Enabling Fast Growing Applications in the Electronics Ecosystem

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The **Transistor**

- **1947**: Invention of the point-contact transistor (Bardeen, Brattain at Bell Labs)
- **1952**: First transistorized US consumer product: Sonotone hearing aid
- **1953**: First silicon transistor (Termanbaum at Bell Labs)
- **1954**: First transistorized computer (Manchester Univ., 48-bit machine, 92 point-contact transistors and 550 diodes)
- **1955**: First all transistor car radio (Chrysler and Philco)
- **1958**: Invention of integrated circuit (Kilby at Texas Instruments)
- **1965**: Moore's Law
- **1971**: First microprocessor (Intel 4004, 2300 transistors, 1½ inch size)
- **1974**: Transistor size below 100nm
- **1984**: Transistor size below 100nm
- **2003**: First commercial chips with high-k/metal gate (HKMG) transistors (45nm node)
- **2016**: Transistor size at below 10nm
- **2016**: First commercial chips with strain-free transistors (Intel)
- **2022**: First volume production of chips with gate all around (GAA) transistors (Samsung)

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Invention of the junction transistor (Shockley at Bell Labs)

First transistor radio (Intemetal Corp., Germany)

First silicon transistor (Termanbaum at Bell Labs)

First commercial silicon transistor (Teal and team at Texas Instruments)

First all transistor satellite (Explorer 1)

First fully transistorized computer (Manchester Univ., 48-bit machine, 92 point-contact transistors and 550 diodes)

Invention of the MOSFET transistor (Atalla and Kahng at Bell Labs)

First commercial DRAM IC chip (Intel 1103)

First commercial mobile phone, powered by transistors: Motorola DynaTAC 800X

First million transistor chip (Intel i860 microprocessor)

Introduction of chips with strained transistors (90nm node)

First commercial chips with FinFET transistors (Intel)

First volume production of chips with gate all around (GAA) transistors (Samsung)
Digitization of Everything Continues to Drive Semiconductor Growth

Sources: KLA Analysis, TechInsights May 2022, Gartner April 2022

1 28nm and above design rules, ex-memory
KLA at a Glance

- Founded in 1976
- Headquarters in Milpitas, CA
- 19 Locations
- 15,200 Employees
- $10.5B CY22 Revenue
- >65% PhD/Master’s among professional roles

Diversified leader in the electronics ecosystem
KLA Organizational Structure

Rick Wallace
President and Chief Executive Officer

Electronic Packaging & Components (EPC)

Oreste Donzella
Executive Vice President, Electronics, Packaging and Components (EPC)

Ahmad Khan
President Semiconductor Process Control (Semi PC)

Semiconductor Process Control

Brian Lorig
Executive Vice President, KLA Services

KLA Services

KLA Non-Confidential | Unrestricted
KLA EPC Journey

Created EPC group to leverage KLA’s Operating Model and accelerate profitable growth

Strategic Benefit
- Extended technology and market reach within electronics value chain
- Diversified revenue base and increased TAM in PCB and FPD markets

2008

ICOS

Strategic Benefit
- Entered packaging equipment industry with leading position in inspection and metrology applications
- Diversified revenue base and increased TAM in silicon packaging market

2019

Strategic Benefit
- Established portfolio of etch, PVD and CVD wafer processing
- Diversified revenue base and increased TAM in semiconductor market

2020

Orbotech
SPTS

2022

Integration completed

2019 Investor Day

Combined acquisitions in a single business group

Electronics, Packaging and Components (EPC)
KLA in the Electronics Ecosystem

Semi PC

- SUBSTRATES
- CHIPS
- RETICLES

EPC

- PRINTED CIRCUIT BOARD
- COMPONENTS
- FLAT PANEL DISPLAY

EPC brings KLA closer to end markets
Packaging and Automotive Opportunities at the 2019 Investor Day

**Targeting New SAM | Advanced Packaging**

<table>
<thead>
<tr>
<th>KLA: ICOS</th>
<th>Orbotech: PCB</th>
</tr>
</thead>
<tbody>
<tr>
<td>$900M</td>
<td>$350M $1,300M $5,400M</td>
</tr>
<tr>
<td>$430M²</td>
<td>$100M² $620M² $3,650M</td>
</tr>
</tbody>
</table>

