose control moving from one platform to the next. Even when they are focused on their current platform activities they need to keep an eye on the future to prolong their important role as a technology and platform leader. An important way to do this is to learn about new technologies and create (access to) important IP rights not only through its own flexible learning organization but also through the organization of its current ecosystems.

IMEC decides between direct IP valorisation and safeguarding at the level of individual technologies. As IMEC aims to define, initiate, and orchestrate innovation ecosystems, technologies (and their IP) are only transferred to external companies when they are less relevant for new IAPs or when they are mature and caught up by the market. IMEC will then license-out to manufacturers while safeguarding the IP rights of the IAP partners. IMEC will spin-off a technology when no external entrepreneurs are found to license-in the technology. IMEC launches spin-offs as follows. First, a feasibility study is conducted and the IP situation is explored. An incubation period of one to two years during which applications are developed is necessary to prepare for the spin-off's establishment. Second, IMEC transfers or licenses-out IP to the spin-off. IMEC is actively involved in the development of its spin-offs and since it has its own seed capital it can work quickly, flexibly, and autonomously to establish spin-offs. An example of an IMEC spin-off is EPIGAN, which was established on the basis of IMEC's mature GaN IP for power electronics.

Comparing the Orchestration Models of IMEC and IBM[23]

Can the IMEC IP model be adopted by other ecosystem orchestrators? To answer this question we compare the IMEC IP model with the IP model that is used by IBM in its semiconductor ecosystem. Although IBM is a large company, it is a small player in the fabrication of ICs compared to the market leaders Intel and TSMC. To keep up with the market leaders, IBM created in 2002 an innovation ecosystem in which it collaborates with various fablite firms and IDMs to develop semiconductor process technology. Within the IBM ecosystem partners collaborate in mixed teams around a specific R&D program and are co-located in East Fishkill, the largest IC production facility of IBM.

The IP model of IBM has several commonalities with the IMEC IP model. First, IBM is also a leader in fundamental semiconductor research and has a strong patent portfolio which it uses to convince firms to join the innovation ecosystem. Firms that join the ecosystem receive a license on IBM's IP portfolio in exchange for a financial contribution. This is similar to the fee that has to be paid for the background IP of IMEC. Furthermore, the foreground IP is shared among partners, similar to the R_1 logic of IMEC. Like IMEC, IBM defines and initiates the ecosystem(s), sets the IP rules for value appropriation, and takes up an orchestrator role. However, there are also important differences with the IMEC IP model. First, the IP that is pooled within the IBM ecosystem is made available to all partners and there is no possibility to restrict the sharing of particular types of IP (R_1^*) like in the IMEC IP model. Second, there is no possibility for the ecosystem partners of IBM to conduct additional proprietary research (R_2) with the orchestrator (IBM).

In summary, both IP models provide ecosystem partners with access to valuable background IP of the orchestrator and allow for a cost-effective build-up of foreground IP. Compared to the IMEC IP model, the IBM IP model does not assist the ecosystem partners in creating a unique IP fingerprint to differentiate technologies and products on the market. This is because IBM is a player-orchestrator and the willingness of ecosystem partners to share company specific information is less prevalent compared to ecosystems orchestrated by a non-player orchestrator. There are also differences in relation to the goals of both ecosystem orchestrators. IMEC sets up IAP programs to jointly create knowledge around new technologies while IBM tries to keep up with the largest players by joining forces with other (smaller) players to share R&D costs and risks.[24]

The comparison with IBM's ecosystem reveals that there are different ways to set up innovation ecosystems in an industry where R&D is becoming excessively expensive. The ways in which the ecosystem and the IP model are designed determine which targets can be reached, the benefits for orchestrator and partners, and the overall stability of the ecosystem.

Ensuring Future Orchestration Success

IMEC orchestrates innovation ecosystems in nano-electronics technologies that are pre-competitive in nature. As mentioned before, the platform literature stresses that platform leaders should not only focus on current platform success but seek ways to prolong their orchestration role in the future. In this respect, IMEC is exploring new applications for its IAP model. Below, we discuss two variants of the IAP model that are developed or are under development by IMEC, and their implications for the IP model that governs the ecosystem.

First, IMEC aims to leverage the IAP model to the life sciences industry in search of nano-electronic applications in this industry. The life science industry is in transition: the pharmaceutical R&D model is under pressure as the number of new drugs is declining despite increased R&D spending. The sector faces similar problems as the semiconductor sector in the late eighties when vertically integrated firms could no longer face the technical challenges and costs of R&D, disintegrated, and joined ecosystems. Likewise, pharmaceutical companies today are vertically integrated and research is getting more costly and complex. Collaboration in innovation ecosystems may provide a solution to these challenges.

IMEC is convinced that their IAP model can be leveraged into life sciences. However, nano-electronics – the expertise of IMEC – will have to be combined with expertise in life sciences. IMEC therefore wants to team up with a second orchestrator that has strong competences in life sciences to create a *dual core, dual site innovation ecosystem* in which two innovation ecosystems are melted together. This is illustrated in Figure 5. In such a system, IMEC and its nano-electronics ecosystem partners will collaborate with a second orchestrator in life sciences and his ecosystem, consisting of hospitals, pharmaceutical companies, clinical labs, CRO's, and biotechnology companies.

Insert Figure 5

The IP rules of the single core IAP model can be largely leveraged to the dual core model. The IP agreements between IMEC (or the second orchestrator) and its ecosystem partners will remain the same, but additional IP arrangements between both orchestrators are needed. IP ownership will be based on contributions and location. Research developed at IMEC is owned by IMEC, and the same holds for the second orchestrator. [25] Furthermore, contributions of IMEC at the location of the other orchestrator lead to co-ownership by IMEC and vice versa. Finally, there is the possibility to cross-license knowledge for internal use and the right for each orchestrator to grant sub-licenses to its own ecosystem partners, in line with their business, which is assumed not to interfere (substantially) with the other ecosystem.

