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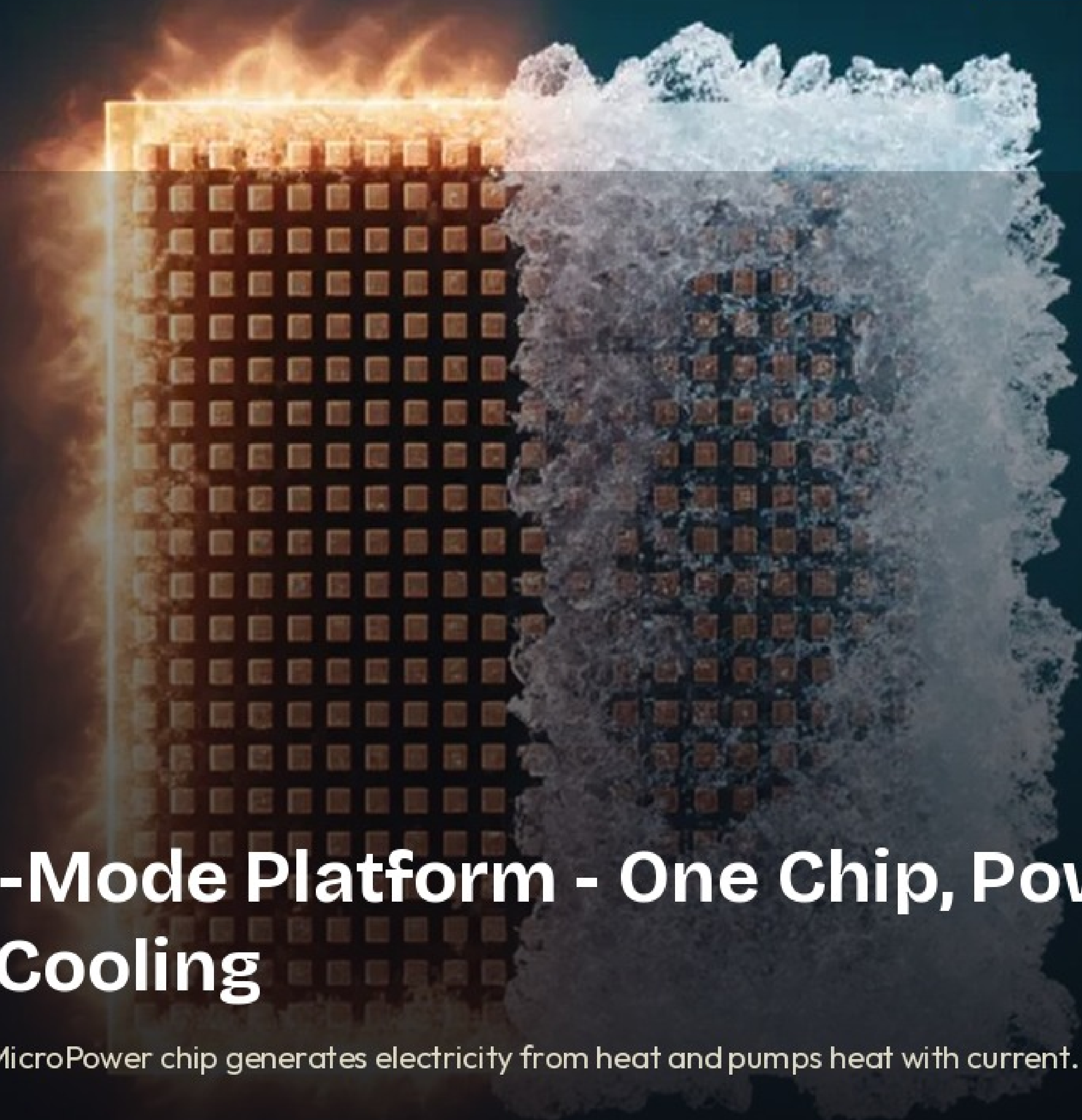

Dual-Mode Platform - One Chip, Power and Cooling

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The thermoelectric effect is reversible. Apply a thermal gradient and the chip generates electricity. Apply current and the chip pumps heat. The same MicroPower chip does both. This paper sets out the platform, the product portfolio that delivers it, and the per-module performance customers can specify against today.

