Europe's dependence on Chinese semiconductor manufacturing

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Abstract

This chapter argues that Europe is increasingly dependent on Chinese semiconductor manufacturing capacity. This is especially true for the final production steps in semiconductor manufacturing: assembly, testing and packaging. While Europe has tried to incentivise the construction of new wafer fabrication capacity in Europe, this final production step has so far received very little attention from policymakers. The chapter argues that an overreliance on Chinese packaging capacity is detrimental to member states' security and Europe's long-term technological competitiveness. The authors suggest several concrete policy actions to strengthen Europe's advanced packaging ecosystem and close collaboration with allies to ensure long-term technological competitiveness vis-à-vis China.

Semiconductors have received considerable attention from policymakers in recent years. They are at the centre of the US-Chinese technology rivalry, and their importance to the automotive industry and many other sectors has become painfully clear during the COVID-19 pandemic and the resulting chip shortages.[24] Several governments have devised plans to invest substantially in their domestic semiconductor industries in order to alleviate current and future supply constraints, strengthen the technological competitiveness of their domestic semiconductor ecosystems and reduce dependence on foreign technology providers.

Europe's efforts in this regard, as set out in the *2030 Digital Compass*,[25] the *Joint Declaration on Processors and Semiconductor Technologies*,[26] and the updated

[24] Jan-Peter Kleinhans and Julia Hess, *Understanding the Global Chip Shortages: Why and How the Semiconductor Value Chain was Disrupted*, Stiftung Neue Verantwortung, November 2021, https://www.stiftung-nv.de/sites/default/files/understanding_the_global_chip_shortages.pdf.

[25] European Commission, *2030 Digital Compass: The European Way for the Digital Decade*, March 2021, https://ec.europa.eu/newsroom/dae/redirection/document/75375.

[26] Joint Declaration, "A European Initiative on Processors and semiconductor technologies", 7 December 2020, https://ec.europa.eu/newsroom/dae/redirection/document/73940.

New Industrial Strategy,[27] are predominantly focused on strengthening capabilities in chip design and front-end fabrication – the first two of the three semiconductor production steps. Increasing the EU's front-end fabrication capacity (building new or expanding existing fabrication plants, or "fabs") has received the most attention from European policymakers. The Digital Compass states that Europe needs to invest in "manufacturing capacities below 5nm nodes aiming at 2nm" within this decade, while the above-mentioned Joint Declaration wants "to strengthen Europe's capabilities to design and eventually fabricate the next generation of trusted, low-power processors".

While Europe's focus on incentivising the construction and expansion of cutting-edge front-end fabs is understandable, it is certainly not the only process step on which Europe is highly dependent on foreign technology providers, specifically China. The third step in semiconductor manufacturing – assembly, test and packaging (ATP), which is also referred to as the "back-end" – has by contrast received little attention from European policymakers. Europe's severe lack of back-end fabs and dependence on Chinese back-end capacity is detrimental to member states' security and long-term economic competitiveness.

This paper first introduces the back-end production steps of semiconductor manufacturing and their increasing importance for future energy efficiency and chip performance. It then reviews the rise of Chinese ATP companies and how Chinese government policies support the development of packaging technology in China. The final section elaborates on why dependence on Chinese back-end capacity creates substantial national security risks and threatens Europe's economic competitiveness.

The role of assembly, test and packaging in semiconductor manufacturing

As noted above, semiconductor manufacturing consists of three distinct steps: chip design, wafer fabrication (front-end), and assembly, test and packaging (or back-end). During wafer fabrication in a front-end fab, integrated circuits are etched on to a wafer using hundreds of chemicals and more than 1000 process steps. During ATP in a back-end fab, the individual integrated circuits (from dozens to hundreds) are tested, cut out of the wafer and encapsulated in protective cases. Wafer fabrication is highly capital intensive with almost insurmountable barriers to market entry at the cutting-edge.[28] ATP, by contrast, has historically been labour intensive with less complicated process steps that rely on cheaper

[27] European Commission, "Updating the 2020 New Industrial Strategy", COM(2021) 350, 2021, https://ec.europa.eu/info/sites/default/files/communication-industrial-strategy-update-2020_en.pdf.