Second, nano-electronics is moving away from a focus on M&M (More-of-Moore) towards *MtM (More-than-Moore)*. M&M captures Moore's law and refers to the trend that the number of transistors that can be placed on an integrated circuit doubles approximately every two years, leading to a continuous decrease in costs and increase in performance. The M&M trajectory becomes increasingly expensive and technologically complex. MtM refers to the practice of adding functionalities on chips (systems on chips or SOCs). This shift poses some challenges for IMEC's IAP model: M&M is easier to plan via long-term research projects as the industry has a common technology roadmap. MtM pushes research in the direction of more short-term and application-oriented research as market trends are volatile and less predictable. The innovation ecosystem partners will push for less pre-competitive and closer to the market research (less R_1 and more R_1* or even R_2). The IAP-IP model (Figure 2) can still be used but IMEC has to find a new balance between keeping sufficient IP in common (R_1) and conducting proprietary research (R_2) with each partner separately. However, this technological trend should not only be considered as a challenge: It also opens up new opportunities since the nano-electronics value chain becomes even more fragmented and many small, specialized players need an orchestrator to coordinate their innovation activities.

Conclusion: How to Orchestrate for Success

The purpose of this study is to add to ecosystem thinking by illustrating the important role the ecosystem orchestrator can play. As ecosystems may turn out to be the preferred way of organizing innovation activities in many industries in the near future it is important to study how ecosystem orchestrators can influence ecosystem success. Several researchers have put forward that, although there are a few case studies on the role of the orchestrator in ecosystems, there is still a need for a deeper understanding of exactly how the ecosystem orchestrator contributes to ecosystem success. By studying the role of IMEC as orchestrator of IAPs we aim to contribute to this understanding. We draw on recent contributions to the ecosystem literature and the well-established platform literature as we demonstrate that IMEC contributes to the success of its current ecosystems by (1) defining, initiating, and shaping valuable innovation ecosystems; (2) offering relevant ecosystem-specific technological expertise to its partners; (3) ensuring value appropriation by all partners through its IP model. The IMEC IP model bears both similarities and differences with IP models that are adopted by other ecosystem orchestrators, such as IBM. Similarities relate to the provision of background IP by orchestrators and a sharing (of most) foreground IP. An important point of differentiation is that the IMEC IP model assists ecosystem partners in creating an unique IP fingerprint to differentiate technologies and products on the market. The IMEC case furthermore demonstrates that innovation ecosystem orchestrators that want to ensure their leading role in future ecosystems have to create and maintain a learning organization that is oriented towards building up crucial technological expertise and have to search for new ways to apply successful orchestration models (as illustrated by IMEC's dual core, dual site innovation ecosystem and its focus on MtM).

The IMEC ecosystem represents a case of an ecosystem with a strong orchestrator that defines the ecosystem, initiates research programs, and sets the IP rules to ensure value appropriation. Strong parallels can be made with the innovation ecosystem that is orchestrated by IBM. Innovation ecosystems can however also be organized in different ways. They can for instance be organized by way of consortia such as SEMATECH[26] and the Structural Genomics Consortium[27]. Consortia can achieve important results too but work in a different, consensus wise way, without a clear orchestrator that determines the direction of the innovation ecosystem, with has both advantages and disadvantages. There are also self-organizing innovation ecosystems where social norms determine to a large extent the functioning of the partners in the ecosystem. Ecosystems in the Dutch vegetables industry offer good examples.[28] Future research may focus on developing a classification scheme of innovation ecosystems with different governance structures and examine the contingencies (including IP models) under which they can deliver the targeted outcomes.

Exhibit 1: 3D Systems Integration IAP

The purpose of the 3D systems integration IAP is to conduct collaborative research on a new technology to create electronic circuits, namely 3D systems integration. Electronic circuits are typically created in a monolithic way, whereby different electronic elements are placed together on a single substrate of semiconductor material, typically silicon. A disadvantage of monolithic chips is that the distance between different electronic elements (e.g. memory and logic) is large, whereby chips consume a lot of power. A 3D integrated chip is a chip in which two or more layers of electronic components are stacked on top of each other and integrated both horizontally and vertically into a single electronic circuit. 3D integrated chips are expected to bring multiple benefits, such as reduced power consumption (related to the smaller distance between components), new design possibilities (and thus new applications) and improved circuit security due to more complex chip designs.[29]

IMEC researchers spotted the opportunity of the 3D technology at scientific conferences and through discussions with universities and companies. Triggered by the potential of the new technology, IMEC started in 2005 with first internal experiments. During these experiments, IP was developed which served as background IP in the 3D program. At the same time, IMEC conducted a mapping of other research experiments that were conducted worldwide. The purpose of the mapping exercise was to identify the most promising technological routes to advance the 3D technology, which would constitute the core of the IAP program under development. When deciding on technological routes, IMEC considered the complexity, costs, and manufacturability of the different routes. The internal experiments and the mapping exercises resulted in the set-up of an IAP on 3D systems integration which was promoted in the industrial world and launched in 2008.

Today, the 3D systems integration IAP brings together IMEC (the orchestrator) and 34 industrial partners in one innovation ecosystem. An overview of the different partners in the 3D systems integration innovation ecosystem is provided in figure 6.

