

Chapter 3: Chemicals, Gases and Photoresist

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CHAPTER

03

STAGE 3 OF 15

Chemicals, Gases and Photoresist

Japanese companies held 78 percent of world photoresist sales in 2023. Supply of chip chemicals, gases and metals has been disrupted three times since 2019.

IN PLAIN TERMS

Photoresist is a coating that changes wherever light hits it. A machine spins a coat of it, thinner than a soap bubble, across the wafer. Light shines through a stencil onto the coat, and a liquid wash then takes away the parts the light reached. What remains is a pattern, and the next machine cuts that pattern into the wafer beneath, a step called etching. Hundreds of other chemicals, gases and materials lay down layers, strip them off and clean the wafer between steps ¹⁵. The cleaning chemicals are purified until metal and other impurities are down to parts per trillion, the Japanese chemical maker Sumitomo Chemical said in 2021 ¹⁶. A chipmaker has to test and approve each new resist in its own factory before using it ⁹. Even a resist that passes the first time takes seven to 17 months to approve, the Semiconductor Industry Association wrote in 2023 ⁹. Japanese companies held 78 percent of world photoresist sales in 2023, by a Fuji Keizai survey that Japan's trade ministry reproduced ¹³.

15 Testimony of the Semiconductor Industry Association (SIA) before the Senate Committee on Environment & Public Works. U.S. Senate Committee on Environment and Public Works · 4 March 2026 · p. 6 [\[A\]](#)
www.epw.senate.gov/public/_cache/files/a/c/ac4552ff-551b-40d5-bea6-19dd17a1cfea/1F7BCD91016CBE352434701BE58395874BEA6A892A23ABEE1D7214EC924EC0EB.03-04-2026-isaacs-testimony.pdf#page=6

16 Sumitomo Chemical to Expand Production Capacity for High-Purity Chemicals for Semiconductors at its Ehime Works and in South Korea. Sumitomo Chemical · 24 August 2021 [\[A\]](#) www.sumitomo-chem.co.jp/english/news/detail/20210824e1.html

9 PFAS-Containing Photo-Acid Generators Used in Semiconductor Manufacturing. Semiconductor Industry Association (Semiconductor PFAS Consortium Photolithography Working Group) · 8 June 2023 · p. 22 [\[A\]](#) www.semiconductors.org/wp-content/uploads/2023/06/FINAL-PAG-Case-Study.pdf#page=22

13 METI, Semiconductor and digital industry strategy: future direction (半導体・デジタル産業戦略の今後の方向性), 23 December 2025. Ministry of Economy, Trade and Industry (Japan) · 23 December 2025 · p. 8 [\[A\]](#)
www.meti.go.jp/policy/mono_info_service/joho/conference/semicon_digital/0014/handeji14-4.pdf#page=8

IN SHORT

In July 2019 Japan began requiring an export license for each contract to sell photoresist, hydrogen fluoride or fluorinated polyimide to South Korea ¹⁰. Japan's hydrogen fluoride exports to South Korea then fell 87.9 percent, but its photoresist exports did not ¹⁰. Production of all three chemicals rose inside South Korea ¹⁰.

China banned exports of the metals gallium, germanium and antimony to the United States in December 2024 ⁴⁰. In Europe, germanium metal averaged an estimated \$4,100 a kilogram in 2025, against \$1,392 in 2023, on Argus Media prices reported by the US Geological Survey ⁴⁴. In November 2025 China suspended the ban until 27 November 2026 ⁴¹.

¹⁰ The impact of export controls on international trade: evidence from the Japan–Korea trade dispute in the semiconductor industry. Research Institute of Economy, Trade and Industry (Japan) · 8 May 2023 [\[A\]](https://www.rieti.go.jp/en/columns/v01_0201.html) www.rieti.go.jp/en/columns/v01_0201.html

⁴⁰ 商务部公告2024年第46号 关于加强相关两用物项对美国出口管制的公告. Ministry of Commerce of the People's Republic of China · 3 December 2024 [\[A\]](https://www.mofcom.gov.cn/zwgk/zcfb/art/2024/art_3d5e990b43424e60828030f58a547b60.html) www.mofcom.gov.cn/zwgk/zcfb/art/2024/art_3d5e990b43424e60828030f58a547b60.html

⁴⁴ Mineral Commodity Summaries 2026: Germanium. U.S. Geological Survey · 5 February 2026 [\[A\]](https://pubs.usgs.gov/periodicals/mcs2026/mcs2026-germanium.pdf) pubs.usgs.gov/periodicals/mcs2026/mcs2026-germanium.pdf

⁴¹ 商务部公告2025年第72号 公布调整实施商务部公告2024年第46号的决定. Ministry of Commerce of the People's Republic of China · 9 November 2025 [\[A\]](https://www.mofcom.gov.cn/zwgk/zcfb/art/2025/art_5c68985a6b1a46778e2e8dbff1bb1601.html) www.mofcom.gov.cn/zwgk/zcfb/art/2025/art_5c68985a6b1a46778e2e8dbff1bb1601.html

