

INDUSTRIAL CASE STUDY

Ultra-High Purity Gas Heating & Silicon Curing

Continuous Inline UHP Nitrogen Gas Heating System for Silicone Encapsulant Curing — Semiconductor Assembly & Packaging Scale

|                                                                     |                                                            |                                                               |                                                         |                                                                        |                                                          |
|---------------------------------------------------------------------|------------------------------------------------------------|---------------------------------------------------------------|---------------------------------------------------------|------------------------------------------------------------------------|----------------------------------------------------------|
| <div>500</div> <div>Nm³/hr</div> <div>UHP N2 HEATING CAPACITY</div> | <div>150</div> <div>°C</div> <div>CURE TEMP., ±1.5°C</div> | <div>5N5</div> <div>99.9995%</div> <div>GAS PURITY (N2)</div> | <div>25</div> <div>min</div> <div>CURE CYCLE TIME</div> | <div>0.4</div> <div>% Void Rate</div> <div>DEFECT LEVEL ACHIEVED</div> | <div>~1.8</div> <div>Yrs</div> <div>PAYBACK PERIOD</div> |
|---------------------------------------------------------------------|------------------------------------------------------------|---------------------------------------------------------------|---------------------------------------------------------|------------------------------------------------------------------------|----------------------------------------------------------|

Designed, Engineered & Validated by KERONE Engineering Solutions Limited

Project Reference Detail

|                     |                                                                                                      |
|---------------------|------------------------------------------------------------------------------------------------------|
| Client Organisation | Apex Semiconductor Packaging Pvt. Ltd. — Bengaluru-based OSAT & sensor-module assembly house         |
| KERONE Reference    | KRDC/ICS/UHPGasCure/2026-01   Based on KRDC Lab Report 12/KRDC/LAB/22                                |
| Technology          | Continuous Inline Ultra-High Purity (UHP) Gas Heating System with Precision Curing Tunnel            |
| Process             | Silicone die-attach adhesive & encapsulant curing on semiconductor substrates and sensor modules     |
| Product Output      | Fully cured silicone encapsulant — Class 10 cleanroom compliant, <0.4% void/delamination defect rate |
| Plant Location      | Client facility (assembly & packaging line) — Inline with die-attach and encapsulation stations      |
| Document Date       | July 2026   Validated on KRDC Lab Data — March 2026                                                  |

Semiconductor Packaging | Ultra-High Purity Gas Systems | Silicone Encapsulant Curing | Cleanroom Thermal Processing | OSAT Yield Improvement | Electronics  
Electronics / Semiconductor

Executive Summary

Apex Semiconductor Packaging Pvt. Ltd., a Bengaluru-based OSAT (Outsourced Semiconductor Assembly and Test) provider serving sensor, MEMS, and power-module customers, faced a yield-limiting bottleneck: its silicone die-attach adhesive and encapsulant curing step relied on a batch convection oven fed with ambient-purity nitrogen, producing inconsistent temperature profiles and gas contamination that led to a 8.2% void/delamination defect rate — well above the Class 3 OSAT reliability specification demanded by its automotive and industrial customers.

KERONE Engineering Solutions Limited was engaged to design, validate, and specify a continuous, cleanroom-compatible Ultra-High Purity (UHP) gas heating and curing system capable of delivering repeatable, contamination-free thermal profiles for silicone curing at a line throughput of up to 2,400 substrates per hour.

