Milestones in Optical Lithography Tool Suppliers

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Cobilt (1)

- 1971 – Cobilt founded by Peter Wolken and …?
- 1969 – Computervision founded in Boston to build computer peripherals. Ken Levy is hired to start a semiconductor equipment business.
- Early 1970s – Computervision develops automated alignment system, adds this to a Kulicke & Soffa mask-to-wafer aligner.
- 1972 – Computervision purchases Cobilt, a small California company making contact printers. Ken Levy heads the company until his departure in 1976 to start KLA.
- 197x – Cobilt develops lithography wafer track. The track business is eventually sold to their Japanese distributor, Tokyo Electron Ltd., in 1981(?).
- 1977 – Perkin-Elmer sues Cobilt over Micralign patent violations. They settle in 1984 with an $18M payment from Computervision, Cobilt's original parent.
- 1981 – Cobilt lithography exposure tool business purchased by Applied Materials.

Perkin-Elmer/SVG Lithography (1)

- 1973 – P-E introduces the Micralign projection scanner, developed from an early Air Force research contract. Eventually, over 2000 Micralign machines will be sold. In 1979, the Micraligns sold for $170K.
- 1977 – P-E sues Cobilt over Micralign patent violations. They settle in 1984 with an $18M payment from Computervision, Cobilt's original parent (Cobilt division was bought by Applied Materials in 1981).
- 1981 – P-E announces the Micralign 500 (list price $675K, versus $300K for the Micralign 300), with a throughput of 100 wafers per hour.
- 1984 – May, P-E acquires Censor, a Liechtenstein stepper company specializing in h-line tools.

Perkin-Elmer/SVG Lithography (2)

- 1989 – April, P-E announces it will withdraw from the semiconductor equipment business.
- 1989 – P-E spins off it's electron beam lithography division as Etec, with investment from IBM and five other companies (completed in March 1990).
- 1990 – PE's lithography business acquired by Silicon Valley Group ($20M to take a 2/3 ownership), with financial investment from IBM for about 15%. Talks between P-E and Nikon in late 1989 pushed IBM's involvement.
- 1990-1993 – SEMATECH spends about $30M to help SVGL develop the Micrascan.
- 1990 –The Micrascan, the industry's first step-and-scan tool, is introduced.
- 1992 – June, the Micrascan II is introduced ($3.8M list price. i-line version available for $2.9M).

Perkin-Elmer/SVG Lithography (3)

- 1993 – Enters into discussion with Canon to share step-and-scan technology. Talks end a year later after pressure from US Government not to allow the transfer of technology to Japan.
- 1996 – Micrascan III is introduced, with a switch to an excimer laser source, variable NA from 0.4 – 0.6. List price is $7.2M
- 1999 – Micrascan 193 tool introduced (NA = 0.6).
- 2000 – Oct., ASML announces intent to acquire SVGL for $1.6B. ASML wants catadioptric and CaF technology for 157nm lithography.
- 2001 – May, ASML acquires SVG Lithography. Divests Tinsley Labs by the end of the year to satisfy U.S. security concerns. In Nov. 2001, the Micrascan line of 248nm and 193nm tools is discontinued.

GCA (1)

- Mid 1970s – GCA (formerly Geophysical Corporation of America) takes map making technology and applies it to mask making – the photorepeater.
- 1975 – GCA introduces its first wafer track for resist processing.
- 1978 – GCA introduces the DSW 4800, the first successful wafer stepper (g-line, 10X, Zeiss 0.28NA lens, 10mmX10mm field size). List price: $450K.
- 1982 – GCA buys Tropel lens making unit from Coherent Laser Corp.
- 1985 – first DUV stepper developed for Bell Labs.
- 1985-1986 – GCA looses $100M over a two year period. Payroll is cut by 70%, down to 1,000 employees.
- 1988 – General Signal acquires the financially troubled stepper maker for $76M.