CHOKEPOINT CARD		HIGH CONCENTRATION
		MODERATELY HARD TO SUBSTITUTE
CONCENTRATION	SUBSTITUTABILITY	PRICE OR MARKET SIZE
High	Moderate Rated on photoresist, the hardest input to replace at this stage ¹ .	\$45.8bn market for wafer fabrication materials in 2025 ² . SEMI's count includes silicon wafers and photomasks ³
WHO LEADS	JP JSR A vehicle of the state-backed Japan Investment Corporation bought 84.36% of JSR in April 2024⁴ JP Tokyo Ohka Kogyo Resist maker with ¥139,668m of sales in the first half of fiscal 2026⁵ FR Air Liquide €2,465m of electronics revenue in 2025, 9.1% of group sales⁶ US Entegris Bought the polishing-slurry maker CMC Materials in July 2022⁷ JP JX Advanced Metals Says it holds about 65% of the world market for semiconductor sputtering targets as of fiscal 2026⁸	
WHERE IT IS MADE	JP Japan Photoresist, ultra-pure hydrofluoric acid, sputtering targets, polishing slurries US United States Entegris polishing slurries, Qnity Electronics resist, Air Products gases FR France Air Liquide electronics gases and precursors KR South Korea Dongjin resist, with output of resist and hydrogen fluoride rising after 2019 CN China Gallium, germanium and antimony refining	
WHY SUBSTITUTION IS POSSIBLE	Each formula is tuned to the layers it prints and has to pass qualification in the fab ¹ . So a new supplier has to develop its version together with the fab, one layer at a time ⁹ . When Japan required individual export licenses for resist and two other chemicals sold to South Korea in 2019, South Korea imported more from the United States, Taiwan and Belgium ¹⁰ .	
WHERE CHINA STANDS	In March 2026 the Chinese resist maker Hubei Dinglong said China had yet to reach large-scale production of advanced resist for 248 nm, 193 nm or extreme-ultraviolet printing ¹¹ . Since August 2023 China has required licenses to export gallium and germanium ¹² .	WHERE THE US STANDS In photoresist, American companies ranked a distant second to Japanese companies by sales in 2023 ¹³ . In 2021 JSR of Japan agreed to buy Inpria, an Oregon maker of resist for extreme ultraviolet ¹⁴ .

1 PFAS-Containing Photo Acid Generators Used in Semiconductor Manufacturing, Semiconductor Industry Association (Semiconductor PFAS Consortium Photolithography Working Group) · 8 June 2023 · p. 21 [A] www.semiconductors.org/wp-content/uploads/2023/06/FINAL-PAG-Case-Study.pdf#page=21

2 Global Semiconductor Materials Market Revenue Reaches Record \$73.2 Billion in 2025, SEMI Reports. PR Newswire · 12 May 2026 [A] www.prnewswire.com/news-releases/global-semiconductor-materials-market-revenue-reaches-record-73-2-billion-in-2025--semi-reports-302768700.html

3 Materials Market Data Subscription (MMDS). SEMI · Accessed 20 October 2026 [A] www.semi.org/en/products-services/market-data/mmds

A chip fab draws on hundreds of chemicals, gases and other materials ¹⁵. A shortage of any one of them can stop it. The French gas company Air Liquide alone supplies more than 200 molecules and roughly 50,000 cylinders a year ⁶.

How it works

The resist has to change only where the light lands. It also has to work with very little light, so the scanner, the machine that projects the pattern, can expose each patch of the wafer in milliseconds.

Since the 1990s the standard has been chemically amplified resist. In resists for 248 nm and 193 nm light, a photon absorbed in the film can free an acid molecule, and little more happens until the wafer is baked. In the bake, each acid molecule sets off hundreds of reactions around itself that turn the film soluble, so a little light does a lot of chemistry ¹⁷. The wash then takes away the exposed film and leaves the rest.

The 248 nm light comes from a krypton fluoride (KrF) laser. The 193 nm light comes from an argon fluoride (ArF) laser. Immersion scanners also pass it through a layer of water, which sharpens the image.

That chemistry works less well with extreme ultraviolet (EUV) light (see Lithography). An absorbed EUV photon instead knocks electrons loose, and a cascade of lower-energy secondary electrons makes the chemical changes in the resist ¹⁸. A 13.5 nm EUV photon carries about fourteen times the energy of a 193

