

MICREL FOUNDRY SERVICES: SILICON MADE IN SILICON VALLEY



Micrel Inc., is a leading global manufacturer of IC solutions for the worldwide high-performance linear and power solutions, LAN, and timing and communications markets. Micrel's custom foundry service is the alternative to traditional foundry services, allowing customers to develop their own unique proprietary process flows, starting from a pure R&D concept to a full high-volume production transfer. The Company's products include advanced mixed-signal, analog and power semiconductors, high performance communication, clock management, Ethernet switch, and physical layer transceiver ICs. Company customers include leading manufacturers of enterprise, consumer, industrial, mobile, telecommunications, automotive, and computer products. Corporation headquarters and state-of-the-art wafer fabrication facilities are located in San Jose, California with regional sales and support offices and advanced technology design centers situated throughout the Americas, Europe, and Asia. In addition, the Company maintains an extensive network of distributors and reps worldwide.

Micrel's Foundry Services for Integrated Circuits and MEMS

Micrel's Wafer Fab division offers foundry services to commercial, military, and MEMS IC designers and all manufacturers seeking a production solution compatible with their specific application and/or technology needs. The Micrel foundry provides a variety of flexible wafer fabrication and processing resources that can address unique requirements from short runs up to volume production. The facility has been certified to ISO14001:1996, the International Environmental Management System Standard. This environmental management system strives to ensure regulatory compliance and reduce environmental impact through waste reduction and recycling. Additionally, Micrel continues to focus on constantly improving its quality, safety, and environmental practices by employing procedures that significantly reduce water and energy consumption, saving considerable operating funds as well as preserving the environment. To ensure compliance with the European directive on the restriction of use of hazardous substances (RoHS) and other similar regulations, Micrel remains committed to providing lead-free products.

Micrel is expanding its toolset capabilities to address the fast-growing MEMS business. Micrel has a state-of-the-art SPTS Pegasus™ DRIE machine that features the fastest deep silicon etch rates available, as well as providing superior sidewall smoothness and cross-wafer uniformity. The Pegasus is the tool of choice for the very high aspect ratio features and large cavities required for today's MEMS products. Micrel has also added a projection aligner that allows us to handle 225 micron to 700 micron thick wafers and up to 20 microns of photoresist. MEMS customers also have the option for monolithic integration with CMOS as well as access to all of Micrel's IC products for package-level integration. At Micrel, fab-less customers can take advantage of the rare capability for production of a full MEMS sensor system at one facility.



The ASML 5x Stepper aligns the mask to the wafer after the photoresist is spun on.



WAFER FAB CAPABILITIES

State-of-the-Art Quality, Process, and Systems

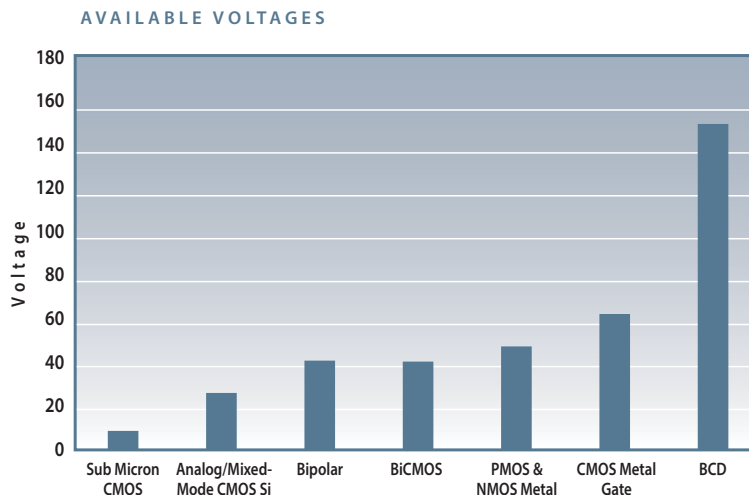
- SPC 100% >1.0 CPK, 90% >1.33 CPK
- Die and fab yields >95%
- On-time delivery (OSD) >95%
- Cycle time:
 - < 1.85 mean Cycle Time Per Layer (CTPL)
 - < 2.1 (98% "tile") CTPL
- QS9000/ISO9002 preferred
- FIT rates:
 - Super-micron >4
 - Sub-micron <0.6
- Customer returns <0.18% of annual sales
- Real time SPC deployment
- World-class benchmarked systems implementation
 - Weekly operations reviews
 - Monthly operations reviews and MBO goals
- Quarterly system reviews
- Annual quality audits/review for critical suppliers