[28] Jan-Peter Kleinhans, "The Lack of Semiconductor Manufacturing in Europe", SNV Policy Paper, April 2021, https://www.stiftung-nv.de/en/node/3045.

equipment, resulting in substantially lower capital expenditure for fabs, lower research and development margins, but also substantially lower value-add compared to chip design and wafer fabrication.[29]

Historically, integrated device manufacturers (IDM), such as Infineon, NXP or ST Microelectronics, took care of ATP in-house in their own back-end fabs. Back-end processes are also often outsourced to foundries such as TSMC or Globalfoundries, however, or to specialist outsourced semiconductor assembly and test (OSAT) companies such as ASE Group or Amkor Technologies.[30]

The economics of back-end manufacturing – relatively labour-intensive with low value-add and narrow profit margins – led increasingly to it being outsourced to China, Taiwan and other countries in Southeast Asia. While the back-end market is substantially less concentrated by market share than cutting edge front-end manufacturing, it is to some extent geographically concentrated. More than 60% of global ATP capacity is currently located in Taiwan and China,[31] which includes the back-end fabs of Western companies located in China and Taiwan.[32] Chinese OSAT companies have been especially successful, growing their global market share to around 20% by 2020.[33]

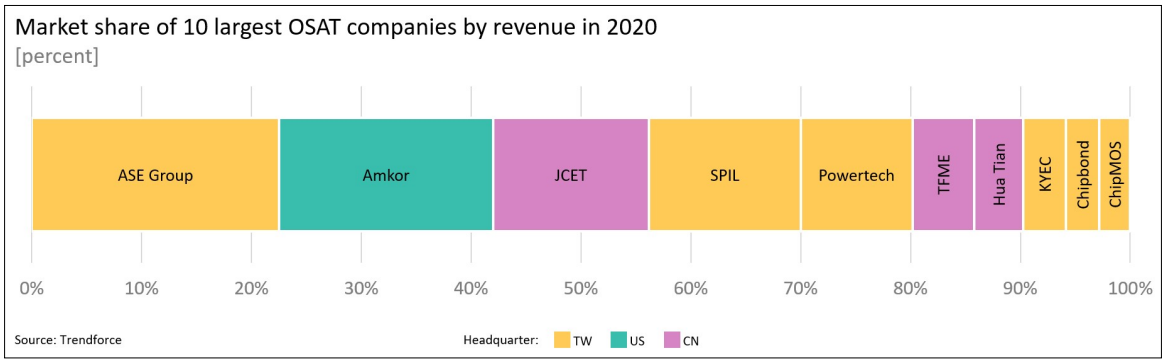

Figure 1: Market share of 10 largest OSAT companies by revenue in 2020 in percent. Source: Own graphic.

[29] Antonio Varas et al., *Strengthening the Global Semiconductor Supply Chain in an Uncertain Era*, Semiconductor Industry Association, April 2021, https://www.semiconductors.org/wp-content/uploads/2021/04/SIA-BCG-Report_Strengthening-the-Global-Semiconductor-Supply-Chain_April-2021.pdf.

[30] Jan-Peter Kleinhans and Nurzat Baisakova, "The Global Semiconductor Value Chain", SNV Policy Paper, October 2020, https://www.stiftung-nv.de/en/publication/global-semiconductor-value-chain-technology-primer-policy-makers.

[31] Semiconductor Industry Association, Public Comment on 86 FR 14308 Semiconductor Manufacturing and Advanced Packaging Supply Chain NOI (Bureau of Industry and Security), Public Comment 79, 6 April 2021, https://www.regulations.gov/comment/BIS-2021-0011-0080.