Insert Figure 6

The 3D innovation ecosystem brings together companies that take different positions in the nano-electronics industry. First, there are the end-users of the 3D technology, such as the fabless companies, IDMs (Integrated Device Manufacturers) and foundries. The fabless companies are important partners in the ecosystem as they design the chips and determine their functionality. Their know-how is in the design of application-specific chips (e.g. Qualcomm makes chips for the mobile market). They are interested in the 3D technology because of the increased possibilities for chip design. Foundries are companies that have manufacturing facilities and which contract manufacturer chips that are designed by others, including the fabless companies. Taiwan Semiconductor Manufacturing Company (TSMC) is the largest foundry in the world and a member of the 3D IAP. Integrated Device Manufacturers (IDMs) both design and manufacture their own chips. The foundries and IDMs are interested in the process and design opportunities of the 3D technology. Furthermore, the Electronic Design Automation (EDA) vendors participate in the ecosystem. They design the software packages that are used by IDMs and fabless to design chips. If new technologies emerge, they have to integrate them in their design platforms. The Original Subcontract and Test (OSAT) companies are responsible for the assembly, testing, and packaging of chips, which will likely be influenced by new chip designs. Finally, to manufacture 3D integrated chips, new types of equipment and materials have to be developed. This is why multiple Equipment Suppliers and Material Suppliers have joined the 3D IAP.

At the start of 3D IAP, IMEC drew up bilateral IP arrangements with all IAP partners, taking into account individual contributions and needs. In general terms, the technology end-users get access to foreground IP related to design and manufacturing. The other ecosystem partners get access to a smaller, more specific set of IP. For example, the equipment suppliers get access to the IP related to their piece(s) of equipment. The equipment and material suppliers typically negotiated restrictions with respect to the access of others to knowledge on the performance of their specific pieces of equipment and materials. Most of the IAP partners negotiated the possibility to conduct a limited amount of proprietary follow-up research with IMEC on the generic technologies developed in the IAP.

Once the first IAP agreements were signed, the IAP started and IMEC researchers collaborate together with industrial residents on the 3D technology. In total, the 3D program hosts 15 FTE industrial researchers and a number of IMEC researchers that is significantly higher.[30] Not all IAP partners send full-time residents to IMEC. Only the large companies, such as the IDMs, foundries and the largest fabless, OSATs, and material suppliers have permanent residents at IMEC. The other companies have temporary residents to IMEC. Also note that not all partners entered the IAP at the same time. The IAP was started when a few key partners agreed to participate, and the possibility was offered to others to enter later.

The 3D IAP program is split up in different technology building blocks (modules), which relate to different aspects of 3D design, metrology, testing, and manufacturability. Figure 7 provides an overview of the different building blocks of the 3D IAP. One process-technology building block is the TSV (through-silicon via). The aim of this module is to develop a process to cut holes in the silicon to make an interconnection between different chips' layers. The IAP research has resulted in a first IP-protected workable TSV process. This process of reference (TSV baseline) has a diameter of 5 µm, a depth of 50 µm, and copper as conductive material; it is implemented by some IAP partners in initial production runs today. At the same time, the research on TSVs continues, with a focus on developing the next generation TSVs that have smaller diameters (TSV path finding).

Insert Figure 7

IMEC has been orchestrating the 3D systems integration IAP for five years. This has resulted in multiple patents on the 3D technology, which are used by IAP partners in further internal research and initial production tries. The program is still operational today.

Exhibit 2: Orchestrating Innovation Ecosystems

IMEC conducts different orchestration tasks within each of the innovation ecosystems (IAPs). First, IMEC *defines, initiates, and organizes innovation ecosystems* that are attractive for industrial partners with diverse needs. The collective performance of an IAP depends on the attractiveness of the research program. IMEC is able to create attractive programs as it has developed over the years a deep understanding of the technological fields in which it is active. IMEC's position as a bridge between universities and industry enables it to stay up-to-date with respect to the latest developments at scientific and technological frontiers. Several researchers studying platforms and ecosystems have stressed that defining ecosystems and *offering ecosystem-specific technological expertise* are of crucial importance for the orchestrator in ensuring its leading role in current as well as future ecosystems. IMEC is organized in such a way that it can continue to build up important technological expertise and thus remain attractive for future partners. State-of-the-art internal technological expertise will enable IMEC to set the research agenda and define new ecosystems in the future.[31]

Second, IMEC *ensures value appropriation for all partners* by negotiating bilateral agreements with all IAP partners on the IAP scope, deliverables (for the partner and the program), and IP access and ownership. The ecosystem and platform literature emphasizes that it is important for the orchestrator or leading technology firm to make sure that all partners are able to appropriate value from their research contributions and are able to use the generated IP to strengthen their own business.[32] Working on the basis of bilateral contracts enables IMEC to quickly start up new IAPs through reducing the time necessary for negotiation, which is important considering the rapidly changing environment it operates in. This is in contrast with the consortium approach that is followed in other ecosystems where decisions are based on a consensus model and which take more time to set-up new programs. Furthermore, the structure of bilateral contracts also ensures that the program has a strong fit with the industrial needs of partners. Another advantage of bilateral contracts is that is allows for flexibility in time (of joining) and in terms of IP benefits for the partners. A drawback of bilateral agreements is that IMEC is solely responsible for setting up IAPs and fully bears the risks associated with this orchestration role, such as investments in background technologies and the pre-financing of new research facilities.

Besides the abovementioned orchestration tasks that are put forward in the literature as important determinants of ecosystem success there are some basic tasks that ecosystem orchestrators need to carry out in order for the ecosystem to function on a day-to-day basis. In this respect, IMEC *coordinates the execution* of IAPs. This is done by splitting up the IAP in different technology building blocks (see exhibit 1). Each building block is executed by a team of researchers (IMEC employees, sometimes supplemented by industrial residents) and managed by an IMEC employee. The coordination of different building blocks is done by project managers and the IAP scientific director. In addition, IMEC sets up a communication structure to share the IAP research findings with the IAP partners. There is a dual communication structure. First, there are weekly or biweekly meetings with the research teams that work on the different building blocks. Second, there are biannual meetings with the senior management of the IAP partners to give an overview of the newly generated IP and to discuss the continuation of the IAP. Depending on the IP arrangements in the bilateral contracts, partners have a right to attend all or some of the communication meetings.