Following structured laboratory validation at KRDC (Kerone Research & Development Centre) using a bench-scale UHP gas heating cell across multiple temperatures (130°C, 150°C, 170°C) and hold times, the optimal industrial process parameters were established. The KERONE continuous inline UHP gas heating system — operating at 150°C with a 25-minute cure residence time under 99.9995% (5N5) purity nitrogen — reduces void/delamination defects from 8.2% to below 0.4%, while lifting first-pass line yield from 88.4% to above 98%.

| CHALLENGE                                                                                                                                                                | KERONE SOLUTION                                                                                                      | OUTCOME ACHIEVED                                                                                                                      |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------|
| Batch-cured silicone encapsulant with 8.2% void/delamination defects, driven by ambient-purity N2 and poor temperature uniformity — capping OSAT customer qualification. | Continuous inline UHP gas heating system at 150°C, 5N5 N2 purity, 25-min residence — validated from KRDC lab trials. | Cured encapsulant with < 0.4% void/delamination rate, Class 10 cleanroom compliance — qualifying for automotive-grade OSAT contracts. |

Key Performance Summary

| KPI                             | Baseline (Batch Convection Oven)    | After KERONE UHP System      | Improvement          |
|---------------------------------|-------------------------------------|------------------------------|----------------------|
| Void / Delamination Defect Rate | 8.2%                                | 0.4%                         | 95% reduction        |
| Process Gas Purity (N2)         | 99.95% (3N5, unheated ambient feed) | 99.9995% (5N5), O2 < 1 ppb   | ~100x cleaner        |
| Cure Temperature Uniformity     | ± 8 °C (convection batch oven)      | ± 1.5 °C (UHP inline tunnel) | 5.3x tighter control |
| Cure Cycle Time                 | 45 min                              | 25 min                       | 44% faster           |
| Line Throughput                 | 1,000 substrates/hr                 | 2,400 substrates/hr          | 2.4x increase        |
| Annual Scrap / Rework Cost      | INR 3.8-4.5 Cr/yr                   | INR 0.3-0.5 Cr/yr            | ~90% reduction       |

Table 1: Key performance indicators — baseline batch process vs KERONE UHP gas heating & curing system

Industry Context & The Business Challenge

India's semiconductor assembly, test, marking and packaging (ATMP/OSAT) sector is expanding rapidly under the India Semiconductor Mission, with several new OSAT facilities commissioned or under construction across Karnataka, Gujarat, and Uttar Pradesh. Silicone-based die-attach adhesives and encapsulants are used extensively in sensor modules, power semiconductors, and MEMS packages to provide mechanical protection, thermal management, and moisture resistance.

Curing of these silicone formulations is highly sensitive to the purity and temperature uniformity of the process atmosphere. Residual oxygen and moisture in the curing gas inhibit the platinum-catalyzed hydrosilylation reaction typical of addition-cure silicones, producing voids, incomplete cure, and delamination at the die-attach or encapsulant interface — a leading cause of field reliability failures and customer return material authorizations (RMAs) in automotive and industrial electronics.

The global market for ultra-high purity process gas equipment used in semiconductor back-end packaging continues to grow as OSAT providers pursue automotive-grade (AEC-Q100) and industrial reliability qualifications, which typically mandate void content below 1% and Class 10-100 cleanroom compliance for encapsulation processes.

The Commercial Problem — Why Uncontrolled Curing Limits Qualification

| Quality Parameter         | Raw / Baseline Process               | OSAT Industry Requirement          | Gap                          |
|---------------------------|--------------------------------------|------------------------------------|------------------------------|
| Void Content (CSAM)       | 8.2%                                 | < 1%                               | FAIL — 8x over limit         |
| Particle Count (Class)    | Class 1000 (uncontrolled ambient N2) | Class 10 (JEDEC/IPC-A-610 Class 3) | FAIL — non-compliant         |
| Moisture Dew Point in Gas | -40°C (industrial grade N2)          | < -70°C                            | FAIL — moisture ingress risk |
| Line Yield (First Pass)   | 88.4%                                | > 98%                              | FAIL — yield gap             |

Table 2: Baseline curing process parameters vs OSAT industry requirement | Source: KRDC Analysis & IPC-A-610 Class 3 Requirements

Yield Opportunity — Upgrading the Existing Curing Step

The Opportunity: At 2,400 substrates/hour operating 7,200 hours/year, the line processes approximately 17.3 million substrates annually. At the baseline 8.2% defect rate, this represents roughly 1.42 million substrates/year requiring rework or scrap at an estimated INR 210/substrate cost — a rework/scrap burden of approximately INR 3.8-4.5 Cr/year. Post-upgrade, the same volume at a 0.4% defect rate reduces this burden to approximately INR 0.3-0.5 Cr/year, a direct annual cost avoidance of over INR 3.5 Cr, in addition to enabling 2.4x higher line throughput on the same footprint.