[32] Like many other Western IDMs and foundries, Infineon, NXP and STMicroelectronics all operate back-end fabs in China.

[33] Manish Nigam et al., "Asia Technology Strategy, China: Can it gain tech independence?" Credit Suisse, 2019.

The rise of Chinese industry in the ATP sector

The back end of the semiconductor value chain is receiving sustained attention from policymakers in China. The Chinese state, from senior leaders in Beijing down through provincial and municipal governments, is focused on promoting coordinated development of the entire value chain, including investment in ATP capacity expansion and technological advances.[34] This presents challenges for Europe – in terms not just of the semiconductor value chain, but also of the multiple industries and technological ecosystems built on it. It has far-reaching implications for national security and the global balance of economic, political and ideational power.

The cost incentives for outsourcing the value chain's back-end to East Asia have had dramatic results. China had become the largest (25%) market for semiconductor packaging materials by 2019, followed by Taiwan, South Korea and Japan.[35] With support from China's state-directed semiconductor industry investment fund, Chinese ATP leaders expanded massively through mergers and acquisitions, while at the same time upgrading their technological capabilities.[36] Further expansion by this path has been blocked by the Taiwanese authorities, however, and in the current geopolitical environment Chinese OSAT firms will need to rely primarily on their own resources and domestic support for any further advances.[37]

"Advanced" packaging techniques, such as heterogeneous integration and 3D stacking, allow chip designers to integrate even more functionality into a single chip, where such functions had previously been separated across multiple chips. Higher levels of integration mean closer proximity to different functionalities and thus higher energy efficiency of the final chip. Numerous advanced packaging techniques are currently being explored by IDMs, foundries and OSATs in an attempt to grow this future market. Advanced packaging still accounts for a minority share of the revenues of Chinese OSAT leaders – by one estimate, around 20%.[38] Nonetheless, these Chinese firms are now pushing the technological frontier in some areas.[39] The leading Chinese firm, JCET, for example,

[34] John Lee and Jan-Peter Kleinhans, "Mapping China's Place in the Global Semiconductor Industry", The Diplomat, 7 September 2021, https://thediplomat.com/2021/09/mapping-chinas-place-in-the-global-semiconductor-industry/.
[35] IHS Markit, "Electronic Chemicals: PCB Chemicals and Semiconductor Packaging Materials", December 2019, https://ihsmarkit.com/products/pcb-chemicals-semiconductor-packaging-materials.html.
[36] John Lee and Jan-Peter Kleinhans, "Mapping China's Semiconductor Ecosystem in Global Context: Strategic Dimensions and Conclusions", MERICS & SNV Policy Paper, 30 June 2021, https://merics.org/en/report/mapping-chinas-semiconductor-ecosystem-global-context-strategic-dimensions-and-conclusions.
[37] Nikkei Asian Review, "Tsinghua Unigroup-SPIL Deal Axed on Policy Worries", 28 April 2016, https://asia.nikkei.com/Business/Tsinghua-Unigroup-SPIL-deal-axed-on-policy-worries.
[38] Litho World, "Current Status of the Integrated Circuit Industry in China: IC Manufacturing Industry", December 2019, https://www.researchgate.net/publication/338341090_Current_Status_of_the_Integrated_Circuit_Industry_in_China_-_Packaging_and_Testing_Industry_Review.
[39] Litho World, "Current Status of the Integrated Circuit Industry in China: IC Manufacturing Industry",

which is now the third largest packaging firm globally by sales, employs cutting-edge techniques such as 2.5 & 3D (heterogenous) packaging.[40]

Chinese OSAT leaders can profitably expand their capacity and R&D activities thanks to demand for semiconductors from the wider Chinese economy for applications such as 5G telecoms infrastructure, electric vehicles and consumer electronics. Due to the way in which these firms have expanded, they also enjoy established relations with US customers, such as chip design leader AMD, which further buttresses their revenue base.[41] China's OSAT leaders are all reportedly planning secondary public offerings to raise capital to invest in capacity expansion and advanced packaging techniques.[42]

Chinese OSAT leaders will also benefit from the local concentration of the *printed circuit board (PCB) substrate industry***.** PCBs are the internal "mounting plates" for all the chips and semiconductors in an assembled electronic system.