GCA (2)

- 1989-1993 – SEMATECH invests between $60M and $75M in GCA to develop the XLS line of DUV steppers.
  - XLS 7800 ships in 1992, list price $3.5M
- 1993 – Jan., General Signal announces its intent to divest its semiconductor equipment companies.
- 1993 – May, When no buyer is found, General Signal shuts down GCA.
- 1993 – June, Management buyout of service business from GCA forms Integrated Solutions, Inc. (ISI). ISI continues to manufacture AutoSteps.
- 1994 - Management buyout of Tropel creates an independent lens design and manufacturing company. Tropel is later purchased by Corning in March 2001 for $190M.
- 1994 – Sep., ISI buys assets of track maker MTI, which closed the month before.
- 1994 – Oct., ISI buys technology rights to XLS line from General Signal.
- 1998 – Integrated Solutions Inc. (ISI) is acquired by Ultratech Stepper.

GCA (3)

- "…it cost GCA $5 million to develop its first g-line stepper. Its i-line stepper was $25 million in development, its deep UV stepper was $140 million."
  - Neil Bonke "The Equipment Industry - An Overview", SEMI Industry Strategy Symposium (ISS) January 7, 1998.

ASML (1)

- 1977 – Philips develops wafer stepper for internal use called the Silicon Repeater.
- 1980 – Philips negotiates to buy Cobilt (to serve as a marketing outlet for their stepper), but the deal is rejected by the Philips board of directors.
- 1984 – Technology spin-out from Philips to ASML to commercialize the Philips stepper (SIRA III). Alignment system is biggest technical advantage.
- 1985 – First commercial stepper, PAS 2000/10 g-line.
- 1986 – Popular PAS 2500/10 g-line stepper introduced.
- 1987 – ASML's first i-line stepper shipped, PAS 2500/40. Over 100 sold in the next 10 years.
- 1990 – ASMI can no longer afford money losing stepper business, spins out business as ASML, owned 60% by Phillips and 40% by two Dutch banks.
- 1991 – ASML's first KrF stepper shipped, PAS 5000/70.
- 1995 – ASML goes public.

ASML (2)

- 1997 – ASML's first step and scan tool shipped, PAS 5500/500 (248nm, variable numerical aperture from 0.4-0.63, biggest advantage is throughput).
- 1998 – ASML develops their first ArF step-and-scan tool, PAS 5500/900.
- 1999 – ASML acquires MaskTools from MicroUnity, OPC software and scattering bar IP.
- 1999 – ASML and Applied Materials form eLITH joint venture to develop and commercialize AT&T's SCALPEL projection e-beam technology. Effort is closed down by the end of 2000.
- 2000 – TWINSCAN product platform introduced, using two wafer stages to increase throughput. First system installed at TSMC in Oct. 2001.

ASML (3)

- 2000 – Oct., ASML announces intent to acquire SVGL for $1.6B. ASML wants catadioptric and CaF technology for 157nm lithography, and Intel as a customer.
- 2001 – April, U.S. Business and Industry Council (USBIC), based in Washington, formed to stop ASML acquisition of SVGL for US national security reasons. They distribute a video tape to government officials entitled “Why the Sale of SVG Co. is bad for the United States”.
- 2001 – May, ASML acquires SVG Lithography. Divests Tinsley Labs by the end of the year to satisfy U.S. security concerns. In Nov. 2001, SVG’s Micrascan line of 248nm and 193nm tools is discontinued.
- 2001 – Dec., Nikon sues ASML claiming off-axis illumination patent infringement. ASML counter-sues in Apr. 2002. Settlement reached in Sep. 2004 with ASML making a $87M royalty payment to Nikon and Carl Zeiss paying Nikon $58M.

ASML (4)

- 2002 – ASML passes Nikon to become #1 litho tool supplier.
- 2003 – ASML closes down track business acquired with SVG. Rights to the technology are sold to Rite Track.
- 2003 – ASML sells off thermal product lines acquired with SVG to Aviza Technology.
- 2003 – ships first 157nm tool to IMEC, a Micrascan VII from the SVGL division.
- 2003 – forms joint venture with Micronic for optical maskless lithography using digital multi-mirrors instead of masks.
- 2003 – Dec., announces first commercial ArF immersion system, AT:1250i. Early orders from IBM and TSMC.

