Applied Plasma Technologies

REDUCTION OF GALLIUM

WWW.PLASMACOMBUSTION.COM

12 December 2025
Applied Plasma Technologies, Corp.

CONTENT

Applied Plasma Technologies

OUR COMPANY

1,500 plasma products in operation

chemically pure, hi-temp RF plasma

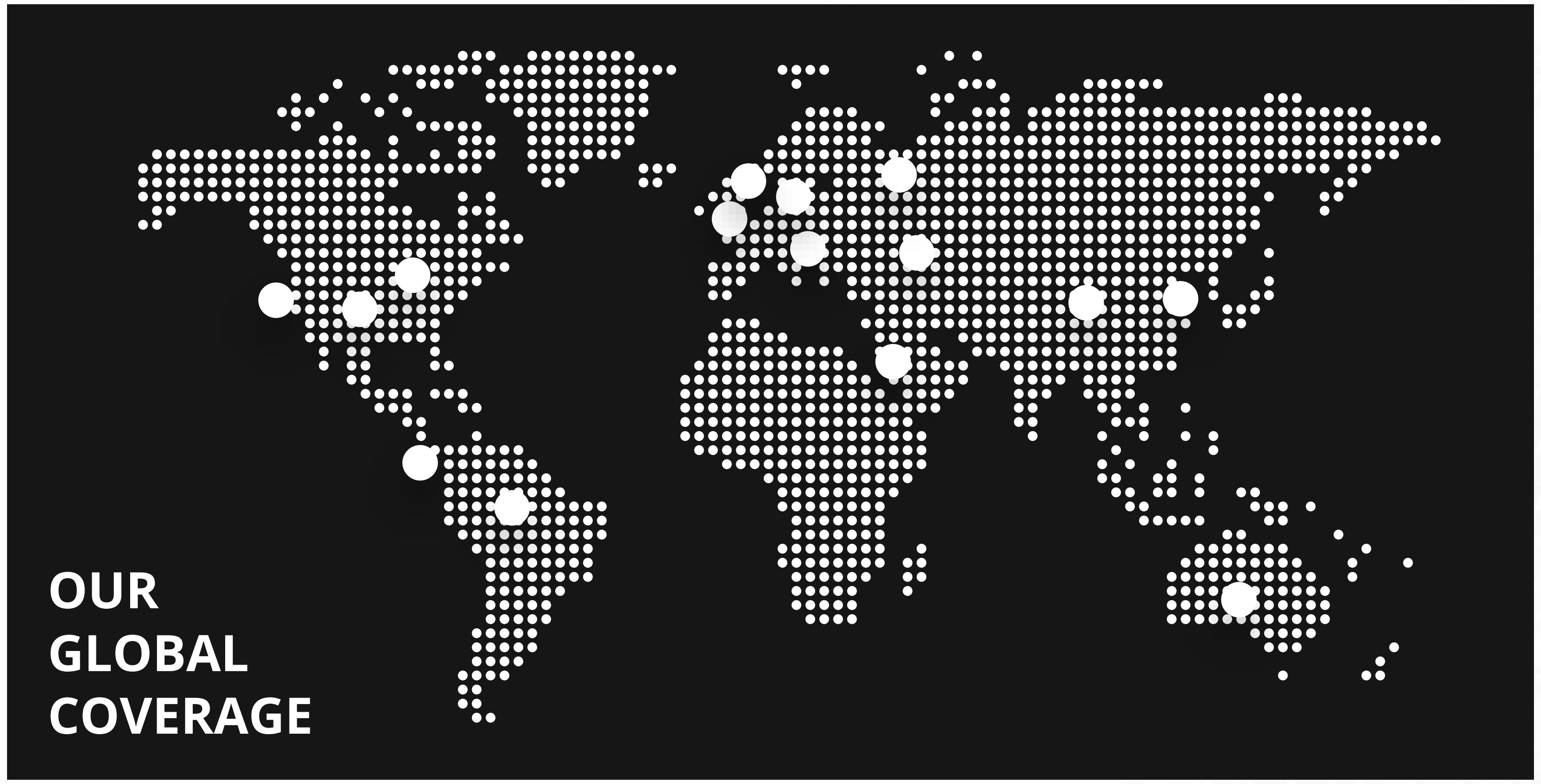
from vaccum to 5 bar of pressure

air, He, Ar, N2 , CO2, steam and different blends

5 continents

13 countries

DARPA certified



Universities	Corporations	Space Agencies	National Labs
30	18+	7	5

- ICP/RF Plasma Systems
- Boron Nitride Nanotubes Production
- Ammonia Combustors
- Coal and Waste Gasification
- ICP/RF Plasma Gasifiers
- Plasma Synthesis of New Materials
- Plasma Ignition and Flame Control
- Plasma Assisted Combustors & Reactors
- Fertilizer Production
- Testing Aerospace Materials
- Plasma Thrusters
- Plasma Mineralogy

GE Aerospace

United Technologies

SIEMENS energy

Kawasaki

LEARN MORE

ABOUT OUR FOUNDER

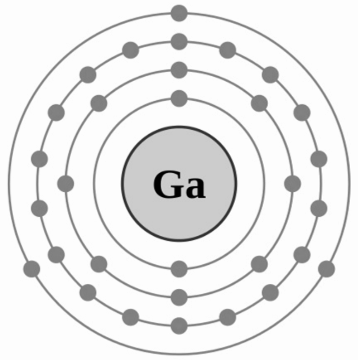
Dr. Igor Matveev is a globally recognized expert in Plasma-Assisted Technologies with 3 published books and over **1,500 plasma systems** developed under his leadership and deployed around the world.