While PCB manufacturers are not considered semiconductor companies, they play a crucial role in the electronics industry. The PCB industry is increasingly closely related to the semiconductor value chain's back-end, as performance demands in consumer electronics drive PCB vendors to pursue miniaturisation.[43] The global PCB supply chain is now concentrated in China, and Chinese suppliers are growing their share in a market dominated by Taiwanese, South Korean and Japanese firms.[44] In 2019, China accounted for over half the global market for the chemicals used in PCB production, and was the fastest growing market followed by Taiwan and South Korea.[45]

In this context, Chinese OSAT leaders are well placed to pursue advanced packaging. Advanced packaging techniques are being promoted by Chinese industry experts as an alternative to the increasing technical difficulty of shrinking fabrication nodes that is implied by "Moore's Law", which is now approaching its physical limits. This technical difficulty is a

December 2019, https://www.researchgate.net/publication/338341090_Current_Status_of_the_Integrated_Circuit_Industry_in_China_-_Packaging_and_Testing_Industry_Reviewe.

[40] Henrik Bork and Michael Eckstein, "Neue Ära: China setzt auf Advanced Packaging und Testing", Elektronik Praxis, 20 April 2021, https://www.elektronikpraxis.vogel.de/neue-aera-china-setzt-auf-advanced-packaging-und-testing-a-1016761/.

[41] TrendForce, "Revenue of top 10 OSAT companies for 2Q21 reaches US$7.88 billion due to strong demand and increased package/test prices, says TrendForce", 6 September 2021, https://www.trendforce.com/presscenter/news/20210906-10926.html.

[42] Henrik Bork and Michael Eckstein, "Neue Ära: China setzt auf Advanced Packaging und Testing", Elektronik Praxis, 20 April 2021, https://www.elektronikpraxis.vogel.de/neue-aera-china-setzt-auf-advanced-packaging-und-testing-a-1016761/.

[43] IHS Markit, "Electronic Chemicals: PCB Chemicals and Semiconductor Packaging Materials", December 2019, https://ihsmarkit.com/products/pcb-chemicals-semiconductor-packaging-materials.html; Pinsheng Electronics, "Substrate-like PCB: The highlight in the future PCB industry", 13September 2021, https://www.quick-pcba.com/pcb-news/substrate-like-pcb-technology.html.

[44] Macquarie Research, "China PCB sector: Growing dominance in the 5G era", 2019.

[45] IHS Markit, 2019, "Electronic Chemicals: PCB Chemicals and Semiconductor Packaging Materials", December 2019, https://ihsmarkit.com/products/pcb-chemicals-semiconductor-packaging-materials.html.

critical bottleneck for China's semiconductor industry, and advanced packaging is being pursued as an alternative pathway, for example at SMIC, China's leading foundry.[46]

The imposition of US export controls on SMIC – and SMIC's inability to acquire certain advanced machinery (such as an EUV stepper from the Dutch equipment maker, ASML) that is indispensable for recent generation fabrication nodes – has highlighted the imperative for China's semiconductor industry as a whole to seek alternative technical pathways simply to keep pace with technological progress, and to mitigate the risk that foreign "decoupling" measures could choke off Chinese industry's capacity to continue to advance semiconductor performance.