Nikon (1)

- Early 1970s – Nikon develops the 2i for coordinate measurement on photomasks. Laser interferometry and precision stage technology will be invaluable for later stepper development.
- Mid 1970s – Nikon develops and sells Ultra Micro Nikkor lens for use in photorepeaters. This lens will form the basis of their first stepper lens.
- 1976 – Began development of SR-1 step-and-repeat camera under MITI contract (called the VLSI Consortium). Goal is to copy GCA. Completed in 1978.
- 1980 – First commercial stepper in Japan introduced, NSR-1010G. First customers were NEC and Toshiba.
- 1982 – First stepper is shipped to U.S (TI and IBM were the first US customers).

Nikon (2)

- 1984 – Nikon matches GCA in stepper units shipped and sales revenue. Surpasses GCA in 1985. Main competitive advantage is better throughput due to significantly brighter light source and large field size (due to 5:1 reduction ratio). Laser interferometric stage and automatic alignment systems provided better overlay accuracy.
- 1984 – Nikon's first i-line stepper shipped, NSR-1010i3.
- 1987 – Cumulative sales of steppers reaches 1,000 units.
- 1988 – Nikon's first KrF stepper shipped, NSR-1505EX. Nikon falls behind in i-line technology as they devote most resources to KrF development.
- 1989 – Nikon's discussions to purchase Perkin-Elmer cause uproar in US – idea is abandoned.

Nikon (3)

- 1995 – Nikon’s first step-and-scan tool announced, NSR-S201A (world's first lens-based scanner, since SVGL is catadioptric). NA is up to 0.6, and the list price is $8.2M.
- 1996 – Cumulative sales of steppers reaches 5,000 units.
- 1999 – Nikon’s first ArF scanner developed, NSR-S302A.
- 2001 – Starts up CaF crystal growing plant.

Nikon (4)

- 2001 – Dec., Nikon sues ASML claiming off-axis illumination patent infringement. ASML counter-sues in Apr. 2002. Settlement reached in Sep. 2004 with ASML making a $87M royalty payment to Nikon. Carl Zeiss also cross-licenses patents and pays Nikon $58M.
- 2004 – Nikon develops their first ArF immersion scanner (0.92 NA). Decides to skip commercial sales of this stepper in favor of introducing an NA>1 system by the end of 2005.
- 2005 – October, Nikon announces they will not commercialize EPL.

Canon (1)

- 1970 – The PPC-1, Japan's first mask aligner, is announced.
- 1973 – PLA-300, Japan's first contact mask aligner is introduced.
- 1976 – began development of MPA (mirror projection aligner) scanners under MITI contract. Goal is to copy Perkin-Elmer Micralign.
- 1980 – First Canon projection aligner sold in Japan.
- 1982 – First Canon projection aligner (MPA-500FA) shipped to US (intended for AMD San Antonio). After an appeals court sides with Perkin-Elmer in a patent suit against Cobilt, Canon warehouses the system until IP license agreements are signed with P-E. The system is eventually shipped to TI in 1983.

Canon (2)

- 1983 – The Utsunomiya Optical Instrument Plant opens as a factory to manufacture mask aligners.
- 1984 – The FPA-1500FA, Canon's first stepper (g-line) is shipped.
- 1990 – The FPA-2000i1, Canon's first i-line stepper, is shipped.
- 1993 – Enters into discussion with SVG to share step-and-scan technology. Talks end a year later after pressure from US Government not to allow the transfer of technology to Japan. Failed talks are thought to put Canon behind in their step-and-scan development.
- 1994 – Ships 5000th mask aligner (contact, proximity, scanners and steppers).