About Apex Semiconductor Packaging Pvt. Ltd.

Apex Semiconductor Packaging Pvt. Ltd. is a privately held OSAT provider with assembly and test operations serving automotive sensor, power module, and industrial MEMS customers across India and Southeast Asia. Its operations span die-attach, wire bonding, encapsulation, and final test, positioning it as an ideal anchor client for KERONE's UHP gas heating and curing technology. The KRDC trial was conducted on Apex's actual production silicone encapsulant formulation (2 kg sample, dispatched for testing in February 2026) to ensure industrial relevance of all process parameters.

Process Validation — From KRDC Lab to Industrial Scale

KERONE's engineering approach mandates laboratory-scale validation before any industrial system specification. The KRDC (Kerone Research & Development Centre) conducted a structured experimental programme on Apex's actual silicone encapsulant formulation over 5 days, using a bench-scale UHP gas heating cell to establish the process envelope that informs the industrial inline system design.

KRDC Experimental Programme — Key Findings

| Test Condition                  | Gas Temp. | Hold Time | Void Content (CSAM) | Assessment                         |
|---------------------------------|-----------|-----------|---------------------|------------------------------------|
| Control (ambient N2, no heater) | N/A       | 0 min     | 8.9%                | Baseline — high void, delamination |
| Low temp                        | 130 °C    | 25 min    | 3.6%                | Insufficient — incomplete cure     |
| OPTIMAL                         | 150 °C    | 25 min    | 0.4%                | Meets Class 3 OSAT spec            |
| High temp                       | 170 °C    | 25 min    | 0.6%                | Slight over-cure — polymer stress  |

Table 3: KRDC Laboratory Results — UHP gas heating trials on Apex silicone encapsulant formulation | KRDC Test Report 12/KRDC/LAB/22 | Void content measured by C-mode Scanning Acoustic Microscopy (CSAM)

Scale-Up Methodology — Lab to Industrial Inline System

KERONE's scale-up process follows a structured engineering framework where laboratory parameters are translated to industrial equipment specifications using validated thermal and gas-flow engineering models. The key translation factors for this project are:

| Parameter               | KRDC Lab (Bench Cell)  | Industrial Plant (Inline Tunnel)   | Scale-Up Factor      |
|-------------------------|------------------------|------------------------------------|----------------------|
| Gas Heating Temperature | 150 °C                 | 150 °C                             | 1:1 (direct)         |
| Optimal Cure Hold Time  | 25 min                 | 25 min residence (tunnel)          | 1:1 (direct)         |
| Gas Flow Rate           | ~2 Nm³/hr (bench cell) | 500 Nm³/hr                         | 250:1                |
| Purity Class            | 5N5 (bottled UHP N2)   | 5N5 (onsite purification + heater) | Direct               |
| Ramp Rate               | 4 °C/min               | Zone-controlled (4 zones)          | Adapted              |
| Handling Mode           | Batch (static boat)    | Continuous inline conveyor         | Configuration change |

Table 4: Scale-up translation factors — KRDC bench cell to industrial inline UHP gas heating & curing system

## Industrial Plant Design — Continuous UHP Gas Heating & Curing System

Process Flow: Substrate Load → UHP Gas Purification → UHP Gas Heater → Curing Tunnel → Cooling Zone → In-line Inspection → Substrate Unload & Sorting.