With little prospect of catching the global leaders in front-end fabrication – TSMC, Samsung and Intel – through node shrinkage, SMIC is likely to focus instead on advanced packaging.[47] This is reflected in SMIC's most recent round of investments, which includes a 12-inch wafer and packaging project that commenced construction in January 2021.[48] The incentives steering Chinese firms towards advanced packaging are reinforced by government policy, which at senior levels now appears to be focused on "post-Moore" technical approaches in order to circumvent the constraints on Chinese industry.[49]

Chinese state policy: pushing technological advances and the development of an integrated value chain

China's 14th Five-year Plan (FYP), which was launched in March 2021, lists semiconductors as one of seven "frontier technologies" prioritised for national breakthroughs. Although the FYP makes no direct reference to advanced packaging techniques, these are likely to feature in the anticipated 14th Five-year Plan for Science and Technology Innovation, currently being developed by China's Ministry of Industry and information Technology, which will implement the FYP's strategic guidance in more specific terms. Advanced packaging should also be

[46] Iris Deng, "China must pursue chip assembly, packaging breakthroughs to catch up with semiconductor leaders, experts say" South China Morning Post, 9 June 2021, https://www.scmp.com/tech/policy/article/3136688/china-must-pursue-chip-assembly-packaging-breakthroughs-catch; Che Pan, "SMIC urges China's chipmakers to embrace advanced packaging as Moore's Law slows nanometre node progress and US sanctions bite", South China Morning Post, 25 January 2021, https://www.scmp.com/tech/big-tech/article/3119174/smic-urges-chinas-chipmakers-embrace-advanced-packaging-moores-law.

[47] Tim Culpan, "An $11 Billion Distraction for China's Chip Ambitions", Bloomberg, 6 September 2021, https://www.bloomberg.com/opinion/articles/2021-09-06/china-is-pouring-billions-of-dollars-into-old-chip-technology.

[48] EET China, "半导体一周要闻 - 莫大康", 2021, https://www.eet-china.com/mp/a75048.html.

[49] Minghe Hu, "China wants to boost disruptive semiconductor technologies as Moore's Law moves towards its limit", South China Morning Post, 15 May 2021, https://www.scmp.com/tech/article/3133613/china-wants-boost-disruptive-semiconductor-technologies-moores-law-moves.

expected to appear in a potential new Medium- to Long-term Plan for Science and Technology Development, which will supersede its 2006–2020 iteration.[50]

These plans will probably be accompanied by one or more new national "special projects" on semiconductor R&D, which would be successors to two such 15-year projects that concluded in 2020. These special projects brought together research institutes, state-owned enterprises and private sector companies in efforts to plug capability gaps in China's domestic industry and develop new technologies. They included several items concerned with packaging technology. China's three leading ATP firms participated in these projects, assisting their progress in advanced packaging techniques.

Semiconductor industry development plans are being promulgated by many of China's sub-national governments, and many of these plans emphasise packaging technologies. For example, the City of Shanghai and Jiangsu Province – both important centres of China's semiconductor industry – are promoting ATP and specific advanced packaging techniques in their 14th FYP implementation plans.[51] These plans emphasise coordinated and holistic development of the semiconductor value chain and aim to create synergies between different steps to mutually catalyse technological progress.

This approach is backed by China's state-directed investment fund for the semiconductor sector – the Big Fund. The goal, to quote the Big Fund's manager, is to "increase cooperation between domestic enterprises, truly realise upstream and downstream integration, and create a virtual IDM [integrated device manufacturer] model".[52] In light of enhanced measures by the US government to restrict Chinese firms' access to semiconductor-related technologies and equipment, leaders in Beijing perceive that long-term national economic security depends on building up the capacities of domestic industry throughout the value chain, of which back-end processes are an indispensable element.

In this context, Beijing will seek to shape the evolution of the global packaging sector, including through measures that support Chinese firms and potentially discriminate against foreign ones, in the service of national strategic objectives. President Xi Jinping has said that China must "pull tight" international supply chains, and practice punitive deterrence against attempts by foreigners to

[50] John Lee and Jan-Peter Kleinhans, "Mapping China's Place in the Global Semiconductor Industry", The Diplomat, 7 September 2021, https://thediplomat.com/2021/09/mapping-chinas-place-in-the-global-semiconductor-industry/.