He received his Ph.D. in Mechanical Engineering in 1984 with a dissertation titled "Development and Implementation of Plasma Ignition Systems for Naval Gas Turbines", which laid the groundwork for his pioneering work in plasma-assisted technologies.

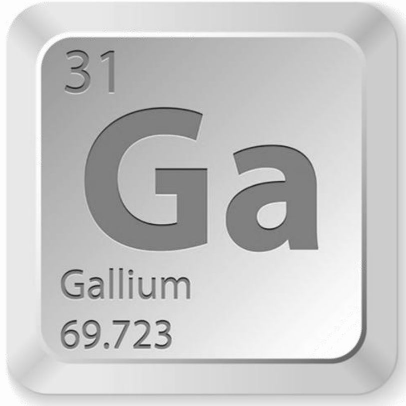
Since 2003, Dr. Matveev has served as President and CEO of **Applied Plasma Technologies** in Marshall, Virginia, driving innovation in high-power plasma systems for industrial, energy, and environmental applications.

His commitment to advancing the field extends to academia and professional service. Since 2004, he has been a **Guest Editor for the IEEE Transactions on Plasma Science** special issues on Plasma-Assisted Technologies. He also served as Organizing Committee Chair for the 2nd through 12th International Conference on Plasma-Assisted Technologies (ICPAT).

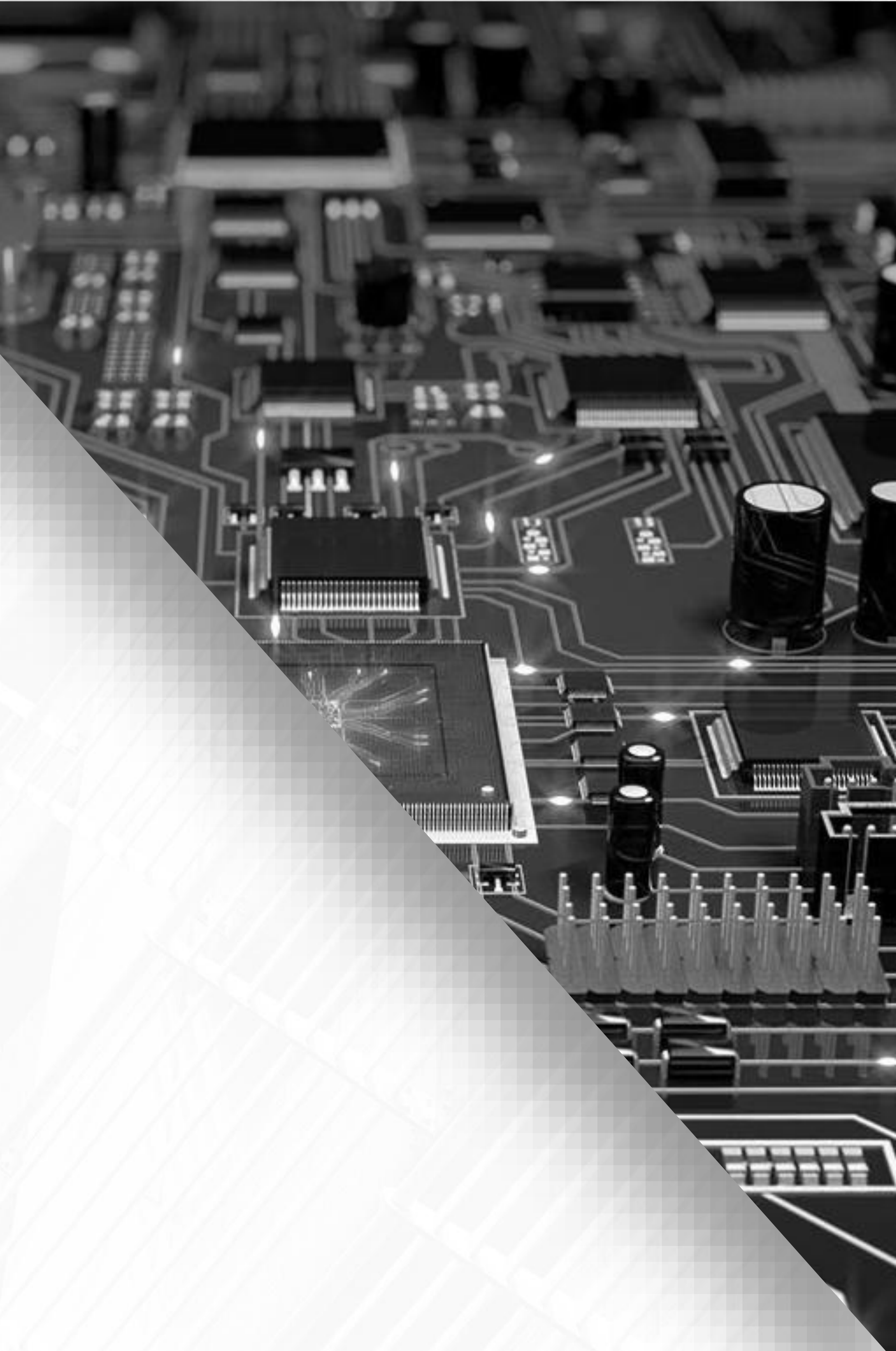
WHY GALLIUM



Gallium is critical for GaN and GaAs semiconductors used in power, 5G/ 6G, communications, aerospace, and defense, with demand rising across advanced industries



China supplies about 95–98% of global gallium, creating strategic supply-chain risk and driving demand for reliable non-China production capacity.