### System Architecture — Major Process Units

| Unit / Section                                     | Equipment                                        | Design Parameters                                              | Function                                                                      |
|----------------------------------------------------|--------------------------------------------------|----------------------------------------------------------------|-------------------------------------------------------------------------------|
| U-01: Substrate Load                               | Belt Conveyor + Robotic Pick-Place               | 2,600 substrates/hr rated                                      | Load substrates onto carrier; align for tunnel entry                          |
| U-02: UHP Gas Purification                         | Getter Bed + Point-of-Use Filter (0.003 µm)      | 5N5 purity, O <sub>2</sub> < 1 ppb, moisture < 1 ppb           | Strip residual O <sub>2</sub> /moisture/hydrocarbons from feed N <sub>2</sub> |
| U-03: UHP Inline Gas Heater (Primary Process Unit) | KERONE Electropolished SS316L Sheathed Heater    | 550 Nm <sup>3</sup> /hr capacity, 150°C ±1.5°C, 4-zone control | Core thermal unit — heats UHP gas without particle/metal contamination        |
| U-04: Curing Tunnel                                | Continuous Convection Tunnel Oven                | L 9m, 4-zone, laminar UHP N <sub>2</sub> flow                  | Cures silicone encapsulant under controlled atmosphere                        |
| U-05: Cooling Zone                                 | N <sub>2</sub> -purged Cooling Tunnel            | Inlet 150°C, outlet < 40°C                                     | Cools cured substrates before ambient exposure                                |
| U-06: In-line Inspection                           | CSAM + AOI Station                               | 100% inline scan, < 3 sec/substrate                            | Detects voids, delamination, particulate defects                              |
| U-07: Substrate Unload & Sorting                   | Robotic Unload + Bin Sorter                      | Auto pass/fail sort                                            | Segregates conforming substrates from rework/reject                           |
| U-08: Safety & Monitoring                          | O <sub>2</sub> Depletion Sensors + Gas Analyzers | < 19.5% O <sub>2</sub> alarm, continuous logging               | Personnel safety and atmosphere-integrity monitoring                          |
| U-09: Process Control                              | PLC/SCADA Control Panel                          | Siemens S7 / Allen Bradley, remote monitoring                  | Automated temperature, flow, dew-point & purity control; data logging         |

Table 5: Process unit descriptions — KERONE continuous UHP gas heating & curing system | U-03 (UHP Gas Heater) is the primary process unit; all others are ancillary

Core Equipment Specification — KERONE UHP Inline Gas Heater

The KERONE Continuous UHP Inline Gas Heater is the heart of the silicon curing upgrade system. Designed and manufactured in-house at KERONE's Ambernath facility using electropolished SS316L wetted-path construction, it directly scales the validated laboratory parameters from KRDC trial 12/KRDC/LAB/22 to industrial throughput while maintaining the identical thermal profile, gas purity, and cleanliness that produced the 0.4% void-content result.

| Parameter              | KERONE UHP Gas Heater — Core Specification                                        |
|------------------------|-----------------------------------------------------------------------------------|
| Design Gas Flow        | 550 Nm <sup>3</sup> /hr (N <sub>2</sub> , expandable to Ar/H <sub>2</sub> blends) |
| Operating Temperature  | 150 °C (max design: 300 °C)                                                       |
| Temperature Uniformity | ± 1.5 °C across heated zone                                                       |
| Gas Purity Retention   | 5N5 (99.9995%) maintained through heater — zero purity loss                       |
| Wetted Path Material   | Electropolished SS316L (Ra < 0.4 μm), orbital-welded joints                       |
| Heating Elements       | Sheathed resistance elements, external to gas path (indirect heating)             |
| Sealing / Fittings     | VCR metal-gasket face-seal fittings — zero elastomer in gas path                  |
| Particle Generation    | < 0.1 particles/ft <sup>3</sup> (Class 10 equivalent) at heater outlet            |
| Installed Power        | ~42 kW (total connected load)                                                     |
| Control System         | PID + SCR power control, ± 0.5 °C setpoint stability                              |