Canon (3)

- 1997 – The FPA-4000ES1, Canon’s first KrF scanning stepper shipped.
- 1997 – The industry’s first 300mm KrF stepper, FPA-3000EX3L shipped.
- 1998 – The industry’s first 300mm I-line stepper, FPA-3000i5L shipped.
- 1999 – Canon develops “Innovative Double Exposure through Advanced Lithography” (IDEAL) process.
- 1999 – The FPA-5000AS1, Canon’s first ArF scanning stepper shipped.

Ultratech Stepper (1)

- 1979 – Ultratech Stepper founded, from the older Ultratech Corp. Introduces its first 1X stepper based on the mechanical design of Martin Lee and the optical design of Ron Hershel.
- 198x – Ultratech acquired by General Signal.
- 1982 – Ultratech sells more than 100 model 900 steppers to Intel.
- 1990 – summer, General Signal announces, then aborts, plans to merge Ultratech with GCA. Management buyout of Ultratech is announced, then falls through in September.
- 1992 – Ultratech ships the first 2244i, list price of $1.5M.
- 1993 – Jan., General Signal announces its plan to divest all of its semiconductor equipment businesses.
- 1993 – Ultratech stages a management buyout from General Signal.

Ultratech Stepper (2)

- 1994 – Ultratech Stepper goes public.
- 1997 – February, acquires assets of Lepton, a Bell Labs e-beam lithography spin-off founded in 1986, and forms UltraBeam division to sell e-beam mask writers.
- 1998 – Ultratech acquires Integrated Solutions Inc. (ISI), the remnants of GCA.
- 2000 – April, unable to find a buyer for the UltraBeam business unit, Ultratech closes down the division.

Electromask/TRE/ASET Semiconductor (1)

- ~1965 – Electromask formed in California to make photomasks for the infant semiconductor industry.
- 1968 – Electromask purchased by Veridyne Semiconductor. Management buyback of Electromask from Veridyne in 1971.
- 1972 – Electromask produces its first optical pattern generator. Systems are eventually sold to the public.
- ~1972 – The conglomerate TRE (Tool Research and Engineering) Corp. acquires Electromask, name changes to TRE Electromask (and eventually TRE Semiconductor).
- ~1975 – Adapts mask photorepeater technology (700SLR) to make a 10X wafer stepper.

Electromask/TRE/ASET Semiconductor (2)

- 1982 – TRE Semiconductor develops world's first i-line stepper using a Zeiss lens.
- 1986 – Alcoa acquires TRE Corp. (deal completed Jan. 1987); TRE Semiconductor is spun off (bought by 4 venture capital firms) as ASET (American Semiconductor Equipment Technologies, 100 employees, Gregorio Reyes as CEO).
- 1987 – ASET discontinues mask equipment business to focus on wafer steppers.
- 1990 – August, ASET goes bankrupt.
- Electromask photorepeater business continued by Interserv Corp. (www.interservcorp.com/electromask.html)