MARKET OVERVIEW

Market volume

Refined Ga: ~350 t/year
EU+UK: ~70–100 t/year
USA+CA: ~50-60 t/year
ASIA+AU: ~170-190t/year

By 2030: 750-900 t/year
By 2035: ~1,200 t/year

★ ★ ★ ★ ★

Market Value

Refined Ga ~$500M
$1,600/kg – Ga (6-8N)
$1,800/kg - GaN

By 2030: ~$800M-$1B
By 2035: ~$1.5B+

★ ★ ★ ★ ★

Geopolitics

Ga is critical material in the US, EU, AU

China imposed export controls (95%> prime)

US/EU will pay a premium for non-China

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Strategy

Bayer liquor + plasma technology = fully China-independent supply chain (zero CO_2)

Fits US/EU/AU strategies for critical minerals diversification

★ ★ ★ ★ ★

Also opens pathways to recover other critical elements (Sc, Ge, V and others) naturally present in Bayer liquor

OUR VISION

We envision a fully electrified gallium production platform that transforms refinery liquor into high-purity Ga and GaN with **zero direct CO_2 emissions**. The process operates within a **clean, hydrogen-ready framework** and integrates seamlessly with existing alumina infrastructure.

Our **modular plasma reactors** convert $Ga(OH)_3$ to Ga_2O_3 and then to **metallic Ga or GaN powder**, delivering scalable output with **industrially proven hardware**. This approach aligns **with Net-Zero and ESG priorities** while creating a **strategic, non-China source of critical semiconductor materials.**

LEARN MORE

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TECHNOLOGY

Overview:

- **Plasma reduction of Al_2O_3** has been known since the 1960s.
- RF N_2/H_2 plasma produces **atomic hydrogen**, enabling **rapid surface reduction** of molten alumina.
- The concept was proven, but past technologies lacked **efficiency, control**, and **scalable quenching**.
- Industrial viability requires **high-enthalpy plasma, atomic H flux, continuous feed**, and **ultra-fast quenching**

"The chemistry has been known and demonstrated. The challenge was engineering scalability."

Historical challenges:

- Low-efficiency RF power supplies (≤40%) → industrial energy cost impractical
- Argon-dominated plasmas → weak heat transfer, poor H_2 activation, low conversion
- No viable quenching technology → rapid re-oxidation of molten aluminum droplets
- MW-scale electrode-less RF/ ICP plasma systems were experimental only

1962–1965
First plasma reduction experiments
(Grosse, Stokes)

1968–1971
RF plasma reduction of Al_2O_3 demonstrated
(Rains, Univ. Michigan)

1970–2000
Continued lab-scale studies; scalability remains unsolved

2000-2020
Advancements in diagnostics, ceramics, modeling;
still no industrial path

2020–2025
Solid-state RF power (>95% efficiency), high-enthalpy N_2/H_2 plasma, ultra-fast quenching → first viable industrial configuration

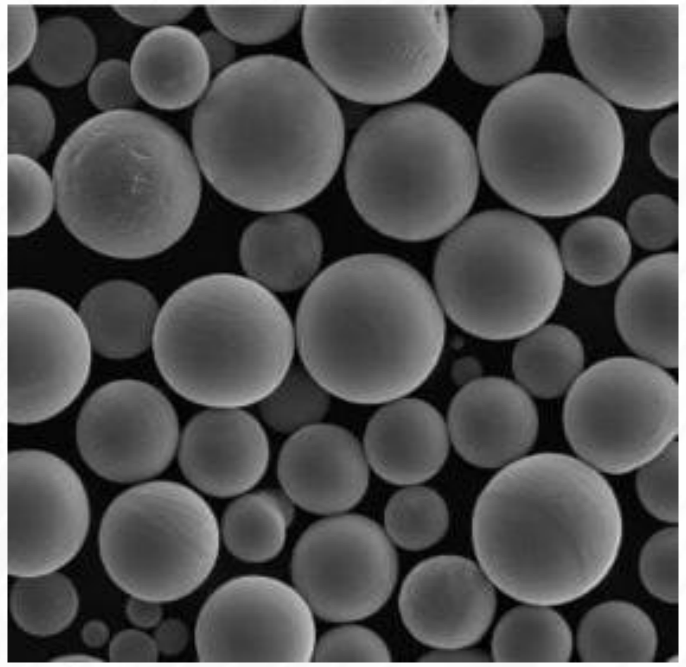
WHY IT WORKS NOW

Power

MW-scale solid-state RF power
~95% efficiency
Industrial and scalable (1-15MW)

Plasma chemistry

N_2/H_2 plasma gas
atomic hydrogen,
rapid reduction of Ga_2O_3
advanced phases separation.