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- 4 Announcement Regarding Result of Tender Offer for JSR Corporation (Securities Code: 4185). Japan Investment Corporation · 17 April 2024 [A] www.jiccapi.com/en/news/assets/E_20240417_JIC_JICC_PressRelease.pdf
- 5 Consolidated Financial Results for the Second Quarter (Interim) of the Fiscal Year Ending December 31, 2026 [J-GAAP]. Tokyo Ohka Kogyo · 6 August 2026 · p. 4 [A] www.tok.co.jp/application/files/7417/8598/0069/q2_2612_en.pdf#page=4
- 6 Air Liquide, electronics page. Air Liquide · Accessed 9 September 2026 [A] www.airliquide.com/group/activities/electronics
- 7 ENTEGRIS INC, Form 8-K current report for the period ended 2022-07-06. U.S. Securities and Exchange Commission (filing by ENTEGRIS INC) · 6 July 2022 [A] www.sec.gov/Archives/edgar/data/1101302/000114036122025275/ny20004647x3_ex99-1.htm
- 8 Quick Guide to JX Advanced Metals. JX Advanced Metals · Accessed 9 September 2026 [A] www.jx-nmm.com/english/company/glance/
- 1 PFAS-Containing Photo-Acid Generators Used in Semiconductor Manufacturing. Semiconductor Industry Association (Semiconductor PFAS Consortium Photolithography Working Group) · 8 June 2023 · p. 21 [A] www.semiconductors.org/wp-content/uploads/2023/06/FINAL-PAG-Case-Study.pdf#page=21
- 9 PFAS-Containing Photo-Acid Generators Used in Semiconductor Manufacturing. Semiconductor Industry Association (Semiconductor PFAS Consortium Photolithography Working Group) · 8 June 2023 · p. 22 [A] www.semiconductors.org/wp-content/uploads/2023/06/FINAL-PAG-Case-Study.pdf#page=22
- 10 The impact of export controls on international trade: evidence from the Japan–Korea trade dispute in the semiconductor industry. Research Institute of Economy, Trade and Industry (Japan) · 8 May 2023 [A] www.rieti.go.jp/en/columns/v01_0201.html
- 11 湖北鼎龙控股股份有限公司2025年年度报告摘要. CNINFO · 27 March 2026 · p. 2 [A] static.cninfo.com.cn/finalpage/2026-03-27/1225036148.PDF#page=2
- 12 商务部 海关总署公告2023年第23号 关于对镓、锗相关物项实施出口管制的公告. Ministry of Commerce of the People's Republic of China · 3 July 2023 [A] www.mofcom.gov.cn/zcfb/dwmygl/art/2023/art_52b9a321087f402bb3d310d18b07967e.html
- 13 METI, Semiconductor and digital industry strategy: future direction (半導体・デジタル産業戦略の今後の方向性), 23 December 2025. Ministry of Economy, Trade and Industry (Japan) · 23 December 2025 · p. 8 [A] www.meti.go.jp/policy/mono_info_service/joho/conference/semicon_digital/0014/handeji14-4.pdf#page=8
- 14 JSR Agrees to Acquire EUV Pioneer Inpria Corporation. JSR Corporation · 17 September 2021 [A] www.jsr.co.jp/jsr_e/news/2021/20210917.html
- 15 Testimony of the Semiconductor Industry Association (SIA) before the Senate Committee on Environment & Public Works. U.S. Senate Committee on Environment and Public Works · 4 March 2026 · p. 6 [A] www.epw.senate.gov/public/_cache/files/a/c/ac4552ff-551b-40d5-bea6-19dd17a1cfca/1F7BCD91016CBE352434701BE58395874BEA6A892A23ABEE1D7214EC924EC0EB.03-04-2026-isaacs-testimony.pdf#page=6
- 17 PFAS-Containing Photo-Acid Generators Used in Semiconductor Manufacturing. Semiconductor Industry Association (Semiconductor PFAS Consortium Photolithography Working Group) · 8 June 2023 · p. 6 [A] www.semiconductors.org/wp-content/uploads/2023/06/FINAL-PAG-Case-Study.pdf#page=6
- 18 How Scientists Are Accelerating the Development of Next-Gen Microelectronics. Lawrence Berkeley National Laboratory · 21 August 2023 [A] newscenter.lbl.gov/2023/08/21/how-scientists-are-accelerating-next-gen-microelectronics/

nm one, so the same dose of light arrives as far fewer photons. With fewer photons, random variation in where each one lands matters more. It shows up as ragged line edges and missing contact holes, the tiny holes that link one layer of a chip to the next.

Resist makers responded with metal-oxide resists, which are built on clusters with a tin-oxide core and absorb more of the EUV light than chemically amplified resists ¹⁹. In 2021 the Japanese resist maker JSR agreed to buy Inpria, an Oregon maker of these resists ¹⁴.

The other chemicals and gases put material on the wafer, take it off or keep it clean. Bulk gases such as nitrogen come by pipeline or from plants built at the fab, and specialty gases come in cylinders ⁶. Silane gas carries the silicon for new layers into the chamber that holds the wafer. A plasma splits nitrogen trifluoride, and the fluorine it frees scrubs the chamber walls clean between wafers. Hydrofluoric acid cleans the wafer itself. Polishing slurries grind each new layer flat before the next goes on.

Sputtering targets are slabs of pure metal. A plasma knocks atoms off them, and the atoms settle on the wafer as thin metal films, including the barrier and seed layers for copper wiring ²⁰. Electroplating then fills in the copper wiring itself ²¹. Filters and wafer carriers keep contamination out.

Variants and trade-offs

RESIST CLASS	WAVELENGTH	WHERE IT IS USED	LIMIT
i-line novolak	365 nm	Packaging, mature nodes	Resolution
KrF chemically amplified	248 nm	Implant layers, thick films	Resolution
ArF immersion chemically amplified	193 nm	Most critical layers below 28 nm	Needs several exposures per layer
EUV chemically amplified	13.5 nm	Leading-edge single-exposure layers	Shot noise from too few photons

¹⁹ Inpria, company website. Inpria · Accessed 9 September 2026 [\[A\] www.inpria.com/](https://www.inpria.com/)

¹⁴ JSR Agrees to Acquire EUV Pioneer Inpria Corporation. JSR Corporation · 17 September 2021 [\[A\] www.jsr.co.jp/jsr_e/news/2021/20210917.html](https://www.jsr.co.jp/jsr_e/news/2021/20210917.html)

⁶ Air Liquide, electronics page. Air Liquide · Accessed 9 September 2026 [\[A\] www.airliquide.com/group/activities/electronics](https://www.airliquide.com/group/activities/electronics)

²⁰ Applied Materials, PVD technology page. Applied Materials · Accessed 9 September 2026 [\[A\] www.appliedmaterials.com/eu/en/semiconductor/semiconductor-technologies/pvd.html](https://www.appliedmaterials.com/eu/en/semiconductor/semiconductor-technologies/pvd.html)

²¹ SABRE Product Family. Lam Research · 11 August 2017 [\[A\] www.lamresearch.com/product/sabre/](https://www.lamresearch.com/product/sabre/)

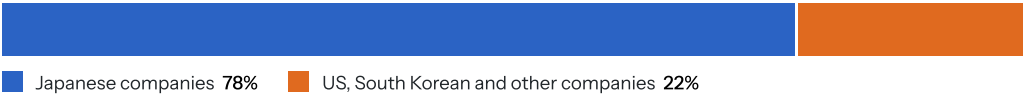
EUV metal-oxide	13.5 nm	High-NA tools, tightest pitches	Cost, defects, outgassing
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Each resist class is made for one kind of lithography, such as EUV, ArF immersion, ArF, KrF or i-line ²².