Figures

Figure 1: Collaboration during the Technology Life Cycle

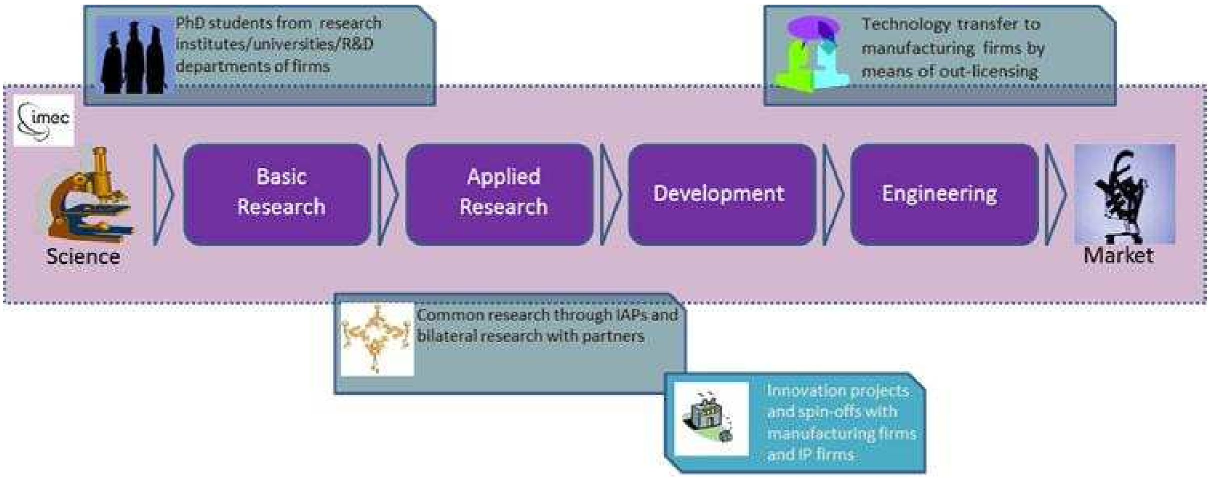


Figure 2: IMEC's IAP-IP Model

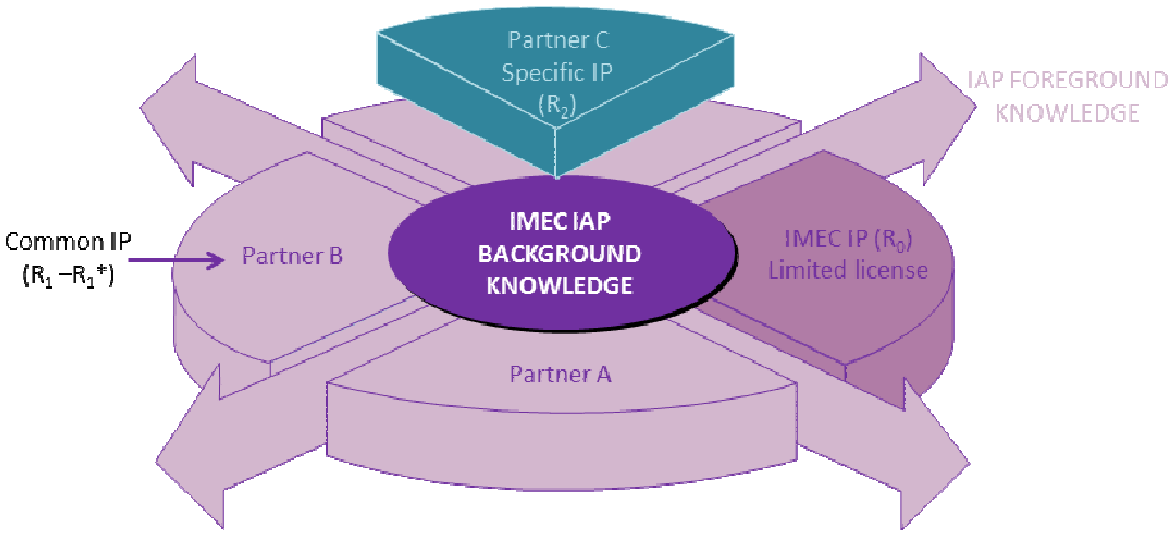


Figure 3: IP Fingerprint of IAP Partners

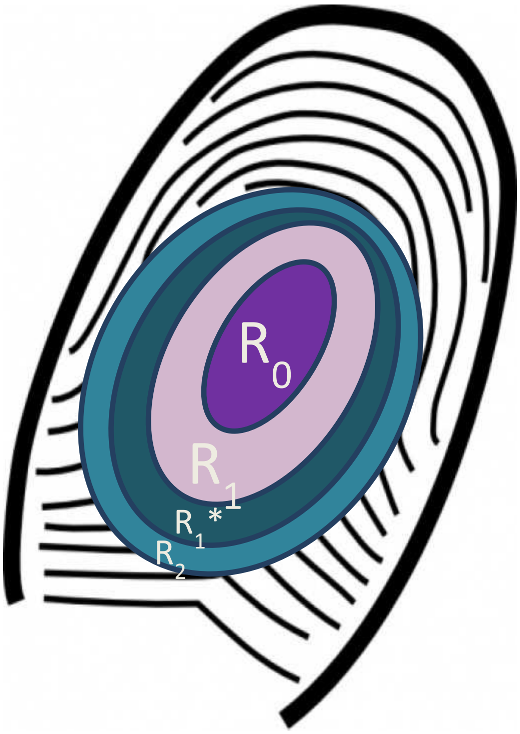
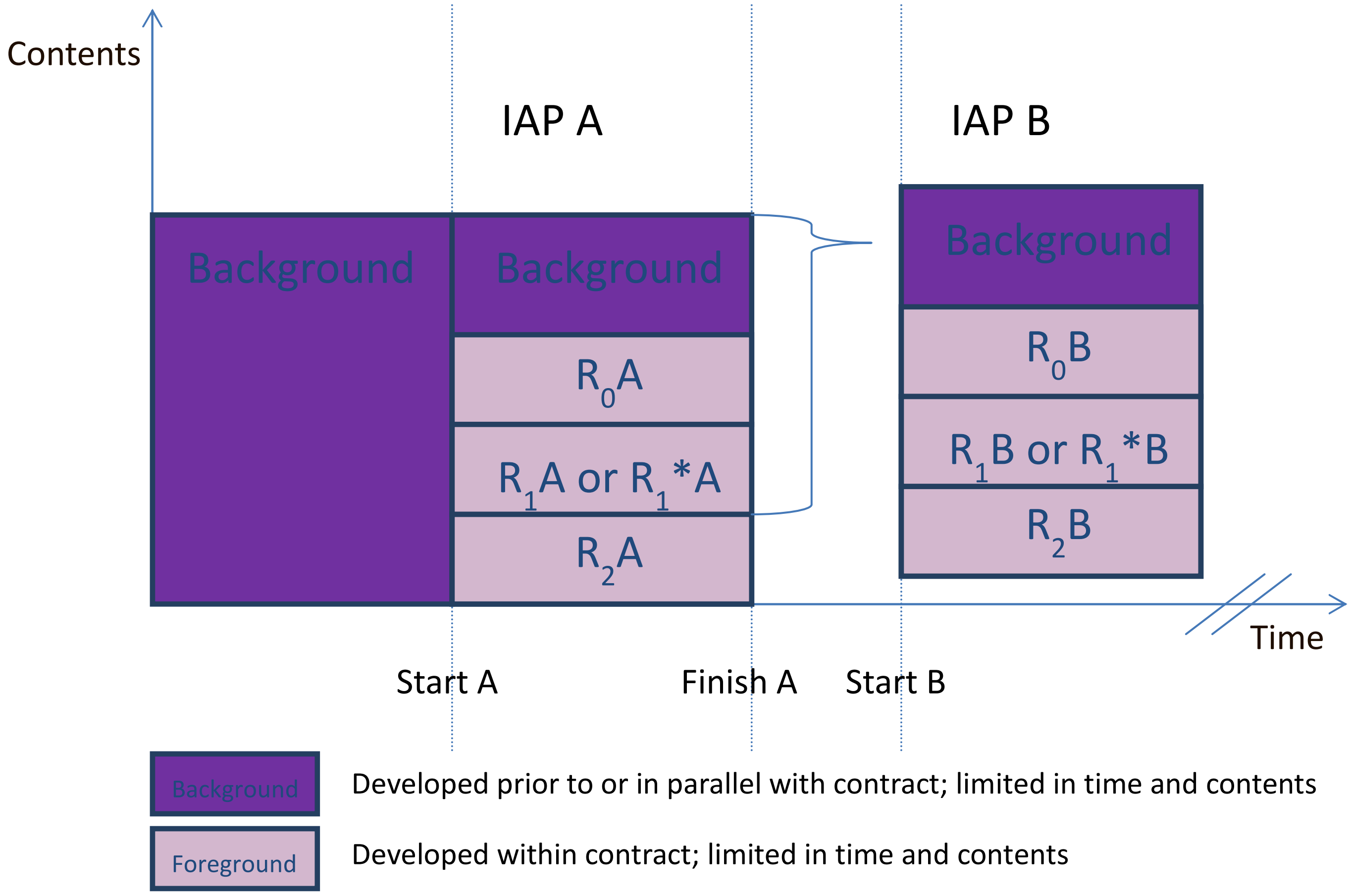