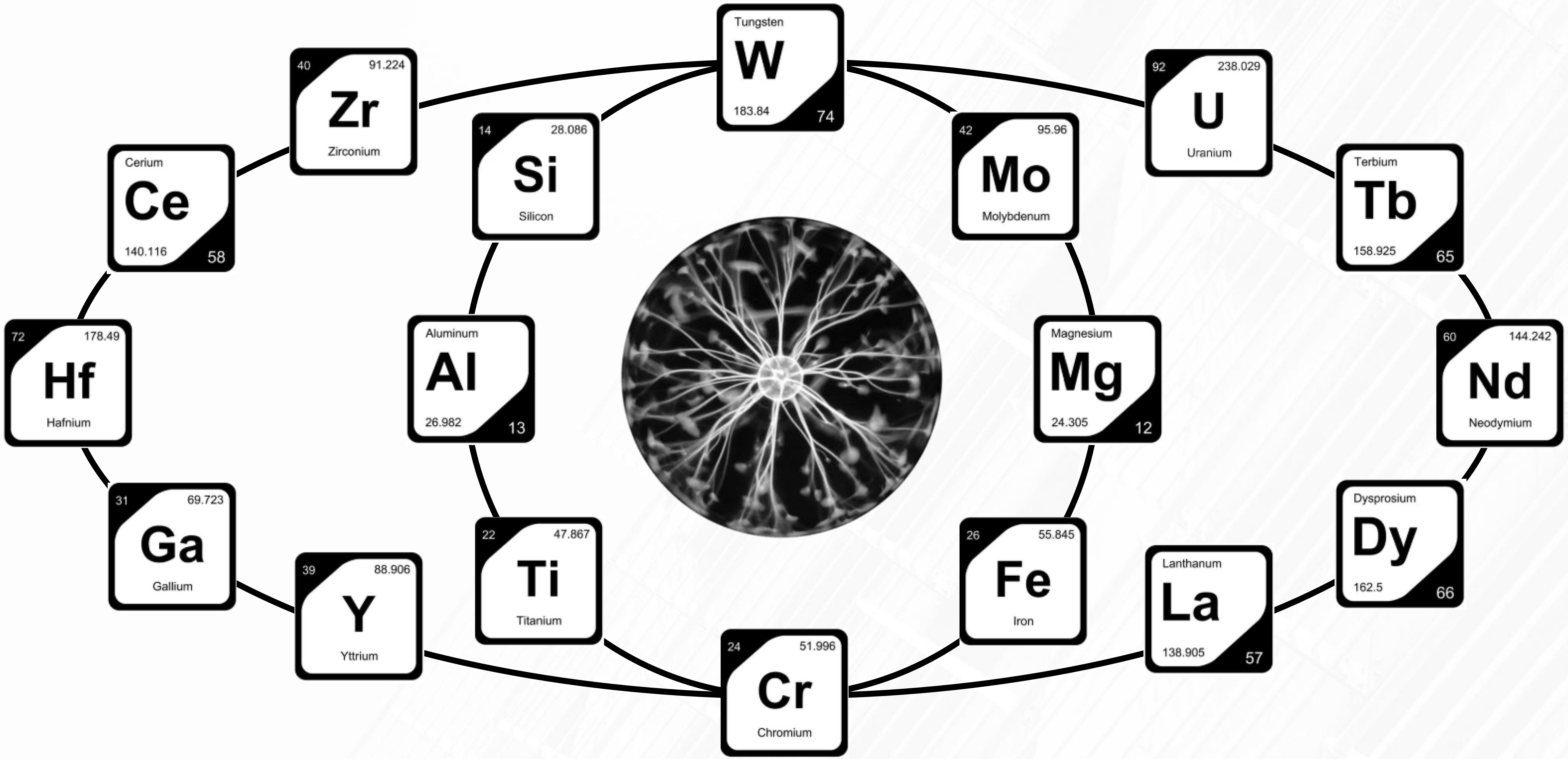
Quenching

10^5–10^6 K/s cooling of Ga droplets. Prevents re-oxidation, stabilizes the metal/ powder

Validation & IP

Patented in 2025 – process, reactor and quench architecture
Confirmed by RUSAL, Stanford, Princeton, NTUA, Metlen, Alba.