ALTERNATE OR SECOND SOURCE PRODUCTS

- Mature MOS or bipolar circuits: customer-owned tooling
- Full custom designs

MICREL FOUNDRY STRENGTHS

- IDMs who need second source and/or capacity
- Small customers with emerging MEMS technologies
 - Micrel offers development with desired customization
 - Micrel welcomes all small volume: 25–100 wafers per year
 - Significant volume available if production is needed
 - 200 wafer starts per day/50K per year



FOUNDRY SERVICES

MEMS, Bipolar, CMOS, BCD, BiCMOS, NMOS, and PMOS

- MEMS precision 3D-capable technology
 - Automotive industry
 - Consumer electronics
 - Medical electronics
- Mixed technologies
 - Digital + Analog + Power + MOSFET
- CMOS/DMOS high voltage with high current
- Low-threshold voltage, low-power CMOS
 - Low-, medium-, and high-voltage bipolar technologies
 - Analog bipolar
- High-speed bipolar and SiGe
- SPICE parameters and characterized library elements are available

Micrel has a modern fabrication facility using 1x and 5x steppers (six-inch), specialized projection aligners (for MEMS devices that require front-to-back alignment and very thick photoresist), positive resist, all-dry etch, and "all implanted" processing, with in-house implant, 8 ASM single wafer EPI reactors, and sputtered metal. With the capability to produce up to 40,000 wafers per month, the Company's sophisticated state-of-the-art measurement equipment is used to monitor and record line widths, particle levels, film thicknesses, and other critical parameters. Final electrical characterization of the wafer test die is provided by automated test equipment.

Micrel offers combinations of design, process, and pure foundry services that are sure to fit your exact needs. There are a number of options from which you can select. Each is designed to match your specific requirements to the appropriate Micrel solution.

IC Foundry	R&D IC Foundry	Semi-Custom IC Foundry	Custom IC Foundry	Full-Service IC Foundry	MEMS Foundry	MEMS+ Foundry
Micrel duplicates your process	Let Micrel develop new processes to meet your needs	Combine your design with Micrel's technology and processes	Add Micrel design expertise, technology, and processes to your circuit	Power your specification using Micrel's design, technology, processes, test, and packaging	Your MEMS design and process flow	Your MEMS design and process flow, plus any of the other IC solutions detailed in this table

THE MICREL ADVANTAGE

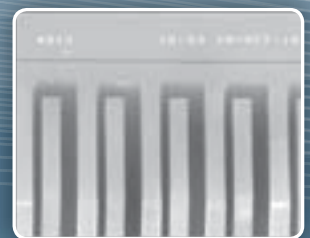
When you choose Micrel for your wafer fabrication needs, you engage a foundry capable of providing engineering support for your product's design, process, production, packaging, and reliability requirements. The same technical staff that has made Micrel's products world-renowned for innovation, quality, and performance is available to assist you in evaluating your circuit design, process recipe, or test system for your semiconductor devices.

Examples of Micrel's foundry commitment to service include the use of Computer-Aided Design (CAD) support and customized test patterns. SPICE parameters are available to aid your design and simulation efforts. Micrel CAD support helps you with often overlooked details, such as proper placement of alignment marks and scribe lines. Micrel can also order your masks from the mask vendor and ensure they are made correctly. Unlike most foundries, Micrel will match your layout rules or design requirements with a customized wafer test pattern. This results in many practical advantages, including:

- **Yield Improvement and Process Development:** Custom test structures, equipped with Spreading Resistance Profile (SRP) bars and optimized for your particular product, streamline data collection and provide accurate characterization data.
- **Correlation with Simulations:** Personalized test patterns provide custom geometry devices that can confirm CAD models. Breadboarding and reliability testing are other benefits.

STATISTICAL PROCESS CONTROL

You have a choice in selecting the classification and quality standards to which your devices are manufactured. You may select upgrades to Industrial Class-B, Military Class-S or Class-B (MIL-STD-883), or custom production requirements designed to your particular specification definitions.