Figure 4: Dynamic View on IMEC's IAP-IP Model



R_0: Solely owned by IMEC, no rights for partner

R_1: Jointly owned by IMEC and partner, no restrictions

R_1*: Jointly owned by IMEC and partner, restrictions

R_2: Solely owned by partner, no rights for IMEC

Figure 5: Dual Core – Dual Site Innovation Ecosystem Model

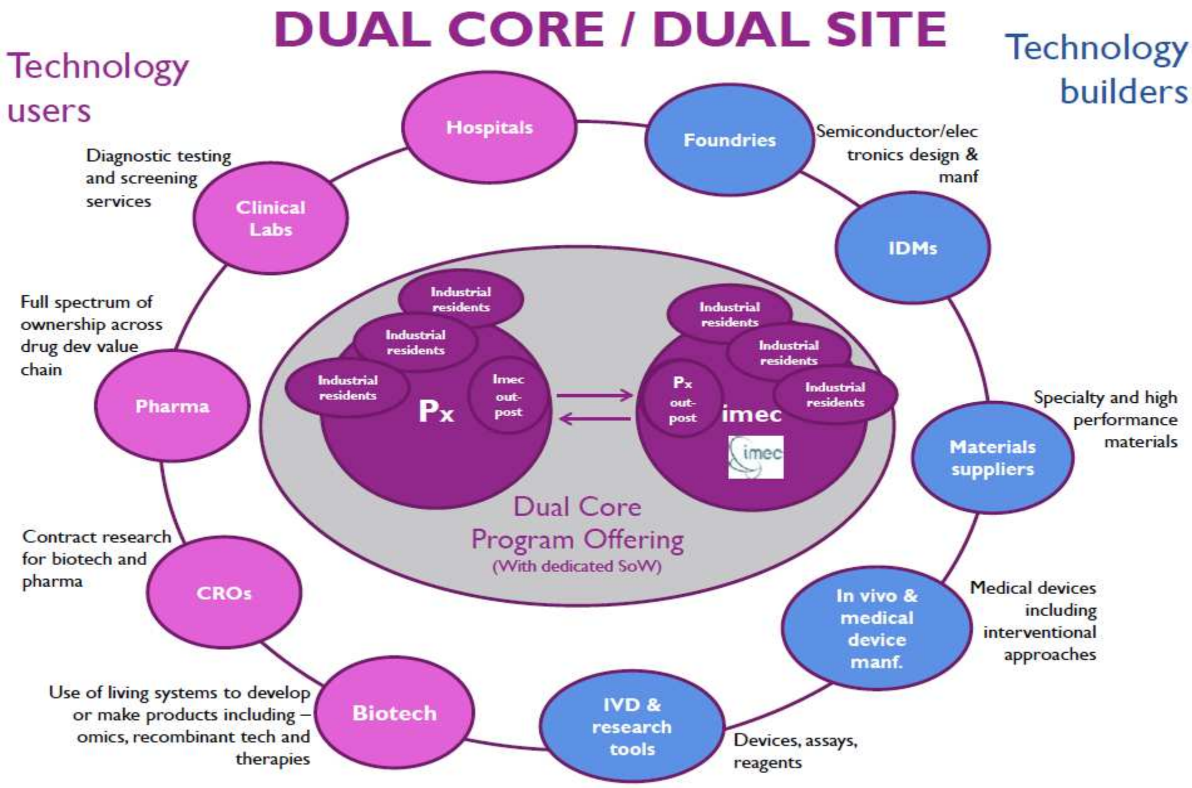


Figure 6: The 3D Systems Integration Innovation Ecosystem

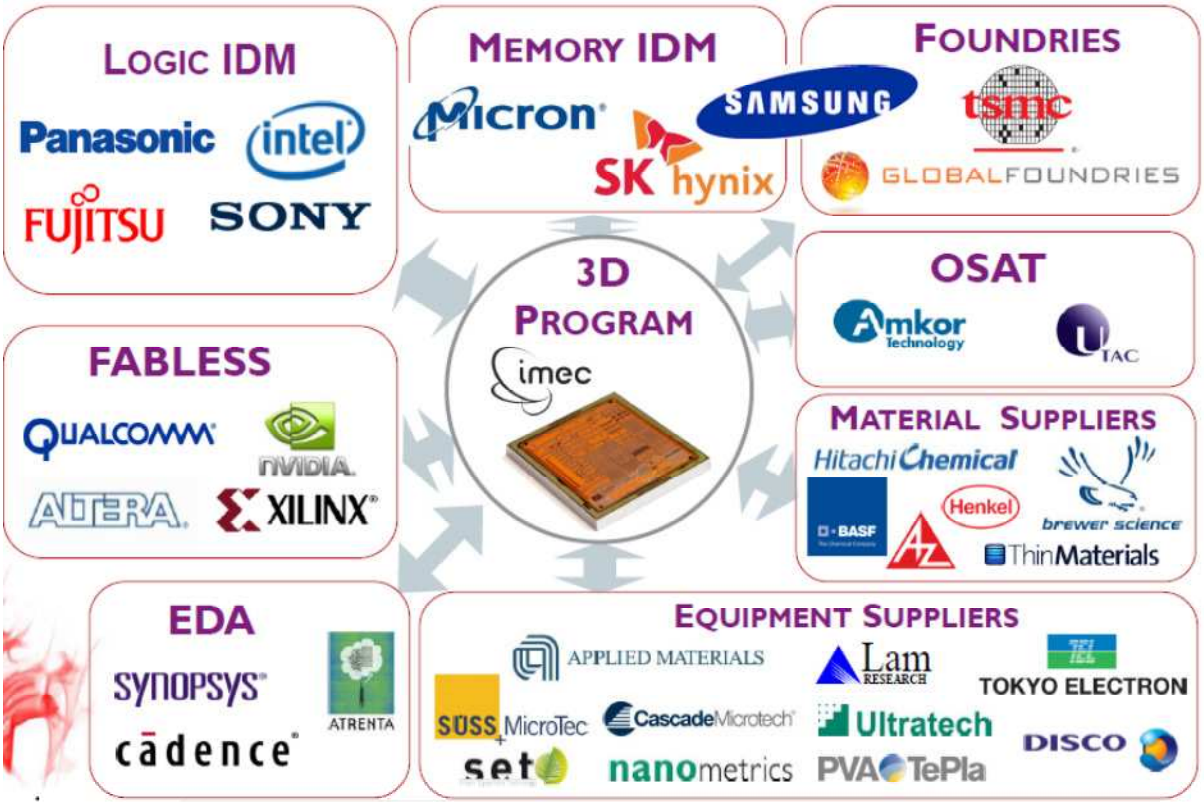
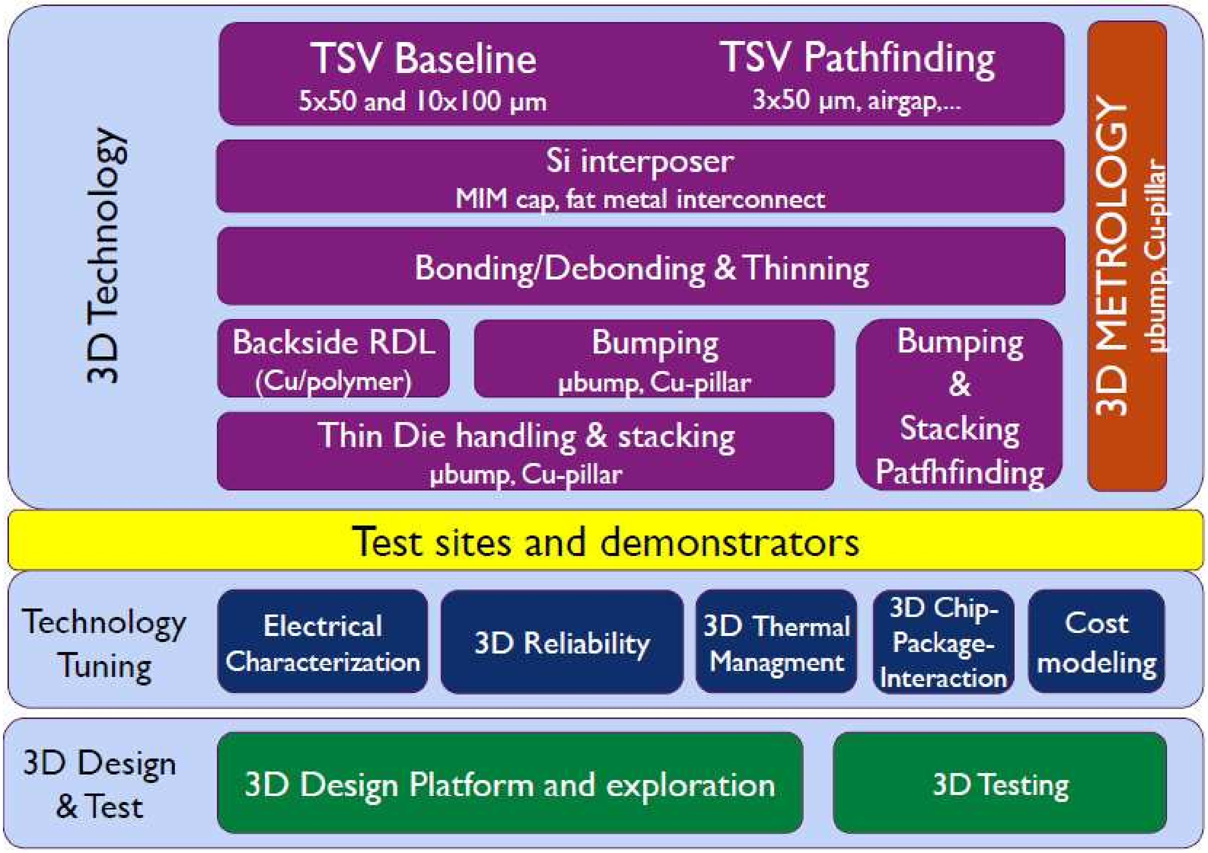