Who makes it

In a January 2021 brief, Georgetown University's Center for Security and Emerging Technology (CSET) put Japan's share of the semiconductor photoresist market at 90 percent, citing a 2019 estimate ²². The brief put most of the rest with US and South Korean firms ²². In a December 2025 strategy presentation, Japan's Ministry of Economy, Trade and Industry (METI) published figures from a separate survey by Fuji Keizai, a Japanese market research firm ¹³. That survey counts sales by company nationality and puts Japanese companies at 77 percent in 2021 and 78 percent in 2023, with American and South Korean companies next ¹³.

Photoresist sales share by company nationality, 2023 %



Source: METI, December 2025, from Fuji Keizai data

CSET's January 2021 brief lists five Japanese resist makers: JSR, Tokyo Ohka Kogyo, Shin-Etsu Chemical, Fujifilm and Sumitomo Chemical ²³. It also lists Dongjin of South Korea, four Chinese firms and three firms it counts as American: DuPont, EMD Performance Materials and Inpria ²³. Qnity Electronics, the former DuPont electronics business, says in its 2025 annual report that it offers lithography materials for every wavelength, including EUV ²⁴. In its 2025 annual report summary, the Chinese firm Hubei Dinglong said China had yet to reach

22 The Semiconductor Supply Chain - Issue Brief. Center for Security and Emerging Technology (CSET) · 21 January 2021 · p. 59 [\[A\]](https://cset.georgetown.edu/wp-content/uploads/The-Semiconductor-Supply-Chain-Issue-Brief-1.pdf#page=59) cset.georgetown.edu/wp-content/uploads/The-Semiconductor-Supply-Chain-Issue-Brief-1.pdf#page=59

13 METI, Semiconductor and digital industry strategy: future direction (半導体・デジタル産業戦略の今後の方向性), 23 December 2025. Ministry of Economy, Trade and Industry (Japan) · 23 December 2025 · p. 8 [\[A\]](https://www.meti.go.jp/policy/mono_info_service/joho/conference/semicon_digital/0014/handeji14-4.pdf#page=8) www.meti.go.jp/policy/mono_info_service/joho/conference/semicon_digital/0014/handeji14-4.pdf#page=8

23 The Semiconductor Supply Chain - Issue Brief. Center for Security and Emerging Technology (CSET) · 21 January 2021 · p. 56 [\[A\]](https://cset.georgetown.edu/wp-content/uploads/The-Semiconductor-Supply-Chain-Issue-Brief-1.pdf#page=56) cset.georgetown.edu/wp-content/uploads/The-Semiconductor-Supply-Chain-Issue-Brief-1.pdf#page=56

24 Qnity Electronics, Inc., Form 10-K annual report for the period ended 2025-12-31 (10-K). U.S. Securities and Exchange Commission (filing by Qnity Electronics, Inc.) · 26 February 2026 [\[A\]](https://www.sec.gov/Archives/edgar/data/2058873/000205887326000010/q-20251231.htm) www.sec.gov/Archives/edgar/data/2058873/000205887326000010/q-20251231.htm

large-scale production of advanced resist for 248 nm, 193 nm or EUV printing ¹¹. The firm also said three of its own resists for 248 nm and 193 nm printing had moved into stable volume supply ²⁵.

A vehicle of Japan Investment Corporation, a state-backed fund, bought 84.36 percent of JSR's shares at ¥4,350 each in a tender offer that closed on 16 April 2024 ⁴. JSR's shares were delisted from the Tokyo Stock Exchange on 25 June 2024 ²⁶.

Tokyo Ohka Kogyo sold ¥139,668 million in the first half of fiscal 2026, up 25.1 percent, as strong demand for AI servers in data centers raised demand for chips ⁵. Fujifilm planned to raise its polishing-slurry capacity at Kumamoto by about 30 percent from January 2025 ²⁷. It also scheduled new production and quality-evaluation equipment for EUV resist at Shizuoka and Pyeongtaek to start in October 2025 ²⁸.

World sales of wafer fabrication materials reached \$45.8 billion in 2025, and sales of packaging materials reached \$27.4 billion ². SEMI counts silicon wafers and photomasks among wafer fabrication materials, along with resists, gases, chemicals and polishing materials ³.