MEMS Processes

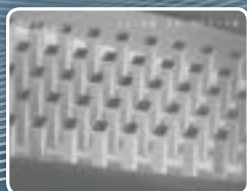
- MEMS-only or CMOS+MEMS integrated processing
- Inkjet; inertial, pressure, Hall, optical and infrared sensors; microphones and resonators
- Electrostatic actuators, capacitive and piezoresistor sensors
- 0.5 μ stepper lithography with front-to-back side alignment
- Stitching capability for large die
- Silicon on Insulator (SOI)
- Thick epi-silicon
- Doped/undoped polysilicon
- Thermal, LPCVD and PECVD oxide
- LPCVD and PECVD (low stress) nitride
- State-of-the-art DRIE etch on SPTS Pegasus
- KOH etch
- CMOS-compatible metals; thin and thick metal dry etch
- Coming soon: XeF₂, anhydrous HF release and bonding



The DNS spin track is an integrated part of the ASML 5x stepper. The spin track applies photoresist to the wafer prior to mask alignment.

CMOS Processes

- Numerous digital and analog Si-gate technologies, from 0.35 μ /3.3V to 16 μ /45V
- Stitching capability for large die
- Anisotropically-etched contacts, down to 0.4 μ
- Anisotropically-etched poly, pitch down to 0.9 μ (.45 μ /.45 μ)
- Dry-etched metal, pitch down to 1.2 μ
- CMOS metal gate technology, down to 5 μ /12V
- Double- or triple-poly technology
- Nitride-on-oxide poly-to-poly capacitors
- LDD/NLDD processes for higher voltages
- DDD processes for higher voltages
- 1 μ , 2 μ , 3 μ and 5 μ extended-drain for higher voltage
- Buried- and surface-channel CCD
- Single- and double-poly EEPROM technology
- Gate oxides, down to 70Å
- Military-style nitride-on-oxide metal gate technology
- Rad-tolerant CMOS Si-gate technologies
- Transient-upset protected CMOS (neutron-irradiation)
- N on N+ CMOS for latch-up protection
- P on P+ CMOS for latch-up reduction
- Retrograde P-well and N-well for latch-up reduction
- Optical sensors with nitride-type anti-reflective coating
- Extended-drain CMOS for high voltage (160V)
- Dielectric isolation capability/experience
- Buried-contact for buried-poly-via capability
- CMOS-type bipolar technology and buried Zeners
- Plasma nitride passivation
- Ink-jet CMOS process technology
- 15 Ω to 1M Ω /sq poly resistors (stabilized)
- Low-noise processes
- Low-leakage processes
- Contrast-enhanced-material lithography
- Zener-trim cells
- Zener-trim





Wafers are brought to very high temperatures in this Thermco furnace to diffuse various N+ or P+ dopants into the areas of the wafer masked off during the masking process.

BiCMOS Processes

- Metal-gate CMOS with power NPNs and PNPs
- Option to add metal-gate LDMOS with no additional masks
- In P-well, Si-gate, or metal-gate CMOS technologies, a high-performance vertical PNP (separate collector) may be added with one additional N-base mask and is supported by predefined macros.
- In P-well, Si-gate CMOS technology, a lateral NPN with good Beta and separate collector may be used and is supported by predefined macros.
- BiCMOS options are available which are fully-isolated (such as bipolar); just N-EPI on N+ starting material, or "No EPI"

Bipolar Processes

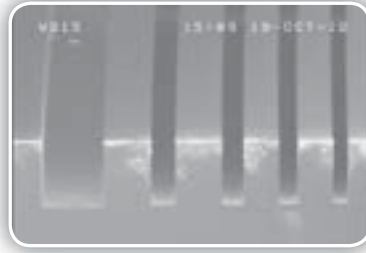
- Bipolar processes from 5μ epi/15V to 10μ epi/170V
- Schottky diodes available with AlSiCu or TiSi2/TiN
- Resistor heater module
- Optical sensors with nitride-type anti-reflective coating
- Dielectric isolation capability/experience
- Plasma-nitride passivation
- Poly-interconnect, resistor or field-plate option
- Washed-emitter technology
- Poly-emitter technology
- Characterized up/down isolation technology
- Complementary bipolar
- 5μ thick metal dry-etch capability
- Low-noise processes
- Low-leakage processes
- Zener-trim cells
- Implanted buried layer