[51] Shanghai Municipal Government, "14th Five-Year Plan for the Development of Advanced Manufacturing Industry in Shanghai" (in Chinese), 2021, https://www.shanghai.gov.cn/nw12344/20210714/0a62ea7944d34f968cbc49eec47dbca.html; Jiangsu Provincial Government, "The 14th Five-Year Plan of Nanjing's Jiangbei New Area" (in Chinese), 2021, http://www.jiangsu.gov.cn/art/2021/8/23/art_46144_9984347.html.

[52] East Money Securities, "The Big Fund's First Phase investments have been most fruitful, Phase Two is ready for launch" (in Chinese), 2019, http://data.eastmoney.com/report/zw_industry.jshtml.

interrupt Chinese industry's supply chains.[53] European strategic planning must account for this holistic and increasingly adversarial mindset that is guiding Chinese industrial policy, and for the implications of the concentration in China of seemingly innocuous and – for the time being – relatively low value-added back-end processes for manufacturing semiconductors.

The risks of overreliance on Chinese back-end manufacturing

Reliance on Chinese OSAT companies and back-end fabs in China creates potential *national security challenges.* Packaging is the most viable production step for an adversary to compromise a chip by hiding additional functionality in it, such as a hardware "backdoor" or a "kill switch".[54] This national security dimension is the reason why the US government's 100-day supply chain review for semiconductors, finalised in June 2021, specifically includes the mapping of dependencies and potential vulnerabilities in the packaging supply chain.[55] Domestic front-end fabs do not alleviate this risk. Even if wafer fabrication is carried out domestically, if the finished wafers are sent to China for ATP the chips could still be compromised during the packaging processes.[56]

There is a further *economic challenge* for the European semiconductor ecosystem if it lacks technological competitiveness in advanced packaging. Improvements in advanced packaging, such as heterogeneous integration, will play a critical role in future chip design.[57] While semiconductor manufacturing was historically all about improvements in the fabrication process (front-end fabs), these improvements now have diminishing returns – the "death" of Moore's Law.[58] Thus, companies are focused more and more on innovations in packaging to make chips more energy efficient and more powerful.[59] While Europe is strong in advanced

[53] Qiushi, "General Secretary Xi Jinping: Industry chains and supply chains must not fall off at critical times" (in Chinese), 2020, http://www.qstheory.cn/zhuanqu/2020-11/03/c_1126690768.htm .
[54] John Lee and Jan-Peter Kleinhans, "Mapping China's Semiconductor Ecosystem in Global Context: Strategic Dimensions and Conclusions", MERICS & SNV Policy Paper, 30 June 2021, https://merics.org/en/report/mapping-chinas-semiconductor-ecosystem-global-context-strategic-dimensions-and-conclusions.
[55] The White House, *Building Resilient Supply Chains, Revitalizing American Manufacturing, and Fostering Broad-Based Growth*, 100-Day Reviews under Executive Order 14017, June 2021, https://www.whitehouse.gov/wp-content/uploads/2021/06/100-day-supply-chain-review-report.pdf
[56] Tiago Perez and Samuel Pagliarini, "A Survey on Split Manufacturing: Attacks, Defenses, and Challenges", 7 October 2020, https://doi.org/10.1109/ACCESS.2020.3029339.
[57] IEEE, "Heterogeneous Integration Roadmap, Chapter 2: High Performance Computing and Data Centers", October 2019, https://eps.ieee.org/images/files/HIR_2019/HIR1_ch02_hpc.pdf.
[58] Samuel K. Moore, "A better way to measure progress in semiconductors", *IEEE Spectrum*, 21 July 2020, https://spectrum.ieee.org/a-better-way-to-measure-progress-in-semiconductors.
[59] IEEE, "Heterogeneous Integration Roadmap", 2021 Symposium, 2019 edition, https://eps.ieee.org/technology/heterogeneous-integration-roadmap.html.

packaging R&D,[60] it has a severe lack of domestic packaging capacity.