In electronic gases, CSET named Merck, Air Products and Air Liquide as the market leaders in January 2021 ²⁹. Air Liquide's electronics business sold €2,465 million in 2025, 9.1 percent of group revenue ⁶. SK Specialty has made nitrogen trifluoride since 2001, when it became the first company to produce the gas in

11 湖北鼎龙控股股份有限公司2025年年度报告摘要. CNINFO · 27 March 2026 · p. 2 [\[A\]](https://static.cninfo.com.cn/finalpage/2026-03-27/1225036148.PDF#page=2) static.cninfo.com.cn/finalpage/2026-03-27/1225036148.PDF#page=2

25 湖北鼎龙控股股份有限公司2025年年度报告摘要. CNINFO · 27 March 2026 · p. 8 [\[A\]](https://static.cninfo.com.cn/finalpage/2026-03-27/1225036148.PDF#page=8) static.cninfo.com.cn/finalpage/2026-03-27/1225036148.PDF#page=8

4 Announcement Regarding Result of Tender Offer for JSR Corporation (Securities Code: 4185). Japan Investment Corporation · 17 April 2024 [\[A\]](https://www.jiccapi.com/en/news/assets/E_20240417_JIC_JICC_PressRelease.pdf) www.jiccapi.com/en/news/assets/E_20240417_JIC_JICC_PressRelease.pdf

26 Announcement of Delisting of Shares of JSR Corporation. JSR Corporation · 24 June 2024 [\[A\]](https://www.jsr.co.jp/jsr_e/news/assets/pdf/20240624_01_e.pdf) www.jsr.co.jp/jsr_e/news/assets/pdf/20240624_01_e.pdf

5 Consolidated Financial Results for the Second Quarter (Interim) of the Fiscal Year Ending December 31, 2026 [J-GAAP]. Tokyo Ohka Kogyo · 6 August 2026 · p. 4 [\[A\]](https://www.tok.co.jp/application/files/7417/8598/0069/q2_2612_en.pdf#page=4) www.tok.co.jp/application/files/7417/8598/0069/q2_2612_en.pdf#page=4

27 Fujifilm to Enhance its Production Capacity of Advanced Semiconductor Material CMP Slurries at the Kumamoto Site. Fujifilm · 5 December 2024 [\[A\]](https://www.fujifilm.com/jp/en/news/hq/11942) www.fujifilm.com/jp/en/news/hq/11942

28 Fujifilm Launches EUV Resist and EUV Developer. Fujifilm · 29 October 2024 [\[A\]](https://www.fujifilm.com/jp/en/news/hq/11842) www.fujifilm.com/jp/en/news/hq/11842

2 Global Semiconductor Materials Market Revenue Reaches Record \$73.2 Billion in 2025, SEMI Reports. PR Newswire · 12 May 2026 [\[A\]](https://www.prnewswire.com/news-releases/global-semiconductor-materials-market-revenue-reaches-record-73-2-billion-in-2025--semi-reports-302768700.html) www.prnewswire.com/news-releases/global-semiconductor-materials-market-revenue-reaches-record-73-2-billion-in-2025--semi-reports-302768700.html

3 Materials Market Data Subscription (MMDS). SEMI · Accessed 20 October 2026 [\[A\]](https://www.semi.org/en/products-services/market-data/mmids) www.semi.org/en/products-services/market-data/mmids

29 The Semiconductor Supply Chain - Issue Brief. Center for Security and Emerging Technology (CSET) · 21 January 2021 · p. 60 [\[A\]](https://cset.georgetown.edu/wp-content/uploads/The-Semiconductor-Supply-Chain-Issue-Brief-1.pdf#page=60) cset.georgetown.edu/wp-content/uploads/The-Semiconductor-Supply-Chain-Issue-Brief-1.pdf#page=60

6 Air Liquide, electronics page. Air Liquide · Accessed 9 September 2026 [\[A\]](https://www.airliquide.com/group/activities/electronics) www.airliquide.com/group/activities/electronics

South Korea ³⁰. Kanto Denka Kogyo refines its own fluorine gas and turns it into specialty gases for deposition, etching and cleaning ³¹. Stella Chemifa makes ultra-high-purity hydrofluoric acid for chipmaking ³². Morita Chemical Industries sells an electronic-grade hydrofluoric acid ³³.

CSET's January 2021 brief, drawing on a 2019 report by the market research firm Mordor Intelligence, put five firms at more than 60 percent of the wet chemicals market ²⁹. Citing a 2019 report by the market research firm Market Reports World, it put DuPont and Cabot Microelectronics at about 56 percent of a \$790 million market for polishing slurries ²². Counting by company nationality, the same Fuji Keizai survey, as published by METI, puts Japanese companies at 51 percent of polishing-slurry sales and 59 percent of high-purity cleaning-liquid sales in 2023 ¹³. Both shares were 49 percent in 2021 ¹³.

Cabot Microelectronics renamed itself CMC Materials in October 2020 ³⁴. The American firm Entegris completed its purchase of CMC Materials on 6 July 2022 ⁷. DuPont separated its electronics business into an independent company, Qnity Electronics, on 1 November 2025 ³⁵. Qnity sells polishing slurries and pads ³⁶.

In sputtering targets for semiconductors, JX Advanced Metals puts its own share of the world market at about 65 percent as of fiscal 2026 ⁸.

The chokepoint

Supply at this stage has been disrupted three times since 2019, twice by governments and once by a war.