Table 6: KERONE UHP Inline Gas Heater — core specifications (industrial unit scaled to 550 Nm<sup>3</sup>/hr rated flow)

Utilities & Ancillary Requirements

| Utility                          | Specification                              | Consumption (at Rated Flow)                     | Source                                            |
|----------------------------------|--------------------------------------------|-------------------------------------------------|---------------------------------------------------|
| Ultra-High Purity N <sub>2</sub> | 99.9995% (5N5) purity, 6-8 bar supply      | 500 Nm <sup>3</sup> /hr (heater + tunnel purge) | Onsite PSA/cryogenic generator or bulk UHP supply |
| Electrical Power                 | 415V, 3-phase, 50Hz                        | ~42 kW connected   ~32 kW avg demand            | Site utility                                      |
| Compressed Dry Air               | 6 bar, instrument grade, dew point < -40°C | 10 Nm <sup>3</sup> /hr                          | Air compressor (site)                             |
| Cooling Water                    | 22°C supply, closed loop                   | 6 m <sup>3</sup> /hr   28°C return              | Chiller / cooling tower                           |
| Space Requirement                | Building / cleanroom bay                   | L 14m x W 5m x H 4m                             | Class 10,000 cleanroom bay or better              |

Table 7: Utilities & ancillary requirements — industrial UHP gas heating & curing system

Atmosphere & Safety Compliance

| Monitoring Point             | Parameter                    | Expected Level / Limit          | Status    |
|------------------------------|------------------------------|---------------------------------|-----------|
| Tunnel Interior              | O <sub>2</sub> Concentration | < 50 ppm (inert atmosphere)     | COMPLIANT |
| Bay Ambient (Personnel Zone) | O <sub>2</sub> Depletion     | > 19.5% (alarm threshold)       | COMPLIANT |
| Heater Outlet Gas            | Moisture Dew Point           | < -70 °C                        | COMPLIANT |
| Heater Outlet Gas            | Particle Count               | < 0.1 particles/ft <sup>3</sup> | COMPLIANT |

Table 8: Atmosphere monitoring and personnel safety compliance points

## Gas Balance & Energy Analysis — Industrial Operation

### Detailed Gas Balance — Per Hour at Full Load

| Stream                     | Material                             | Flow Rate (Nm <sup>3</sup> /hr) | Notes                                        |
|----------------------------|--------------------------------------|---------------------------------|----------------------------------------------|
| Feed (IN)                  | UHP N2 from purification skid        | 500                             | 5N5 purity, -76°C dew point, <1 ppb O2       |
| Tunnel Purge Loss          | N2 lost to tunnel seals/exhaust      | ~35                             | ~7% of feed; recovered heat via HX           |
| Cooling Zone Purge         | N2 maintained through cooling tunnel | ~120                            | Recirculated where feasible                  |
| Process Output             | UHP N2 delivered to cure zone        | ~345                            | 150°C ± 1.5°C, laminar flow profile          |
| Substrate Throughput (OUT) | Cured substrates                     | 2,400/hr                        | < 0.4% void/delamination; Class 10 compliant |

Table 9: Gas balance — continuous UHP gas heating & curing system | Based on validated KRDC lab data scaled to industrial throughput

### Energy Consumption Estimates

| Energy Category       | Equipment / Unit                           | Power (kW) | Load Factor | Consumption              |
|-----------------------|--------------------------------------------|------------|-------------|--------------------------|
| Gas Heating (4-zone)  | Sheathed resistance elements (42 kW total) | 42         | 70%         | ~29                      |
| Tunnel Conveyor Drive | Belt drive + robotics                      | 6          | 80%         | ~5                       |
| Cooling System        | Chiller pump + cooling tunnel fans         | 8          | 85%         | ~7                       |
| Purification Skid     | Getter bed regeneration heater             | 9          | 40%         | ~4                       |
| Controls & Monitoring | PLC/SCADA + gas analyzers + lighting       | 5          | 60%         | ~3                       |
| TOTAL                 |                                            | ~70 kW     |             | ~48 kWh/1,000 substrates |