DMOS Processes

- Discrete devices up to 2GHz and up to 300 Watts
- Dual-well metal-gate DMOS/CMOS technology to 80V
- D.I. version of DMOS/CMOS
- Lateral (Si-gate or metal-gate) or vertical DMOS

Micrel Si-Gate Bipolar/CMOS/DMOS (BCD)

- DMOS/HVPCH and bipolar transistors: 50V, 100V or 200V
- High-voltage CMOS: 45V
- 6V, 7V, 8V Zeners/buried Zeners
- Pre-tested analog/digital macros
- $5V_{IN}$ to $200V_{OUT}$ translators
- H-bridge capability (all-VDMOS)
- Double-poly high-voltage nitride-on-oxide capacitor technology
- Depletion devices
- High-voltage resistors: 100V/200V
- High-efficiency voltage tripler
- Stabilized bandgap references
- Overtemperature/overvoltage capability
- Sense-FET capability (on-chip)
- Latch-up-proof process
- LDMOS and VDMOS on same wafer
- High-voltage (100V/200V) gate VDMOS option
- Option for no-body-effect on VDMOS or HPCH



MICREL'S UNIQUE CAPABILITIES

- Micrel stands apart from existing MEMS foundries who only dabble in MEMS
- Micrel offers full MEMS+CMOS solution
- Micrel fully supports small volume projects
- Micrel is an IDM with a vital foundry services business
 - Willing to do full custom design or process based on customer needs
 - Strong commitment to IP protection

MICREL'S COMPETITIVE ADVANTAGE

- **North American Location**
 - Many companies, especially medical device companies, want to manufacture in the USA
 - Strongly connected to Silicon Valley ecosystem
- **150mm Wafers**
 - Versatile production platform
 - Willing to do small volume project (25-100 wafers/year)
- **MEMS+CMOS Capabilities Under One Roof**
 - Reduces number of vendors, shortens cycle time, and increases yield
 - MEMS and IC co-design and co-optimization
- **Enduring Foundry Experience with Custom, Small Batch Processes**
 - Differentiates from other "me too" IC fabs in MEMS business

MICREL STRENGTHS

- Publicly traded company, well-established IC fab, world class foundry, 24/7 operation, >7,000 customers worldwide
- Provides IC + MEMS solutions
- Experienced and comfortable with custom, small batch work and custom technology development
 - An IDM with a vital and long-history of foundry services
- 150mm foundry dedicated capacity ~50K wafers/yr
- Very experienced process staff

- Short and efficient development cycles
- Great yield and throughput in production
- Silicon made in Silicon Valley, USA
- Local pool of highly skilled experts

TECHNOLOGY OVERVIEW:

- **Capabilities**
 - 0.35 μ m Lithography
 - Double Poly, Triple Metal
 - Poly Emitters, SiGe, Poly & TiN Resistors
 - SOG, CMP, REB, Shallow Trench Isolation, Tungsten Plug
 - Proprietary films for optical, high voltage applications
 - KOH Etch, Si Texturing
 - DRIE TSV (Through Silicon Via) Deep Trench
 - Double sided wafer processing
 - Stitching, front-to-back alignment
 - Wafer cavity technology
 - » Full wafer thickness support structure allows processing through most tools
 - 225 – 750 μ m
 - » Thin Device (cavity) region for MEMS requirements
 - 140-400 μ m

MICREL INTERACTIONS WITH MEMS CUSTOMERS

- Micrel engineering has experience supporting incomplete designs and processes
 - Micrel engineering is prepared to work with the customer where development is almost always required
- Micrel works with customers to establish discrete phases as customers move toward production goals
 - Concept, prototype, pilot, production phases
 - Will help customer to set realistic expectations
- Micrel is committed to continuous improvement with customers in production phase
 - Yield improvement, cost reduction, failure analysis and on time delivery

ONLINE SUPPORT

For online support for all your foundry needs and to take a virtual tour of the Micrel foundry, please visit Micrel at:
<http://www.micrel.com/index.php/en/foundry.html>

FOUNDRY SOLUTIONS

- ICs and MEMS under one roof
- 150mm wafers, 50K wafers per year dedicated MEMS capacity
- Custom technology development
- Experience with custom and small batch work
- Applications for emerging MEMS technologies
- Made in America by highly skilled experts
- World class fab with 24/7/365 operations
- More than 30 years of manufacturing innovation



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