**Our Targeted, Strategic Initiatives within Auto Electronics**

- **Capitalizing on Secular Trends**
  - Leverage strengths of KLA portfolio of differentiated solutions

- **Fortify Industry Leadership**
  - Define industry standards
  - Expand Automotive Semiconductor solutions through the acquisition of Orbotech (Feb 2019)

- **Initial Entry into Industry**
  - Development of internal capabilities: I-PAT in-line quality screening methodology
  - Formal industry outreach: host workshops and build awareness

Packaging and Automotive highlighted as fast-growth market opportunities in the 2019 Investor Day
Advanced Packaging
Semiconductor Technology has Been Scaling for 50+ years

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<tbody>
<tr>
<td></td>
<td>g-line (436nm)</td>
<td>i-line (365nm)</td>
<td>KrF (248nm)</td>
<td>ArF (193nm)</td>
<td>ArF Immersion (193i)</td>
</tr>
</tbody>
</table>

Conventional scaling is still happening, but it has become slow and expensive
New Technologies and Architectures Allow Moore’s Law to Continue

Transitioning From EUV to High-NA EUV

ArF Immersion (193i)

EUV (13.5nm)

EUV

High-NA EUV

FinFETs to Gate All Around (GAA)

FinFET

Gate All Around
Advanced Packaging is Another Way to Improve Performance

1D on-board

logic
memory
PCB

2D package-level

system in package (SiP)

2.5D chip-level

Si interposer and TSVs

3D chip-level

memory stacking
logic stacking

Heterogeneous integration (chiplet) no longer the technology of the future
Heterogeneous Integration is Here and Requires a Paradigm Shift

- Heterogeneous integration and chiplets are no longer the “technology of the future” in HPC (data/AI)
- Large, single-die monolithic designs are no longer performance/cost competitive in the high-end
Semiconductor of the Past: Three Separate Worlds

- **Front end semiconductor**: Performance driven by technical innovations
- **IC substrates**: Support, protect and connect at lowest cost
- **Packaging**: Protect and connect at lowest cost
‘New’ Semiconductor: Bridging Front End, Packaging and Substrates

Performance driven by technical innovations

IC substrate enabling device performance
- Scaling
- New materials
- Novel processes
- Increased layer count

Package enabling device performance
- Scaling
- New materials
- Novel processes
- Increased layer count
Wafer-Level Packaging Processes are Blending with Front End
Advanced Packaging Requires Front End-Like Process Control

Kronos™ 1190 Wafer Inspection

High-Resolution Optics

AI Algorithms

Line bridging

Line open

Line bending

Mosaic™ Plasma Dicing

Mechanical Dicing

Plasma Dicing

Strong focus on wafer and die cleanliness to ensure high yield in multi-die packages

SPTS Plasma Dicing Units Sale

IC Substrate Processes are Blending with Wafer-Level Packaging
Advanced IC Substrates Require Wafer-Level Process and Inspection

**Next Generation Laser Direct Imaging**

- Large Scan Optics, High DOF
- Multi-Wavelength Illumination

- Fine structure
- Uniformity
- No stitching \(\Rightarrow\) productivity
- Resist compatibility

**Next Generation Automated Optical Inspection**

- Multi-Modality
- Omni Sphere Illumination
- Area Camera

- Sub micron defects
- Repeatability
- AI classification

Extending laser direct imaging capability with tolerance to panel warpage for <5µm line patterning

Extending defect detection capability well beyond conventional panel AOI performance

Enabling pattern scaling with new lithography and process control development
Advanced Packaging at KLA

- **33%**  
  KLA Packaging System Revenue CAGR $^2$

- **>10**  
  New Products Under Development

- **>50**  
  New Products Penetration

- **>40**  
  Collaboration Projects with Top 5 Semi $^4$

**KLA Packaging Revenue**

- **Process Control (Semi PC, EPC)**
- **Process (EPC)**
- **IC Substrate (EPC)**

$^1$ Includes IC Substrate

$^2$ 2017-22 CAGR (System only, no Service)

$^3$ First product penetration at top 5 Semi, top 5 OSATs, top 5 ICS suppliers

$^4$ Technical engagement on new applications and/or technologies with top 5 Semi

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M&A (Orbotech, SPTS → EPC)

Increased process complexity

Process control intensity
Automotive Electronics
The Automotive Industry is Being Transformed...