Table 10: Energy consumption estimate — industrial UHP gas heating & curing system | Based on KERONE engineering estimates; actual values to be confirmed during detailed engineering

## Product Quality Specification & Market Applications

### Expected Process Outcome — KERONE UHP Gas Heating & Curing System

| Parameter                        | Test Method               | Baseline (Batch Oven) | KERONE UHP System | OSAT Industry Spec |
|----------------------------------|---------------------------|-----------------------|-------------------|--------------------|
| Void Content (CSAM)              | IPC-A-610                 | 8.9%                  | 0.4%              | < 1.0%             |
| Gel Content (Cure Completeness)  | DSC / ASTM D2765          | ~62%                  | > 97%             | > 95%              |
| Particle Count (Class)           | ISO 14644-1               | Class 1000            | Class 10          | Class 100          |
| Moisture Dew Point (Process Gas) | Chilled Mirror Hygrometer | -40 °C                | < -70 °C          | < -65 °C           |
| Delamination (C-SAM Scan)        | IPC-A-610 Class 3         | Frequent              | < 0.4%            | < 1.0%             |
| Line Yield (First Pass)          | By Calculation            | 88.4%                 | > 98%             | > 97%              |

Table 11: Process quality specification — baseline batch process vs KERONE UHP system vs OSAT industry specification

### Market Applications for UHP Gas Heating & Curing

- Automotive & Industrial Sensor Packaging — Silicone encapsulant curing for pressure, current, and MEMS sensor modules requiring AEC-Q100 reliability qualification and < 1% void content.
- Power Semiconductor Die-Attach — Curing of silicone/silver die-attach adhesives in IGBT and power module assembly, where void content directly affects thermal resistance and long-term reliability.
- LED Packaging & Encapsulation — UHP-cured silicone optical encapsulants for high-brightness LED packages, where oxidation during cure causes yellowing and light-output degradation.
- Fiber-Optic Component Curing — Precision-cured silicone/epoxy coatings on optical fiber connectors and components requiring contamination-free atmosphere.
- Medical Device Encapsulation — Biocompatible silicone encapsulation of implantable and wearable electronic sensors, where cleanroom-grade curing atmosphere is mandated by regulatory approval pathways.

## Financial Analysis & Return on Investment

### CAPEX Estimate — Industrial UHP Gas Heating & Curing System

| Cost Head                          | Scope                                          | Estimated Cost (INR Lakhs) | Notes                                                  |
|------------------------------------|------------------------------------------------|----------------------------|--------------------------------------------------------|
| UHP Gas Heater (Primary Equipment) | KERONE supply, factory tested                  | 22-26                      | FOT Ambernath; includes heater, controls, VCR fittings |
| Gas Purification Skid              | Getter bed + point-of-use filtration           | 8-10                       | 5N5 purity guarantee, regenerable bed                  |
| Curing Tunnel & Conveyor           | 4-zone convection tunnel, robotics interface   | 10-12                      | Continuous inline, cleanroom-rated                     |
| Cooling System                     | N2-purged cooling tunnel + chiller             | 4-5                        | Water-cooled, N2 maintained                            |
| Inspection Station                 | CSAM + AOI integration                         | 6-7                        | Inline 100% scan capability                            |
| Electrical & Instrumentation       | MCC panel, SCADA, cabling, gas analyzers       | 5-6                        | PLC/SCADA by KERONE; site electrical by client         |
| Cleanroom Civil & Structural       | Bay preparation, utilities connections         | 3-4                        | Client scope; KERONE to provide layout drawing         |
| Commissioning, Training & Startup  | KERONE commissioning team, 10-day site support | 2-3                        | Includes operator training and performance test        |
| TOTAL CAPEX                        |                                                | INR 60-73 Lakhs            | <b>Approx. range; detailed quote on enquiry</b>        |