30 SK specialty, company website. SK specialty · Accessed 18 October 2026 [\[A\]](https://www.skspecialty.com/new/eng/html/main/) www.skspecialty.com/new/eng/html/main/

31 Specialty Gases. Kanto Denka Kogyo · Accessed 18 October 2026 [\[A\]](https://www.kantodenka.co.jp/english/product/gas/) www.kantodenka.co.jp/english/product/gas/

32 High-purity Chemical Business. Stella Chemifa · Accessed 18 October 2026 [\[A\]](https://www.stella-chemifa.co.jp/english/business/chemical/) www.stella-chemifa.co.jp/english/business/chemical/

33 Electronic grade Hydrofluoric acid. Morita Chemical Industries · Accessed 18 October 2026 [\[A\]](https://www.morita-kagaku.co.jp/en/products/hafce/9/) www.morita-kagaku.co.jp/en/products/hafce/9/

29 The Semiconductor Supply Chain - Issue Brief. Center for Security and Emerging Technology (CSET) · 21 January 2021 · p. 60 [\[A\]](https://cset.georgetown.edu/wp-content/uploads/The-Semiconductor-Supply-Chain-Issue-Brief-1.pdf#page=60) cset.georgetown.edu/wp-content/uploads/The-Semiconductor-Supply-Chain-Issue-Brief-1.pdf#page=60

22 The Semiconductor Supply Chain - Issue Brief. Center for Security and Emerging Technology (CSET) · 21 January 2021 · p. 59 [\[A\]](https://cset.georgetown.edu/wp-content/uploads/The-Semiconductor-Supply-Chain-Issue-Brief-1.pdf#page=59) cset.georgetown.edu/wp-content/uploads/The-Semiconductor-Supply-Chain-Issue-Brief-1.pdf#page=59

13 METI, Semiconductor and digital industry strategy: future direction (半導体・デジタル産業戦略の今後の方向性), 23 December 2025. Ministry of Economy, Trade and Industry (Japan) · 23 December 2025 · p. 8 [\[A\]](https://www.meti.go.jp/policy/mono_info_service/joho/conference/semicon_digital/0014/handeji14-4.pdf#page=8) www.meti.go.jp/policy/mono_info_service/joho/conference/semicon_digital/0014/handeji14-4.pdf#page=8

34 CMC Materials, Inc., Form 8-K current report for the period ended 2020-09-28 (8-K). U.S. Securities and Exchange Commission (filing by CMC Materials, Inc.) · 1 October 2020 [\[A\]](https://www.sec.gov/Archives/edgar/data/1102934/000110293420000048/ccmp-20201001xex991.htm) www.sec.gov/Archives/edgar/data/1102934/000110293420000048/ccmp-20201001xex991.htm

7 ENTEGRIS INC, Form 8-K current report for the period ended 2022-07-06. U.S. Securities and Exchange Commission (filing by ENTEGRIS INC) · 6 July 2022 [\[A\]](https://www.sec.gov/Archives/edgar/data/1101302/000114036122025275/ny20004647x3_ex99-1.htm) www.sec.gov/Archives/edgar/data/1101302/000114036122025275/ny20004647x3_ex99-1.htm

35 DuPont Completes Separation of Qnity Electronics. DuPont · 3 November 2025 [\[A\]](https://www.investors.dupont.com/news-and-media/press-release-details/2025/DuPont-Completes-Separation-of-Qnity-Electronics/default.aspx) www.investors.dupont.com/news-and-media/press-release-details/2025/DuPont-Completes-Separation-of-Qnity-Electronics/default.aspx

36 Chemical Mechanical Planarization (CMP) Materials for Semiconductor. Qnity Electronics · Accessed 9 September 2026 [\[A\]](https://www.qnityelectronics.com/semiconductor-cmp.html) www.qnityelectronics.com/semiconductor-cmp.html

8 Quick Guide to JX Advanced Metals. JX Advanced Metals · Accessed 9 September 2026 [\[A\]](https://www.jx-nmm.com/english/company/glance/) www.jx-nmm.com/english/company/glance/

In July 2019 Japan put photoresist, hydrogen fluoride and fluorinated polyimide under individual export licenses for South Korea, so each export contract needed its own license ¹⁰. Japan had supplied more than 90 percent of South Korea's imports of two of the three ¹⁰. Its hydrogen fluoride exports to South Korea then fell 87.9 percent ¹⁰. Japanese photoresist exports to South Korea did not fall, possibly in part because Japan allowed three-year bulk licenses for some resist sales in December 2019 ¹⁰.

South Korea bought more hydrogen fluoride from the United States and Taiwan and more photoresist from Belgium ¹⁰. Production of all three chemicals rose inside South Korea ¹⁰. The rise came both from South Korean firms and from Japanese companies' affiliates in South Korea ¹⁰.

Researchers at Japan's Research Institute of Economy, Trade and Industry (RIETI) found that Japanese hydrogen fluoride exports to the United States rose ¹⁰. They say some Japanese supply may have reached South Korea by way of the United States ¹⁰. Japan ended the individual licenses on 23 March 2023, when it put exports of the three chemicals to South Korea under its bulk export license system ³⁷.

In 2022 Russia invaded Ukraine, which supplied about 70 percent of the world's neon and 90 percent of the semiconductor-grade neon used by US industry ³⁸. Gas mixtures containing neon fill the lasers used in lithography, but EUV scanners use

¹⁰ The impact of export controls on international trade: evidence from the Japan–Korea trade dispute in the semiconductor industry. Research Institute of Economy, Trade and Industry (Japan) · 8 May 2023 [\[A\] www.rieti.go.jp/en/columns/v01_0201.html](https://www.rieti.go.jp/en/columns/v01_0201.html)

³⁷ Circular Notice on Partial Amendment to the Circular Notice on the Operation of the Cabinet Order on Export Trade Control and other circular notices (Review of Export Control to South Korea). Ministry of Economy, Trade and Industry (Japan) · 23 March 2023 [\[A\] web.archive.org/web/20250408171837/https://www.meti.go.jp/english/press/2023/0323_001.html](https://web.archive.org/web/20250408171837/https://www.meti.go.jp/english/press/2023/0323_001.html)