Chip Shortage
- Just-in-time to just-in-case
- Strategic supply agreements and direct fab investments

Electrification
- New platforms and factories
- Batteries, inverters and power semiconductors

Software-Defined Vehicles
- >80% of innovation enabled by semiconductors
- OEMs working directly with chip companies
- Subscription services

Driver Assistance
- Sensor proliferation and domain controllers
- Leading-edge CPU/GPU, memory

New entrants | New requirements | New partnerships
Driving Broad-based Demand for Semiconductors

**Strong Growth**

Auto Semi Forecast ($Billion)\(^1\)

<table>
<thead>
<tr>
<th>Year</th>
<th>2023</th>
<th>2024</th>
<th>2025</th>
<th>2026</th>
<th>2027</th>
<th>2028</th>
<th>2029</th>
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<td>$63</td>
<td>$74</td>
<td>$82</td>
<td>$88</td>
<td>$95</td>
<td>$103</td>
<td>$110</td>
<td>$116</td>
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**All Device Types\(^2\)**

- Power 34%
- Memory 9%
- Processors 4%
- Photonics 9%
- Sensors MEMS 13%
- MCU 15%
- Analog 7%
- RF 2%
- ASIC 7%

**All Design Rules**

- ≥ 350nm
- 110–250nm
- 28–90nm
- ≤ 16nm

<table>
<thead>
<tr>
<th>Year</th>
<th>≥ 350nm</th>
<th>110–250nm</th>
<th>28–90nm</th>
<th>≤ 16nm</th>
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<tbody>
<tr>
<td>Fab</td>
<td>15</td>
<td>6</td>
<td>4</td>
<td>7</td>
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**Incremental Automotive Fab Capacity Needed by 2027 (WSPM)\(^3\)**

- 370,333
- 146,250
- 110,167
- 174,250

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\(^1\)Source: IHS, Cowen and Company

\(^2\)Source: Yole 2021 breakdown

\(^3\)Source: Yole, others. 25k WSPM typical automotive fab size
Zero Defect Strategy and SiC Adoption are Opportunities for KLA

Enabling automotive industry secular shift into the autonomous and electrification era

AI methodology to Screen Potential Reliability Failures

Plasma Deposition and Etching Custom Solutions for SiC

I-PAT® on 89xx

Test Escapes

Latent Defects

Omeka® Plasma Etch

Flat Trench Bottom

Round Trench Bottom

Aggregated and weighted defectivity

Outlier statistical filtering

Merged with electrical test data

Sigma® PVD1 (Frontside and backside metallization)

PVD = Plasma Vapor Deposition
Automotive at KLA

- **37%** KLA Auto System Revenue CAGR\(^1\)
- **11%** KLA Auto Service Revenue CAGR\(^1\)
- **>3x** KLA vs. Total Auto Semi CAGR\(^2\)
- **>$300M** Power SiC Revenue in 2022
- **>35%** Auto % of SPTS Revenue in 2022

**KLA Automotive Revenue**

- Process Control (Semi PC)
- Specialty Process (EPC)

<table>
<thead>
<tr>
<th>Year</th>
<th>$M</th>
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<tbody>
<tr>
<td>2017</td>
<td></td>
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<tr>
<td>2022</td>
<td></td>
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<tr>
<td>2023F</td>
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\(^1\) KLA Auto Semi CAGR 2017-2023F

\(^2\) Combined KLA System + Service revenue (30%) vs. IHS/Cowen total auto semi (8.8%), 2017-2023F

- M&A (SPTS → EPC)
- Increasing process control intensity
- SiC
Summary

The front end semiconductor industry continues to produce innovation pushing Moore’s Law forward.

Heterogeneous integration is a key component in enabling overall semiconductor technology roadmap.

Front end, packaging and substrate domains are becoming integrated just like the packages and systems they create.

KLA will provide solutions to bridge front end, packaging and substrate worlds, given the large presence in all these markets.

The automotive industry has been forever changed by the chip shortage, vehicle electrification and the software-defined vehicle.

KLA works closely with the automotive ecosystem to develop a comprehensive portfolio of process control solutions.

The rise of SiC power semi devices poses additional yield, reliability, and cost challenges.

Inline defect screening is being adopted by automotive fabs to reduce escapes for reliability sensitive devices.

Packaging and Automotive Markets – New Growth Engines for KLA