Figure 7: The 3D Systems Integration Program



Appendix 1: Interviews

Date of interview	Interviewees	Main Topics
April 20, 2010	Person A	IMEC, IAP program, IAP-IP model, IP strategy
December 22, 2011	Person B	IAP history, IAP-IP model and value appropriation, bilateral contracts, from More-of-Moore to More-than-Moore
March 22, 2012	Person B	Value appropriation in ecosystems, challenges for the IAP model, benchmarking with other ecosystems and programs
May 7, 2012	Person B	IP strategy: A dynamic view, orchestrating ecosystems, IP valorisation, boundary conditions for ecosystems
July 12, 2012	Person B	IAP membership models, IAP portfolio, and IAP links
August 14, 2012	Person B, Person C	IAP success factors, IP co-ownership, and co-patenting
December 6, 2012	Person B, Person C	Dual core-dual site IAP model, benchmarking with other ecosystems in nano-electronics, IAP success factors
January 11, 2013	Person B, Person D, Person E	3D IAP: Program structure and management, ecosystem initiation, ecosystem governance, IP rules, program output

Endnotes

[1] While early semiconductor fabrication facilities were affordable to many companies, the costs to build an advanced fab moved past $1 billion US dollars once the features sizes dropped below 180 nano-meters.

[2] P. Williamson, and A. De Meyer, "Ecosystem Advantage: How to Successfully Harness the Power of Partners", *California Management Review,* 2012, 55(1), 24-46.

[3] C. Freeman, "Japan: A new National Innovation System?", in G. Dosi, C. Freeman, R. Nelson, G. Silverberg, and L. Soete (eds.) *Technology and Economy Theory*, 1988, London: Pinter.

[4] M. Porter, *The competitive Advantage of Nations*, New York: Free Press, 1990.

[5] M. Cusumano, *Staying Power: Six Enduring Principles for Managing Strategy and Innovation in an Unpredictable World,* Oxford University Press, 2010.

[6] J. Moore, "Predators and Prey: A new Ecology of Competition", *Harvard Business Review*, 1993, May/June.

[7] S. Nambisan, and M. Sawney, *The Global Brain: Your Roadmap for Innovating Faster and Smarter in a Networked World,* Upper Saddle River, NJ: Wharton School Publishing/Pearson Press, 2007.

[8] G. Lorenzoni, and C. Baden-Fuller, "Creating a Strategic Center to Manage a Web of Partners", *California Management Review*, 1995, 37(3), 146-163. C. Dhanaraj, and A. Parkhe, "Orchestrating Innovation Networks", *Academy of Management Review*, 2006, 31(3), 659-669. S. Nambisan, and M. Sawhney, "Orchestration Processes in Network-Centric Innovation: Evidence from the Field", *Academy of Management Perspectives*, 2011, August, 40-57.

[9] Ibid.

[10] A. Gawer and M. Cusumano, *Platform Leadership: How Intel, Microsoft, and Cisco Drive Industry Innovation*, Harvard Business School Press, 2002. A. Gawer and M. Cusumano, "How Companies become Platform Leaders", *MIT Sloan Management Review,* 2008, 49 (2), 29-30.