³⁸ Russia's Invasion of Ukraine Impacts Gas Markets Critical to Chip Production. Center for Strategic and International Studies · 14 March 2022 [\[A\] www.csis.org/blogs/perspectives-innovation/russias-invasion-ukraine-impacts-gas-markets-critical-chip-production](https://www.csis.org/blogs/perspectives-innovation/russias-invasion-ukraine-impacts-gas-markets-critical-chip-production)

a tin light source instead ³⁹. Many chipmakers had added to their gas stockpiles after Russia annexed Crimea in 2014 ³⁸. Samsung, SK hynix, Renesas and Rohm reported adequate neon supplies from China ³⁸.

At this stage, China's export controls cover metals. On 3 July 2023 China announced that exports of gallium and germanium would need licenses from 1 August ¹². On 3 December 2024 it said it would in principle grant no licenses to export gallium, germanium, antimony or superhard materials to the United States ⁴⁰. On 9 November 2025 it suspended that ban until 27 November 2026 ⁴¹. In February 2026 the US Geological Survey put China's share of world production of primary low-purity gallium at 99 percent ⁴².

The White House set out a trade deal with China on 1 November 2025 ⁴³. It said that under the deal China would also issue general licenses for exports of gallium, germanium and antimony for the benefit of US end users and their suppliers ⁴³.

In the United States, germanium goes mainly into fiber optics, infrared optics, semiconductors and solar cells, and radiation detectors ⁴⁴. Of the gallium used in the United States in 2025, 73 percent went into integrated circuits built on gallium arsenide or gallium nitride ⁴². Another 26 percent went into optoelectronic devices such as LEDs and laser diodes ⁴². Gallium is recovered mostly as a byproduct of processing bauxite, the ore that aluminum is made from ⁴². Germanium comes from certain zinc ores and coal deposits, so the supply of each metal depends on another industry's economics ⁴⁵.

39 The Semiconductor Supply Chain - Issue Brief. Center for Security and Emerging Technology (CSET) · 21 January 2021 · p. 97
[\[A\] cset.georgetown.edu/wp-content/uploads/The-Semiconductor-Supply-Chain-Issue-Brief-1.pdf#page=97](https://cset.georgetown.edu/wp-content/uploads/The-Semiconductor-Supply-Chain-Issue-Brief-1.pdf#page=97)

38 Russia's Invasion of Ukraine Impacts Gas Markets Critical to Chip Production. Center for Strategic and International Studies · 14 March 2022 [\[A\] www.csis.org/blogs/perspectives-innovation/russias-invasion-ukraine-impacts-gas-markets-critical-chip-production](https://www.csis.org/blogs/perspectives-innovation/russias-invasion-ukraine-impacts-gas-markets-critical-chip-production)

12 商务部 海关总署公告2023年第23号 关于对镓、锗相关物项实施出口管制的公告. Ministry of Commerce of the People's Republic of China · 3 July 2023 [\[A\] www.mofcom.gov.cn/zcfb/dwmygl/art/2023/art_52b9a321087f402bb3d310d18b07967e.html](http://www.mofcom.gov.cn/zcfb/dwmygl/art/2023/art_52b9a321087f402bb3d310d18b07967e.html)

40 商务部公告2024年第46号 关于加强相关两用物项对美国出口管制的公告. Ministry of Commerce of the People's Republic of China · 3 December 2024 [\[A\] www.mofcom.gov.cn/zwgk/zcfb/art/2024/art_3d5e990b43424e60828030f58a547b60.html](http://www.mofcom.gov.cn/zwgk/zcfb/art/2024/art_3d5e990b43424e60828030f58a547b60.html)

41 商务部公告2025年第72号 公布调整实施商务部公告2024年第46号的决定. Ministry of Commerce of the People's Republic of China · 9 November 2025 [\[A\] www.mofcom.gov.cn/zwgk/zcfb/art/2025/art_5c68985a6b1a46778e2e8dbff1bb1601.html](http://www.mofcom.gov.cn/zwgk/zcfb/art/2025/art_5c68985a6b1a46778e2e8dbff1bb1601.html)

42 Mineral Commodity Summaries 2026: Gallium. U.S. Geological Survey · 5 February 2026 [\[A\] pubs.usgs.gov/periodicals/mcs2026/mcs2026-gallium.pdf](https://pubs.usgs.gov/periodicals/mcs2026/mcs2026-gallium.pdf)

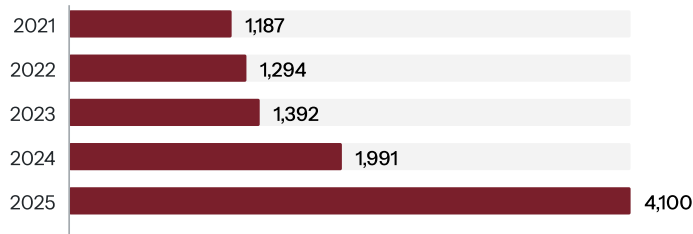
43 Fact Sheet: President Donald J. Trump Strikes Deal on Economic and Trade Relations with China. The White House · 1 November 2025 [\[A\] www.whitehouse.gov/fact-sheets/2025/11/fact-sheet-president-donald-j-trump-strikes-deal-on-economic-and-trade-relations-with-china/](https://www.whitehouse.gov/fact-sheets/2025/11/fact-sheet-president-donald-j-trump-strikes-deal-on-economic-and-trade-relations-with-china/)