1 · Platform summary

MicroPower's chip is a high-temperature thermoelectric semiconductor device. The chip is dual-mode – the same physical device runs in Seebeck mode (converting a heat gradient to electricity) and in Peltier mode (converting current to a heat gradient that pumps heat from cold side to hot side). One chip, two useful behaviours.

The platform delivers 14% module efficiency at 550 °C in Seebeck mode (extrapolated from ARL's evaluation of MicroPower's standard modules; independently confirmed by NREL against datasheet). The chip is designed to 1,000 °C; continuous operation is lab- and field-proven 440–550 °C (Gerdau 2,500+ hours). The top of the 1,000 °C design range is not yet lab-proven for continuous duty. In Peltier (cooling) mode, the platform supports high-temperature operation across hot-side environments where conventional bismuth-telluride (BiTe) modules cannot survive. MicroPower's separately patented MBE-grown energy-sorting barrier-layer architecture multiplies chip-level power density 1.5–1.8× on top of the baseline platform; that figure is from internal MicroPower lab measurement on the prototype barrier layer and is not in production-spec modules today.

2 · The physics, in one paragraph

A thermoelectric chip is a semiconductor wafer with a temperature gradient across it. In Seebeck mode, electrons and holes drift from hot to cold, generating an open-circuit voltage proportional to the gradient; a connected load returns DC electrical power. In Peltier mode, an externally driven current forces electrons and holes to move against their thermal preference, carrying heat from one side of the chip to the other against the gradient. Both modes depend on the same material-level figure of merit (ZT), and the same chip runs either way – just connect it differently.

What makes the MicroPower platform usable at high temperature is the combination of (a) the underlying PbTe / TAGS material system and (b) the high-temperature contact and thermal-interface structures. The chip's high-temperature contact and thermal-interface structures were informed by an early MicroPower collaboration with the U.S. Army Research Laboratory and have been substantially evolved internally since. The 14% module conversion efficiency at 550 °C (Seebeck mode) is extrapolated from the U.S. Army

Research Laboratory's evaluation of MicroPower's standard modules. NREL subsequently confirmed independently that production modules met datasheet specification. Commercial thermoelectric modules without comparable contact engineering typically degrade above 250 °C; MicroPower's platform is designed to 1,000 °C, with continuous operation lab- and field-proven 440–550 °C (Gerdau 2,500+ hours).

3 · Product portfolio

Three product families are built on the MicroPower chip platform. These are the per-module ratings customers can specify against at current manufacturing readiness. System-level deployments aggregate multiple modules.

Product	Rated output	Form factor	Typical application
Base Module	3 W	1.7 × 2.1 cm chip-pair envelope	Lab, research, portable demonstrator
PowerRing	10–50 W	Pipe-wrap, clamps to existing pipe OD	Genset / CHP exhaust, industrial piping
PowerBlock	10–200 W	Flat-plate, bolts to rejection surface	EAF ducts, furnace walls, waste-heat plates

Reference deployments. CS-A Gerdau Manitoba is two PowerBlocks in an access-hatch geometry on the EAF cooling duct, with 2,500+ hours of validated runtime. CS-C BrasilGTW is three partial-population PowerRings engineered for a 200 kW genset exhaust; the deployment was planned and engineered but did not materialise due to COVID, and is cited here as a reference application rather than an active deployment.

4 · Seebeck mode – power generation

Power generation in Seebeck mode is the primary MicroPower commercial application today. The hot-side temperature is set by the customer's waste-heat source; the cold side is managed with a cooling loop (water, forced air, or natural convection depending on heat density). Seebeck-mode module conversion efficiency is 14% at 550 °C, extrapolated from ARL's evaluation of MicroPower's standard modules and independently confirmed by NREL against datasheet. Seebeck-mode installed-system efficiency, after heat-exchanger losses, thermal interfaces, and cold-side gradient, is typically 6–10% under realistic field conditions.