[11] Information on IMEC was collected from two sources: (1) internal company documents and; (2) interviews with IMEC managers. Data through interviews were collected during the period 2010-2013 starting with exploratory and unstructured interviews providing general information about IMEC's innovation ecosystems and the IP model applied in the IAPs. Next, we interviewed several leading IP and strategy experts at IMEC using an interview guide reflecting the theoretical framework we constructed based on the information from the exploratory interviews. Finally, our understanding of IMEC's ecosystem strategy and IP model was further refined during a few focused interviews during which ambiguities about specific details of the model were clarified with IMEC's IP managers. Each of these interviews lasted between one and two hours. We prepared transcripts of the interviews and conducted follow-up phone calls with the interviewees. Appendix 1 contains more detailed information on the date of the interviews, the attendees, and the main topics discussed. In order to increase reliability, different researchers conducted different interviews. This should enhance reliability of the conclusions. Each interview was recorded, transcribed, and the transcription was discussed among researchers to arrive at a common understanding. To further increase reliability researchers discussed their understanding of the IMEC model with IMEC management at several occasions. To increase internal validity, we constructed a framework of the IP model after the first exploratory interviews when management explained their views on the model. During the next interviews we gradually converged to the final model where we reached consistency between the views about all details. Studying IP-based orchestration models is fairly new so that pattern matching (a comparison between patterns observed in this study and those in previous studies) is fairly difficult. Although external validity (generalizability) is problematic with a research design such as the current one, the main objective is to employ analytical generalization—from empirical observation to theory building (R. Yin, Case Study Research-Design and Methods, Thousand Oaks (CA): Sage Publications, 200). Therefore, we make no claim to generalize the findings beyond the current industry. Further empirical analysis of ecosystems in other industries could significantly improve external validity and therefore represents a promising area of future inquiry.

[12] Complexity relates in this case to the embryonic nature of the technologies are development, which coincides with high levels of uncertainty on the most promising technological routes to advance the technology.

[13] Besides in Leuven, where the main research labs are located, IMEC has R&D centers in the Netherlands, India, and Taiwan and representation offices in China, Japan, and the USA.

[14] Flanders is the Dutch-speaking region of Belgium where more than 50% of the population resides.

[15] R. Nelson, "The Simple Economics of Basic Scientific Research", *The Journal of Political Economy*, 1959, 67(3), 297-306.

[16] A. Gawer and M. Cusumano, "How Companies become Platform Leaders", *MIT Sloan Management Review,* 2008, 49 (2), 29-30.

[17] S. Nambisan, and M. Sawney, *The Global Brain: Your Roadmap for Innovating Faster and Smarter in a Networked World,* Upper Saddle River, NJ: Wharton School Publishing/Pearson Press, 2007.

[18] S. Nambisan, and M. Sawhney, "Orchestration Processes in Network-Centric Innovation: Evidence from the Field", *Academy of Management Perspectives*, 2011, August, 40-57.

[19] A. Gawer and M. Cusumano, *Platform Leadership: How Intel, Microsoft, and Cisco Drive Industry Innovation*, Harvard Business School Press, 2002.

[20] The standard rule is that co-ownership takes the form of co-patents. IMEC provides co-owners the freedom to license, but they make agreements on litigation as IMEC wants to limit the number of cases in which they end up as a plaintiff in a litigation lawsuit against a firm that is a partner in one of the IAPs. Collaboration contracts contain litigation clauses that state that patent co-assignees first have to try to reach a mutual agreement with a potential patent infringer before going to trial. When reaching an agreement is not possible and a co-owner initiates an infringement lawsuit, IMEC will mostly take a passive role in which they do not contribute to the costs, and do not share in the potential revenues, from the lawsuits. While co-ownership is the standard rule, IMEC prefers single-ownership coupled to a license with sublicensing rights for their partner and will try to negotiate this. There are two reasons why single-ownership is preferred. First, it gives IMEC more control over their patents. Second, it reduces the patent administration and governance costs.

[21] B. Cassiman, R. Veugelers, and S. Arts, "*How to Capture Value from Linking to Science-driven Basic Research: Boundary Crossing Inventors and Partnerships*", Working Paper, KU Leuven, 2011.

[22] S. Nambisan, and M. Sawhney, "Orchestration Processes in Network-Centric Innovation: Evidence from the Field", *Academy of Management Perspectives*, 2011, August, 40-57. A. Gawer and M. Cusumano, "How Companies become Platform Leaders", *MIT Sloan Management Review,* 2008, 49 (2), 29-30.

[23] Information on the innovation ecosystem of IBM is based on: Shih, W., Pisano, G., and King A. (2008), Radical collaboration: IBM microelectronics joint development alliances (HBS case and Teaching Note).

[24] This also translates into a different mix of partners in both innovation ecosystems.

[25] The reason is that each orchestrator has a different task and work content.

[26] SEMATECH (Semiconductor Manufacturing Technology) started as a consortium of semiconductor manufacturers to develop next-generation manufacturing technology. Today, it has broader industry participation, including IDMs, foundries, fabless, OSATs, equipment, and material suppliers. Member firms participate in pre-competitive research programs on semiconductor technologies, and get –conditional upon their membership fee- access (licenses) to all the research results of the programs (P. Grindley, D. Mowery, B. Silverman, "SEMATECH and collaborative research: Lessons in the design of high-technology consortia", *Journal of Policy Analysis and Management*, 1994, 13(4), 723-758; www.sematech.org).

[27] The Structural Genomics Consortium (SGC) is a consortium of pharmaceutical companies, universities, and public and charitable organizations that does research on 3D structures of proteins relevant for human health. The research results are made freely available by publishing and depositing protein structures in an open protein databank (M. Perkmann, "Trading off revealing and appropriating in drug discovery: The role of trusted intermediaries", *Best Paper Proceedings of the 2009 Academy of Management Meeting*).

[28] A-P De Man (2006); Alliantiebesturing: Samenwerking als precisie-instrument, Koninklijke Van Gorcum/ Stichting Management Studies, Chapter 7.

[29] Product design complexity can be used as an alternative to patents to appropriate innovation returns.

[30] For confidentiality reasons we cannot provide the exact number of IMEC researchers working on the 3D IAP. We can only say that this number is several times higher than the number of industrial residents.

[31] M. Cusumano, *Staying Power: Six Enduring Principles for Managing Strategy and Innovation in an Unpredictable World,* Oxford University Press, 2010.

[32] Ibid.