44 Mineral Commodity Summaries 2026: Germanium. U.S. Geological Survey · 5 February 2026 [\[A\] pubs.usgs.gov/periodicals/mcs2026/mcs2026-germanium.pdf](https://pubs.usgs.gov/periodicals/mcs2026/mcs2026-germanium.pdf)

45 Quantifying Potential Effects of China's Gallium and Germanium Export Restrictions on the U.S. Economy (Open-File Report 2024-1057). U.S. Geological Survey · 15 October 2024 · p. 11 [\[A\] pubs.usgs.gov/of/2024/1057/ofr20241057.pdf#page=11](https://pubs.usgs.gov/of/2024/1057/ofr20241057.pdf#page=11)

In Europe, germanium metal averaged an estimated \$4,100 a kilogram in 2025, against \$1,392 in 2023, on Argus Media prices reported by the US Geological Survey ⁴⁴. US imports of the metal fell an estimated 67 percent in 2025 because of China's ban ⁴⁴. In October 2024 the US Geological Survey estimated that a total Chinese ban on gallium and germanium exports could cut US GDP by \$3.4 billion ⁴⁶.

Germanium metal, annual average price in Europe (\$/kg). China required export licenses from August 2023, banned shipments to the US in December 2024 and suspended the ban from November 2025 to 27 November 2026 \$/KG



Source: USGS Mineral Commodity Summaries, February 2026 (Argus Media European prices, 2025 estimated)

A slower risk is the European Union's proposed restriction on PFAS, the long-lived fluorinated chemicals. These chemicals are used throughout a fab, from some etch gases to seals, filters and the plastic linings of chemical tanks and pipes. Most of the photoacid generators that free the acid in resist contain PFAS too ⁴⁷. The Semiconductor Industry Association wrote in 2023 that photoresist needs the most rigorous qualification of any chemical a chipmaker uses, because each resist is tuned to the layers it prints ¹. The resist maker adjusts its formula over rounds of tests in the fab, and some resists have to be qualified one after another ⁹.

The national authorities of Denmark, Germany, the Netherlands, Norway and Sweden prepared the proposal and updated it after evaluating more than 5,600

44 Mineral Commodity Summaries 2026: Germanium. U.S. Geological Survey · 5 February 2026 pubs.usgs.gov/periodicals/mcs2026/mcs2026-germanium.pdf

46 Quantifying Potential Effects of China's Gallium and Germanium Export Restrictions on the U.S. Economy (Open-File Report 2024-1057). U.S. Geological Survey · 15 October 2024 · p. 9 pubs.usgs.gov/of/2024/1057/ofr20241057.pdf#page=9

47 PFAS-Containing Photo-Acid Generators Used in Semiconductor Manufacturing. Semiconductor Industry Association (Semiconductor PFAS Consortium Photolithography Working Group) · 8 June 2023 · p. 4 www.semiconductors.org/wp-content/uploads/2023/06/FINAL-PAG-Case-Study.pdf#page=4

1 PFAS-Containing Photo-Acid Generators Used in Semiconductor Manufacturing. Semiconductor Industry Association (Semiconductor PFAS Consortium Photolithography Working Group) · 8 June 2023 · p. 21 www.semiconductors.org/wp-content/uploads/2023/06/FINAL-PAG-Case-Study.pdf#page=21

9 PFAS-Containing Photo-Acid Generators Used in Semiconductor Manufacturing. Semiconductor Industry Association (Semiconductor PFAS Consortium Photolithography Working Group) · 8 June 2023 · p. 22 www.semiconductors.org/wp-content/uploads/2023/06/FINAL-PAG-Case-Study.pdf#page=22

comments ⁴⁸. ECHA, the EU chemicals agency, published the updated proposal on 20 August 2025 ⁴⁸. The updated proposal assessed options that would let electronics and semiconductor makers keep using PFAS where the risks can be controlled ⁴⁸.

In March 2026 ECHA's two scientific committees backed an EU-wide restriction with targeted derogations, or exemptions ⁴⁹. One committee gave its backing in a final opinion and the other in a draft, and their evaluation is due to finish by the end of 2026 ⁴⁹. The European Commission will decide in consultation with the member states ⁴⁸.

FOUR THINGS TO REMEMBER

- Photoresist holds the pattern printed by light so the next step can etch it into the wafer.
- Japanese companies held 77 percent of world photoresist sales in 2021 and 78 percent in 2023.
- A chipmaker has to approve each new resist in its own fab, and even one that passes the first time takes seven to 17 months.
- China has required licenses to export gallium and germanium since August 2023.

Made by **Yashvardhan Sharma** with Claude. Corrections and questions: contact@chipsupplychain.org.

UPDATED 20 OCTOBER 2026

A company filings, governments, standards bodies, universities and research institutions; **B** SemiAnalysis, Reuters, the Financial Times and Nikkei Asia.

HOW TO CITE THIS CHAPTER

⁴⁸ ECHA publishes updated PFAS restriction proposal. European Chemicals Agency · 20 August 2025 **A** echa.europa.eu/-/echa-publishes-updated-pfas-restriction-proposal

⁴⁹ ECHA supports PFAS restriction with targeted derogations. European Chemicals Agency · 26 March 2026 **A** echa.europa.eu/-/echa-supports-pfas-restriction-with-targeted-derogations

▼ Details

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