UMBRELLA TECHNOLOGY



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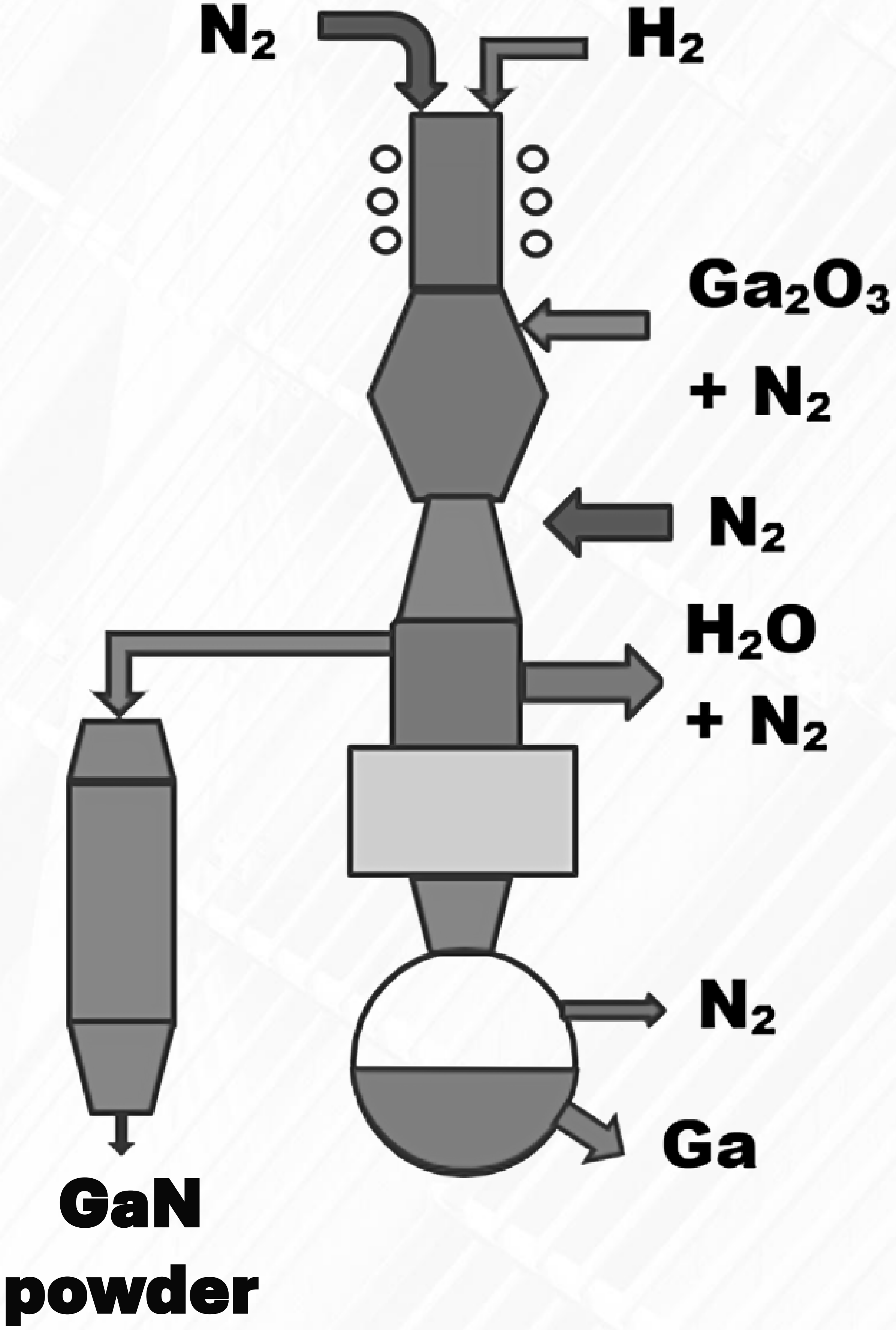
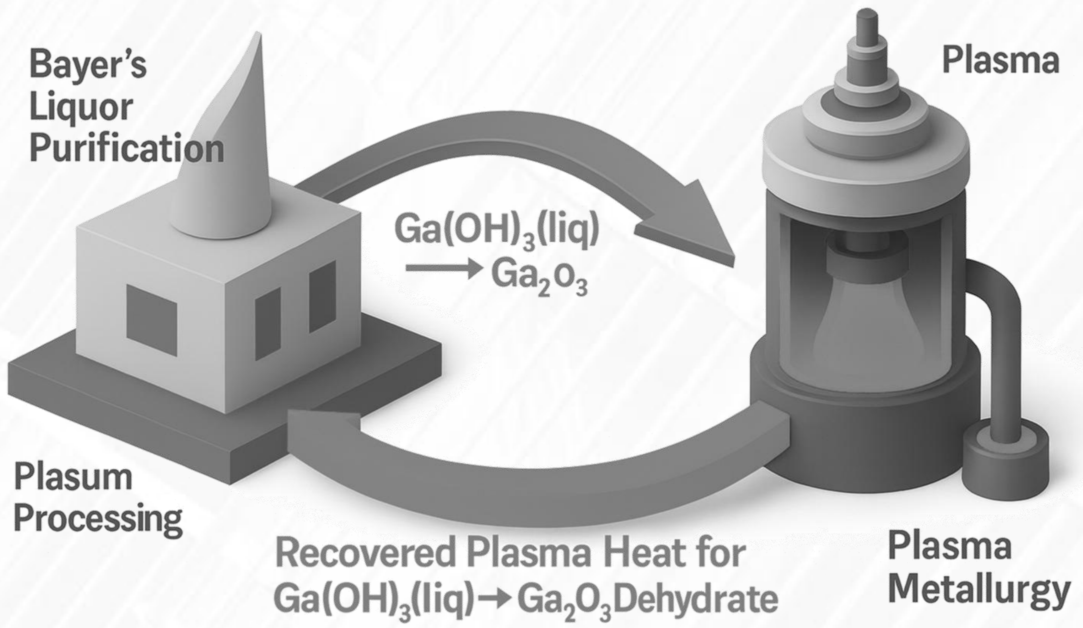
PROCESS OVERVIEW

FEEDSTOCK	N_2, H_2, Ga_2O_3
FLOW	RF Plasma → Gallium oxide injection → Metal microdroplets →
OUTPUTS	Ingot or spherical powder, Water, Nitrogen



STRATEGIC FIT



Thermally Integrated Green Platform — turning regional resources into competitive advantage:

- Circular value creation from existing refinery streams.
- Anchors hydrogen demand with stable industrial load.
- Builds national leadership in advanced materials and GaN technologies.
- Aligned with Net Zero, CBAM, and ESG frameworks.