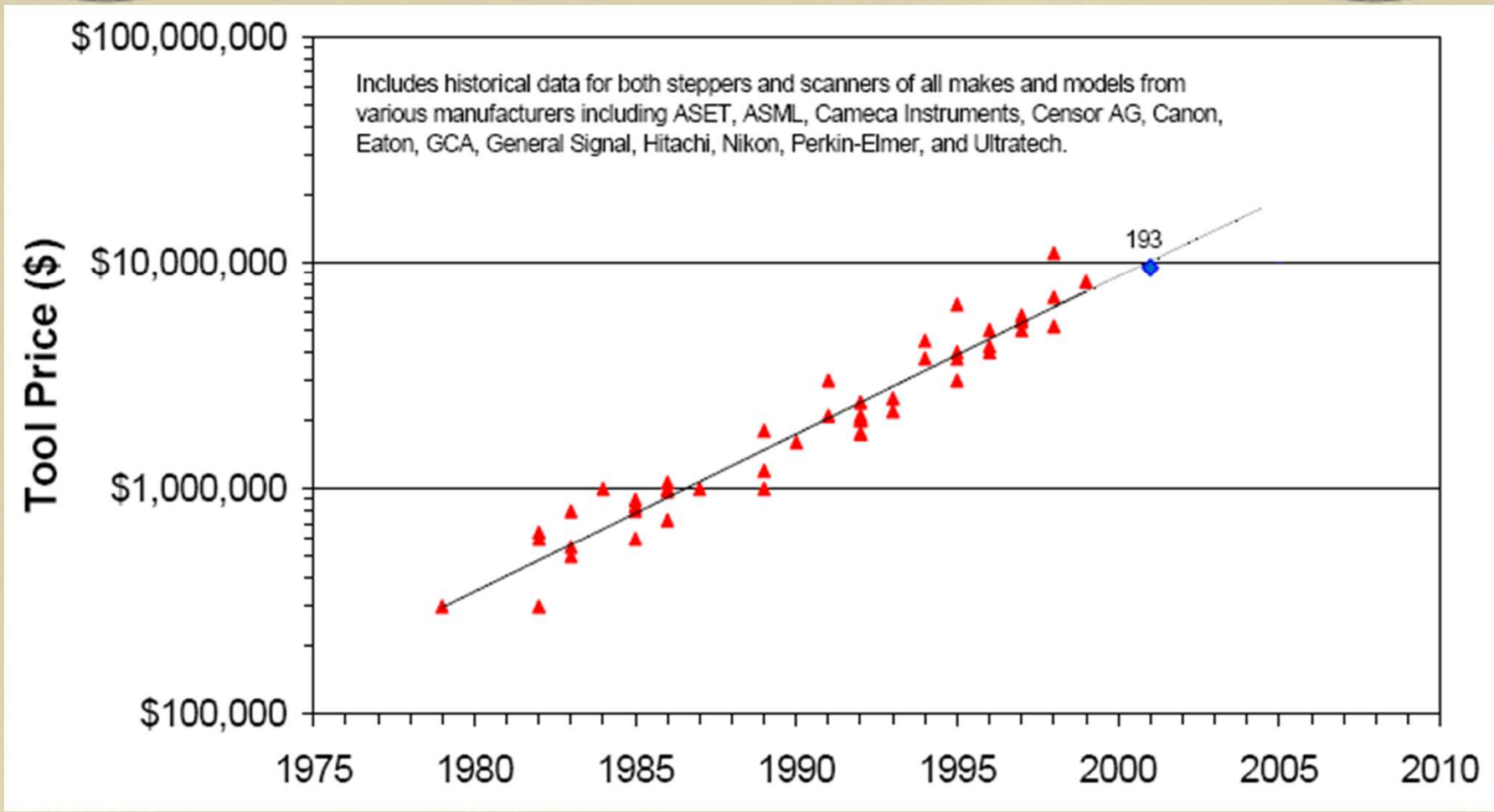
Eaton Optimetrix

- 1982 – Jan., Eaton Corp. buys the remaining 50% of Optimetrix that it didn’t already own.
- 1986 – Eaton Corp. liquidates Optimetrix.

In 1982 Eaton Corp., a midwestern manufacturer of truck transmissions and electrical controls, bought Optimetrix, a Mountain View, Calif.-based manufacturer of wafer-steppers used to image silicon chips. Hutcheson: "[Optimetrix] had already sold about 20 of the machines, so it looked hot, but customers were then so anxious to get steppers that they took machines whose alignment systems didn't work. Optimetrix never could get them to work. "At the celebration following the acquisition, the chief executive officer of Eaton gave a speech in which he said he looked forward to working with Karl Johannsmeier, the head of Optimetrix. Johannsmeier pulled out a dime and said, 'Call me.' He went to the South Pacific." Eaton liquidated Optimetrix in 1985.

When Exxon could have beaten Intel
Forbes.com, John H. Christy, July 7, 1997

Historical Tool Prices



Trendline: Tool price doubles every ~4.4 years

Source: SEMATECH, 2000 (http://ismi.sematech.org/modeling/meetings/20001109/docs/05Litho.pdf)