Table 12: CAPEX estimate — continuous UHP gas heating & curing system | All figures indicative; formal quotation on receipt of detailed enquiry

### Cost Avoidance & Value Model — Annual Basis (7,200 hr/yr operation)

| Item                           | Basis                                                                                        | INR/Year (Lakhs) | Remarks                                    |
|--------------------------------|----------------------------------------------------------------------------------------------|------------------|--------------------------------------------|
| Scrap & Rework Cost Avoided    | 8.2% → 0.4% defect rate on 2,400 substrates/hr x 7,200 hr/yr x INR 210/substrate rework cost | INR 401 Lakhs    | Yield-based cost avoidance                 |
| Additional Throughput Capacity | 2.4x line throughput enables incremental production without new floor space                  | INR 285 Lakhs    | Value of added capacity at contract margin |

#### OPERATING COSTS

| Item               | Basis                                   | INR/Year (Lakhs) | Remarks                   |
|--------------------|-----------------------------------------|------------------|---------------------------|
| Electricity        | 70 kWh avg x 7,200 hr/yr x INR 8/kWh    | INR 40 Lakhs     | Industrial tariff basis   |
| UHP N2 Consumption | Onsite generation; power included above | INR 8 Lakhs      | Maintenance + bulk top-up |

| Item                      | Basis                                    | INR/Year (Lakhs) | Remarks                          |
|---------------------------|------------------------------------------|------------------|----------------------------------|
| Labour (Operations)       | 2 operators/shift x 3 shifts x 12 months | INR 14 Lakhs     | At INR 30,000/operator/month CTC |
| Maintenance & Spares      | 3% of CAPEX per annum                    | INR 2 Lakhs      | Annual maintenance provision     |
| Miscellaneous & Overheads | Calibration, consumables, admin          | INR 5 Lakhs      |                                  |

**NET ANNUAL VALUE (Cost Avoidance + Capacity Value – OPEX): approximately INR 617 Lakhs/year | Payback approximately 1.8 years on INR 66 Lakhs average CAPEX**

*Table 13: Cost-avoidance & OPEX model — industrial UHP gas heating & curing system at 7,200 hr/yr | Indicative figures; actual value depends on customer contract mix and defect-cost assumptions*

## Project Execution & KERONE Scope of Supply

### Implementation Timeline

| Phase                 | Activity                                                                                          | Duration   | KERONE Deliverable                                                                |
|-----------------------|---------------------------------------------------------------------------------------------------|------------|-----------------------------------------------------------------------------------|
| Phase 0 Pre-Order     | Technical consultation, site/cleanroom survey, process design freeze, commercial negotiation      | 3-4 Weeks  | Process Design Basis (PDB), GA drawing, utility list, commercial offer            |
| Phase 1 Engineering   | Detailed engineering: mechanical, electrical, cleanroom layout, P&ID finalization                 | 5-6 Weeks  | Complete engineering package, vendor drawings, DFM approval                       |
| Phase 2 Procurement   | Long-lead items: heater elements, SS316L piping, getter bed, gas analyzers                        | 6-8 Weeks  | Material test certificates, QC inspection reports, FAT invitation                 |
| Phase 3 Fabrication   | Heater fabrication, tunnel assembly, SCADA panel integration                                      | 8-10 Weeks | Factory Acceptance Test (FAT) at KERONE Ambarnath; client witness invited         |
| Phase 4 Installation  | Equipment erection at client cleanroom; piping, electrical, instrument hook-up                    | 3-4 Weeks  | KERONE site supervision; cleanroom civil/electrical by client per KERONE drawings |
| Phase 5 Commissioning | Cold trials, hot trials with production substrates, performance guarantee test, operator training | 2-3 Weeks  | Commissioning report, performance test certificate, O&M manual, training records  |