The delta between module and installed-system efficiency is where the engineering work lives. Two drivers dominate. First, cold-side maintenance: a chip at 550 °C hot side and 100 °C cold side delivers materially different module output than the same chip at 550 °C hot side and 200 °C cold side. The cold-side architecture is the number-one design choice on any MicroPower deployment. Second, hot-side thermal contact: the chip must make intimate thermal contact with the heat source through the module's metal-contact and thermal-interface stack. This interface is the principal output of the ARL contact-structure work.

5 · Peltier mode – solid-state cooling

The Peltier cooling mode is where the dual-mode advantage compounds. The same chip, driven with current rather than a thermal gradient, pumps heat outward – with no refrigerant, no compressor, no rotating machinery. The coefficient of performance (COP) is the Peltier-side efficiency metric.

5.1 High-temperature Peltier cooling (150–600 °C hot-side range). MicroPower's high-current contact structures – built for 300–1,000 °C Seebeck-mode operation – are what make Peltier mode usable in high-temperature environments that commercial BiTe Peltier devices cannot survive. The downhole drilling electronics paper (No. 09) covers the oil-and-gas case; the bioreactor partnership note (No. 13) covers the biopharma case.

5.2 Precision sub-ambient cooling. Cascade Peltier geometries can drive cold-side temperatures below ambient. A multi-stage laboratory cascade demonstration on a pre-MicroPower predecessor material system reached cold-side temperatures below −150 °C – a research demonstration, not a commercial product. See the cryogenic capability note (No. 07) for the bounded framing.

5.3 Zero-refrigerant industrial cooling. Regulatory pressure on HFC and HFO refrigerants, and handling constraints in sensitive production environments, are driving demand for cooling without refrigerants. Solid-state cooling fits those constraints directly. Commercial-scale product development in this segment depends on partners with existing chiller-integration capabilities.

6 · What dual-mode means for deployment

A partner evaluating MicroPower for a power-generation application has, as a by-product of the same chip technology, access to the corresponding cooling capability on the same manufacturing base. Two applications that might otherwise require separate technology vendors and separate integration cycles share a single supplier, a single chip inventory, and a single platform engineering conversation.

The same customer site can run both modes simultaneously from adjacent chip stacks: power generation on a hot rejection surface on one side of the plant, precision cooling on a process stream on the other side. The plant electrical engineering team sees two distinct products from MicroPower's catalogue; the underlying chip is the same.

7 · Bounded capability

- Cryogenic cooling below −150 °C in commercial-scale industrial form factor. The laboratory cascade demonstration exists on a pre-MicroPower predecessor material system; a commercial cryostat product does not.
- Cooling at hot-side temperatures above 600 °C in Peltier mode. Peltier-mode operation is limited to a narrower hot-side envelope than Seebeck-mode; extending it to the full 1,000 °C Seebeck range is a development objective, not a commercial deliverable today.
- Very high-density integrated chillers (> 1 kW cooling per cm^2 chip area). Commercial Peltier chillers of any manufacturer are a niche product class; MicroPower's material advantage is at high-temperature and precision-control applications.

- The MBE-grown energy-sorting barrier layer in production-spec modules. The barrier layer architecture is patented and demonstrated; reintroducing it into production modules is on the post-funding production roadmap. Production-spec modules deliver the 14% module efficiency baseline without it.

8 · Closing

The MicroPower chip platform is a dual-mode thermoelectric architecture. Seebeck mode: 300–1,000 °C hot-side design range with continuous operation lab- and field-proven 440–550 °C, 14% module efficiency at 550 °C, 11 W/cm² chip-level power density. Peltier mode: high-temperature operation across a narrower hot-side window than the full Seebeck range, with sub-ambient cooling demonstrations on current material and — on a pre-MicroPower predecessor material system in laboratory cascade — sub-cryogenic cold-side demonstrations. The product portfolio is the Base Module, PowerRing, and PowerBlock families at the per-module ratings in Table 1. Every flagship white paper in the resources library builds on some slice of this platform.

MicroPower engages selectively with partners interested in dual-mode deployments – power generation, precision cooling, or both on the same site. Introductions and structured enquiries are welcome via the MicroPower Global contact page.

References

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