Increased reliance on Chinese back-end services would provide a supply chain chokepoint through which Beijing could exert *political pressure* of the kind used against Sweden, Germany and other EU member states concerning Huawei and 5G networks.[61] China's new counter-sanctions law – and the scope for retaliation against foreign actions that is provided for in Chinese legislation such as the Foreign Investment Law and Data Security Law, which likewise can be exercised with extraterritorial jurisdiction – indicate that Beijing intends increasingly to have the option of directly punishing foreign businesses, to shape development of transnational technological ecosystems such as the semiconductor value chain in ways that favour Chinese firms.[62]

Finally, a global economy in which Chinese firms shape technological ecosystems *will present ideational challenges* for Europe. As the European Commission's Strategic Foresight Report puts it, "setting favourable conditions across the value chain" is essential to the EU's capacity and freedom to act on the global stage.[63] If Chinese firms take the lead in advanced packaging, this will have advantageous flow-on effects for China's wider semiconductor sector and other industry verticals, such as the automotive sector as it transitions to increasingly electrified and computerised vehicles.

This will erode European firms' competitiveness along the semiconductor value chain and in the many industry verticals that depend on it, which in turn means diminished influence vis-à-vis Beijing's regulatory and political preferences. Ideational power as expressed in technological ecosystems is based on economic competitiveness and market share. For example, advanced packaging capabilities in China could support local development of AI accelerators and hence Chinese-developed AI solutions. These products would be shaped by the Chinese state's frameworks for data regulation and ethical governance of AI, which could displace European approaches in these fields internationally if Chinese products enjoy a competitive advantage linked to the underlying domestic semiconductor ecosystem.

More immediately, the Chinese authorities are increasingly involving themselves in domestic supply chain mapping and management, and increasingly requiring extensive data exchanges with

[60] The leading semiconductor research and technology organisations (RTO) in Europe – CEA-Leti, Fraunhofer and imec – are all heavily invested in cutting-edge advanced packaging and heterogeneous integration research.

[61] Politico, "Sweden faces Chinese blowback over Huawei ban", 21 January 2021, https://www.politico.eu/article/sweden-faces-chinese-blowback-over-huawei-ban/.

[62] Katja Drinhausen and Helena Lagarda, "China's Anti-Foreign Sanctions Law: A warning to the world", MERICS, 24 June 2021, https://merics.org/en/short-analysis/chinas-anti-foreign-sanctions-law-warning-world.

[63] European Commission, "2021 Strategic Foresight Report: Enhancing the EU's long-term capacity and freedom to act", COM(2021) 750, 2021, https://ec.europa.eu/info/sites/default/files/foresight_report_com750_en.pdf.

industry.[64] These impositions will be made unavoidable for European actors by the packaging sector's concentration in China, which will increasingly challenge European preferences regarding appropriate levels of government intervention in private sector business operations. It will also expose European interests to growing visibility and exercise of leverage on the part of the Chinese authorities, which is likely to be wielded in the service of Chinese political priorities.

Unfortunately, ATP does not play any role in Europe's semiconductor strategy as laid out in the 2030 Digital Compass and the Joint Declaration on Processors and Semiconductor Technologies. The strong focus on incentivising semiconductor companies to invest in cutting-edge front-end fabs in Europe ignores the fact that finished silicon wafers would still need to be shipped to Taiwan or China for assembly, test and packaging. It also underestimates the importance of advanced packaging and heterogeneous integration to future chip development, and hence its importance to the European semiconductor ecosystem in gaining technological leadership.