ENERGY EFFICIENCY – PLASMA TORCH

METAL

$\eta \leq 70\%$

Traditional metallic torches (known since the 1950s–60s) suffer from **eddy current losses** (Foucault currents) and **high radiative heat flux**, wasting much of the input power.

CERAMICS

$\eta \leq 85\%$

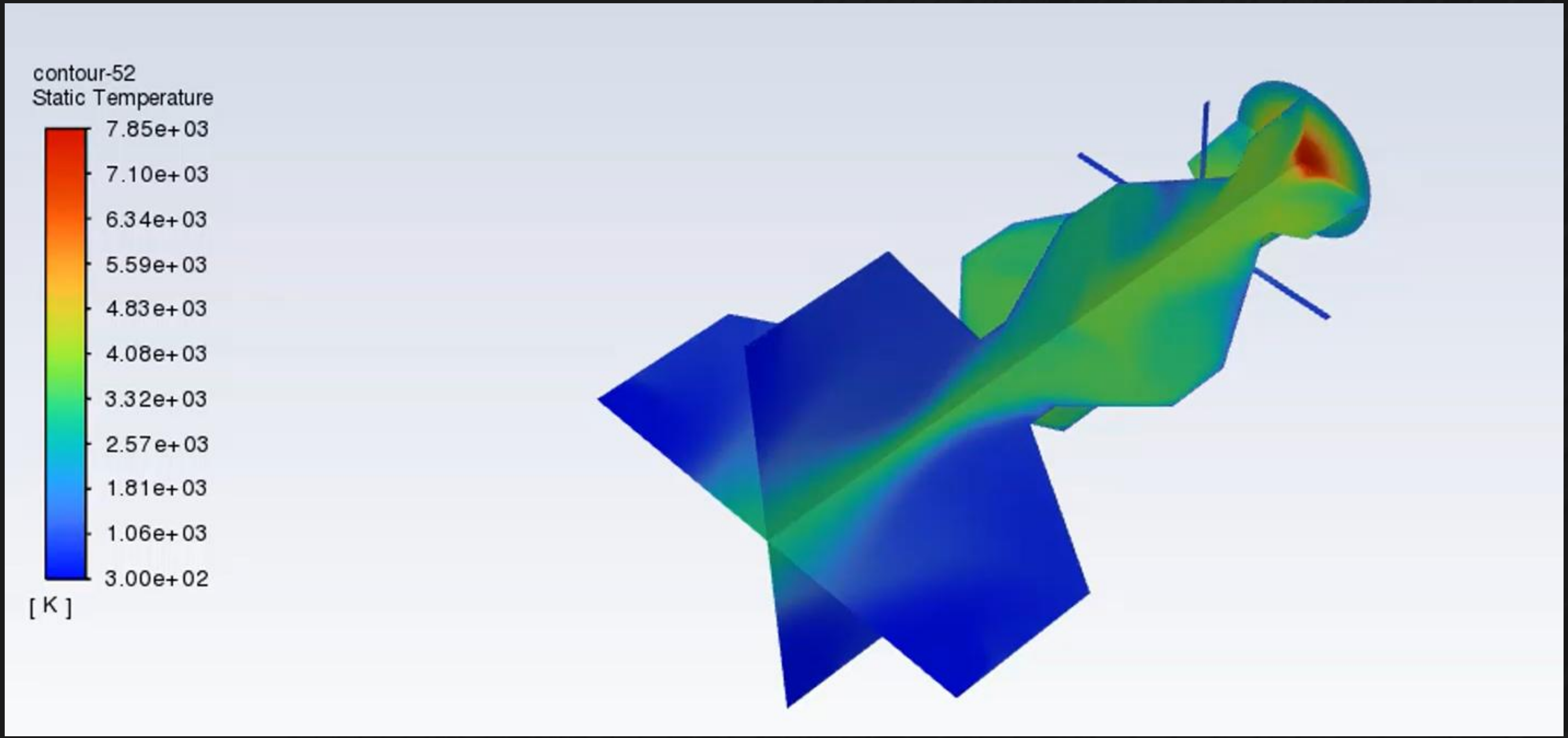
The world's first ceramic plasma torch:
a breakthrough in energy efficiency and design

- **No eddy currents:** ceramic body is non-conductive.
- **~10% wall losses only** (vs 30–40% typical).
- Combined with **solid-state RF power supplies (95% efficiency)** → total system efficiency **>70%**, nearly **2× higher** than existing designs.

WHY AL2O3→AL ≠ GA2O3→GA

PARAMETER	Al_2O_3 → Al	Ga_2O_3 → Ga/ GaN
H_2 demand	~112 kg H_2 / ton Al (high inventory → higher safety class)	~43 kg H_2 / ton Ga (x2–3 lower inventory)
Energy intensity (SEC)	7–8 MWh/t; heavy thermal load; large quench & power requirements	3.2–3.3 MWh/t; enables thermal integration with $Ga(OH)_3$ → Ga_2O_3 dehydration
Plasma & chemistry	High H_2 fraction; requires ultra-fast quench (~10^6 K/s) to avoid re-oxidation	Low flow regime; Ga_2O_3 → Ga and GaN formation; GaN can be produced as an additional product stream
Safety regime	Hot steam + Al aerosols; strict safety envelope even for tests	Simpler off-gas and safety requirements; mild thermal conditions
Scale & CAPEX logic	70+ Mt/y Al → MW-scale units; large CAPEX blocks	~550 t/y Ga → few MW total; specialty CAPEX