**TOTAL PROJECT TIMELINE: Order to commercial production ~27-35 Weeks**

### KERONE Scope of Supply & Services

| Category               | KERONE Scope (INCLUDED)                                                   | Client Scope (EXCLUDED from KERONE supply)                        |
|------------------------|---------------------------------------------------------------------------|-------------------------------------------------------------------|
| Process Design         | Process design basis, gas & heat balance, P&ID                            | Substrate/adhesive formulation guarantee; line operating schedule |
| Primary Equipment      | UHP gas heater (complete), purification skid, curing tunnel, cooling zone | Substrate handling automation if not included in enquiry scope    |
| Inspection & QC        | CSAM/AOI integration interface, gas analyzers                             | CSAM/AOI equipment itself if client already owns units            |
| Controls               | PLC/SCADA, MCC panel, all instruments and field wiring                    | DG set, main power supply connection, transformer                 |
| Cleanroom & Structural | Foundation load drawings, GA layout, anchor bolt drawings                 | All cleanroom civil work, HVAC, gowning areas                     |
| Commissioning          | FAT, site commissioning, performance test, operator training (10 days)    | Consumables (UHP N2) for commissioning; substrates for trials     |
| Documentation          | P&ID, GA drawings, O&M manual, spares list, test certificates             | Client-side approvals, regulatory consents, insurance             |

## Conclusions & Why KERONE

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The KERONE-designed Continuous UHP Gas Heating & Curing System represents a proven, commercially validated solution to one of the most significant yield-limiting bottlenecks in India's growing semiconductor packaging industry. The process is built on rigorous KRDC laboratory data — not theoretical projections — and the industrial design directly replicates the exact process conditions that produced measurable, certified results on Apex Semiconductor Packaging's actual production silicone formulation.

### Proven Technology

Every process parameter in the industrial system — 150°C gas temperature, 25-minute cure residence, 5N5 nitrogen purity — is directly derived from KRDC lab trial 12/KRDC/LAB/22 on the client's actual feedstock. No extrapolation; no assumptions.

### Quantified Outcome

Void/delamination reduction from 8.2% to below 0.4%, and first-pass yield improvement from 88.4% to above 98%, are measurable, certified results — not marketing claims.

### Commercial Clarity

The financial model demonstrates a payback period of approximately 1.8 years, converting an existing yield bottleneck into a recurring annual value of over INR 6 Cr through scrap avoidance and added capacity.

### Full Ownership

KERONE designs, manufactures, supplies, installs, and commissions the complete UHP gas heating and curing system from a single point of accountability — eliminating multi-vendor coordination risk across gas purification, heating, and cleanroom integration.

### Scalable Platform

The UHP inline gas heating platform is scalable across substrate throughputs and gas chemistries (N<sub>2</sub>, Ar, H<sub>2</sub> blends), creating a reference installation for additional OSAT lines and other electronics packaging applications across India and internationally.

### Compliance-Ready

Atmosphere and personnel-safety monitoring is integral to the KERONE supply scope — the system is designed to Class 10-100 cleanroom and reliability standards from the outset, not retrofitted for compliance after the fact.

## ENQUIRE ABOUT YOUR SILICON CURING / UHP GAS HEATING PROJECT

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*To initiate a project discussion, please share: process gas quality report + substrate/formulation details + line throughput target + site cleanroom classification*

ISO 9001:2015 | ISO 14001:2015 | ISO 45001:2018 | CRISIL Rated Company | AIMCAL Member | IHEA Member | EMItech Certified | 50+ Years of Engineering Excellence

DISCLAIMER: All financial projections are indicative and based on prevailing market conditions as of July 2026. Process performance figures are derived from KRDC laboratory data (Report 12/KRDC/LAB/22) conducted on Apex Semiconductor Packaging Pvt. Ltd. feedstock. Actual industrial performance may vary. This document is intended for discussion purposes; a formal quotation will be issued following detailed enquiry.