Conclusions and recommendations for Europe

While Europe is right to invest in front-end fabs, this should not be the sole focus of the EU's semiconductor strategy. Europe and its semiconductor manufacturers are already heavily dependent on Chinese back-end capacity, a dependence that presents a potential national security threat and threatens a loss of technological competitiveness. Europe would do well to invest in its back-end capacity in the same way that it is currently incentivising the construction of front-end fabs. Four immediate recommendations to strengthen Europe's position and competitiveness in the semiconductor packaging sector are set out below.

- *Incentivise the construction of new and the expansion of existing back-end fabs, with a focus on advanced packaging capabilities*. The IPCEI Microelectronics 2 should be used not only to subsidise the construction of front-end fabs, but also to strengthen back-end capacity. The focus should be on advanced packaging and heterogeneous integration.
- *Include advanced packaging in EU monitoring initiatives:* The new EU Observatory for Critical Technologies should monitor China's role in the global semiconductor value chain, including advanced packaging.[65] Information-sharing channels should be put in place with other

[64] See e.g. "Jiangmen City Bureau of Industry and Information Technology: Concerning the issuance of the 'work plan on ensuring the stability of industrial and supply chains"', 2021, http://www.jiangmen.gov.cn/bmpd/jmsgyhxxhj/ywfl/ghyyxjck/content/post_2071311.html (in Chinese).

[65] European Commission, "Action Plan on synergies between civil, defence and space industries", COM(2021) 70, 2021, https://ec.europa.eu/info/sites/default/files/com-2021-70_en_act_part1_v8_en.pdf.

European monitoring initiatives on Chinese technology policy, espionage and corporate activity.

- *Strengthen cooperation with international partners in advanced packaging:* The Japanese government is subsidising construction of a joint advanced packaging R&D centre together with TSMC, and Japanese equipment vendors and chemical suppliers.[66] In their current conversations with international technology providers such as Intel and TSMC, European governments should devise long-term strategic partnerships on advanced packaging and heterogeneous integration. Back-end fabs are significantly less expensive than front-end fabs with substantially lower barriers to market entry, making them ideal candidates for joint investment.
- *Discuss advanced packaging with the Biden administration in the new EU-US Trade and Technology Council:* "supply chain security" and "ICT security and competitiveness" are among the designated topics for discussion by the Council, which met for the first time on 29 September 2021.[67] The advanced packaging R&D being conducted by US companies with the support of the US Department of Defense provides a potential focus for these discussions.[68]

The packaging sector is just one example of how China's growing prominence in the global semiconductor value chain is raising critical issues for European policymakers. Various open and emerging questions can only be addressed by combining a deep technical understanding of the semiconductor sector with expertise on China's political economy and policy priorities. This combined skillset provides the best foundation on which to build analyses of China's changing role in the global semiconductor ecosystem, and of how best to strengthen Europe's semiconductor sector in response while also positioning Europe in the context of deepening US-Chinese global rivalry over critical technologies. This should not be a short-term or one-off exercise but requires an ongoing commitment to supporting high-quality research that brings together technology- and China-oriented analysts. In an increasingly competitive international environment, policymakers would be well served by access to an accurate and dynamic picture of China's role in the semiconductor value chain and its impacts on European interests.

[66] Phil Garrou, "TSMC Considering Chip Packaging in Japan; US "On Shoring" Report Issued", 3D Incites, 3 August 2021, https://www.3dincites.com/2021/08/iftle-493-tsmc-considering-chip-packaging-in-japan-us-on-shoring-report-issued/.

[67] European Commission, "Trade and Technology Council: US and EU announce inaugural meeting", Press release, 9 September 2021, https://trade.ec.europa.eu/doclib/press/index.cfm?id=2298.

[68] NSTXL, "DoD and S2MARTS Impacting the Microelectronics Ecosystem through the Rapid Assured Microelectronics Prototypes–Commercial (RAMP-C) Project" [n.d.], https://nstxl.org/dod-and-s2marts-impacting-the-microelectronics-ecosystem-through-the-rapid-assured-microelectronics-prototypes-commercial-ramp-c-project/.

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