Al_2O_3 POWDER INJECTION INTO PLASMA STREAM



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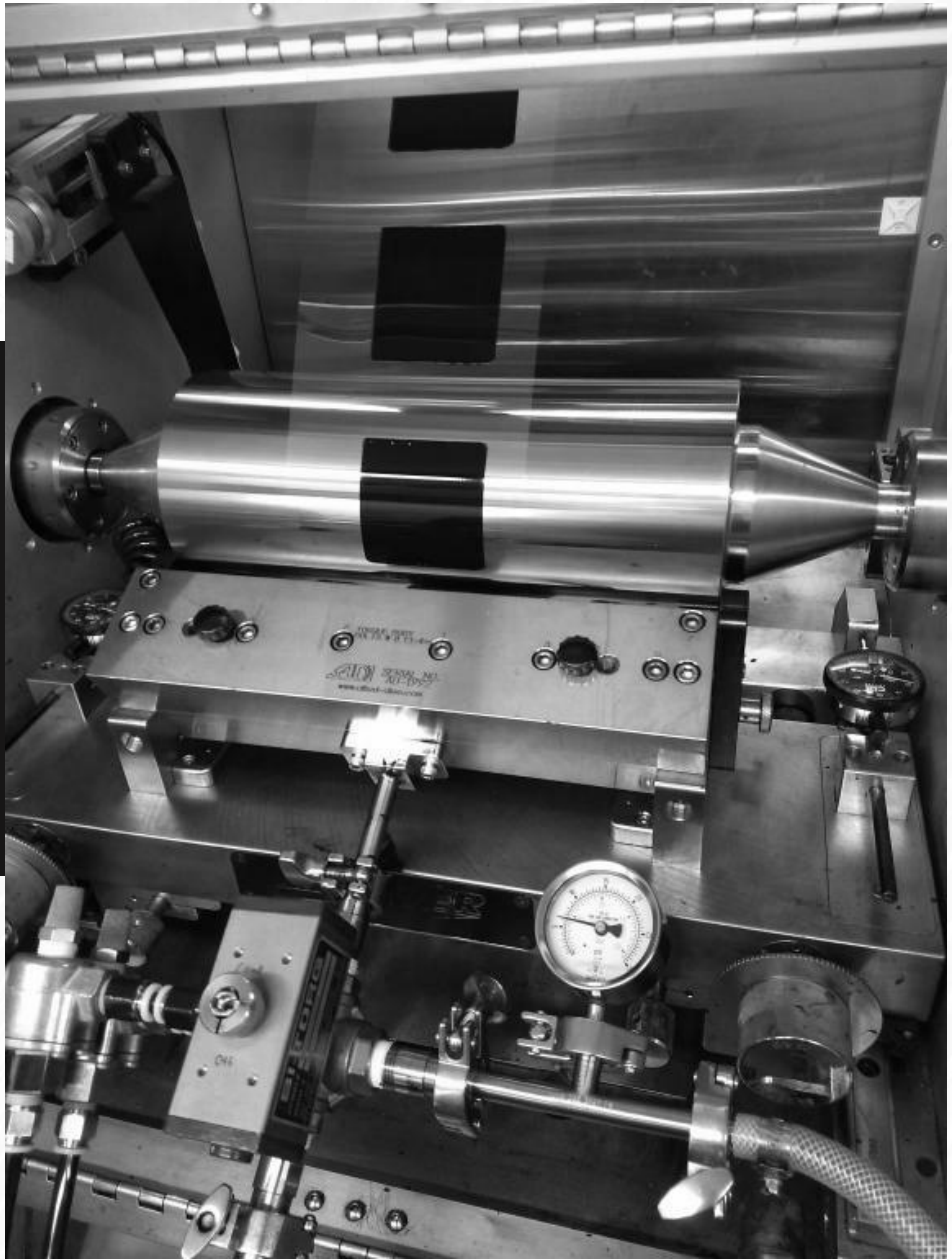
ENERGY BASELINE & OPTIMIZATION

Our plasma route cuts specific energy consumption by more than 40% relative to conventional gallium recovery and reduction processes, approaching the thermodynamic minimum for $Ga_2O_3 \rightarrow Ga$

- Thermodynamic minimum: ~3.0 MWh/t Ga
- Conventional industry (China): 5-6 MWh/t Ga
- **Plasma Pilot: ~3.2-3.2 MWh/t**
- **Plasma Optimized: ~3.0-3.1 MWh/t (close to theoretical limit)**

SAFETY ASPECTS

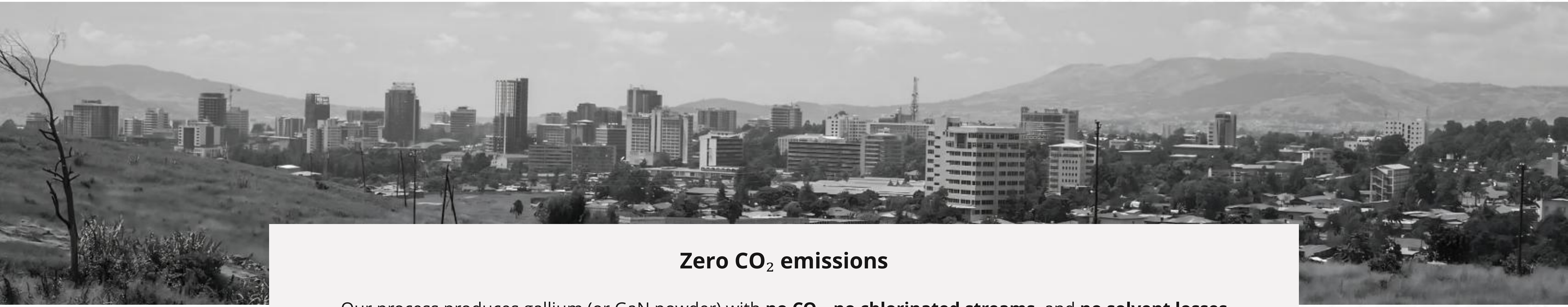
- Hydrogen only inside reactor
- At outlet: $H_2 \rightarrow H_2O$, inert downstream
- No cryolite, no carbon anodes, no fluorides
- Standard industrial plasma safety protocols



NB

Inside torch H_2 can be 40–45 vol%, ~33–35% in reactor;
O_2 is consumed → downstream gas becomes non-flammable (below LEL risk)

ENVIRONMENTAL GAIN



Zero CO_2 emissions

Our process produces gallium (or GaN powder) with **no CO_2, no chlorinated streams**, and **no solvent losses**

No CO_2. No Cl-chemistry. No nitrate or SX waste

Instead of toxic by-products, the outputs are **Ga / GaN, pure H_2O**, and **inert off-gas**.
This is the world's first **zero-emission Ga_2O_3** → **Ga** production pathway.

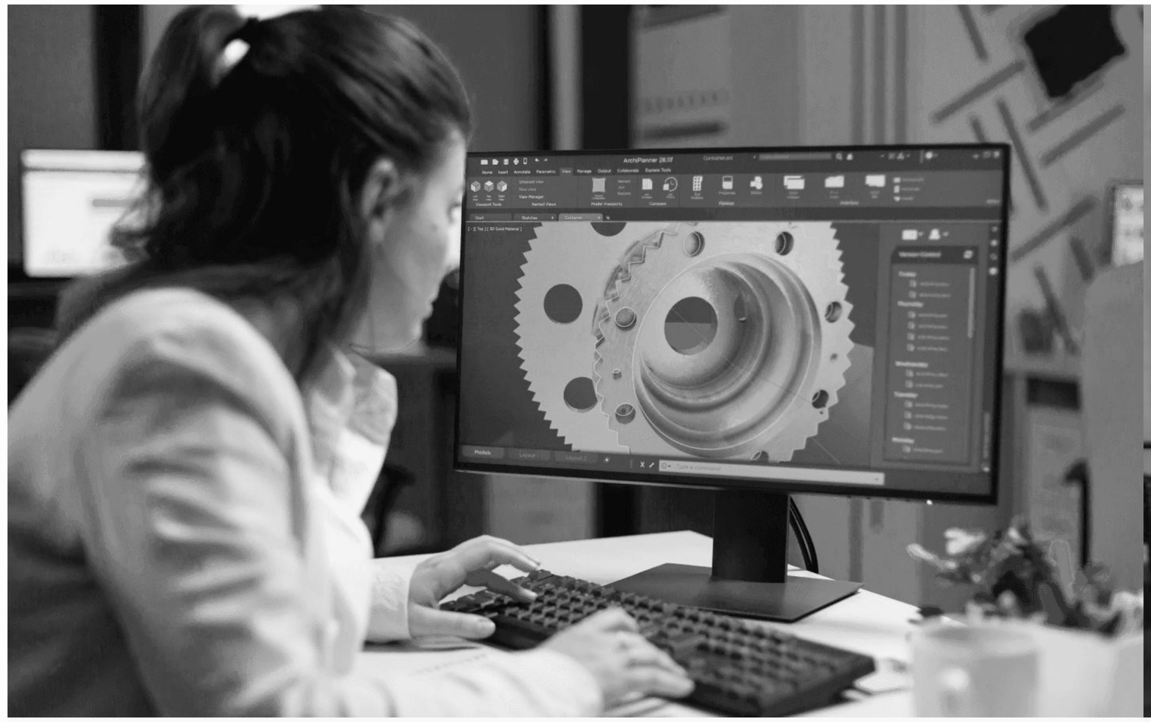
MORE INFORMATION

SCALABILITY

100kW	=	~12 t/ year
200 kW	=	~25 t/ year
500 kW	=	~65 t/ year
1 MW	=	~120 t/ year

200-300 t/year → 2–3 modules
CAPEX: ~$4M per 1 MW module

PILOT PROJECT ROADMAP (1-12M)



Modeling & Design (M1-M7)

Modeling & design of reactor, quench, separation/filtration, collection furnace; **CAD complete; RFQs** for tundish, heated crucibles, ceramic filters; production budget.

APT-100 tests (M1-M5)

APT-100 validation with high-H_2 and N_2–H_2 plasmas; build H_2 feeding & dilution (≥0.72 kg/h) and N_2 system (≥180 kg/h); establish Ga_2O_3 → Ga / GaN operating window; capture experimental data for scale-up.

Fabrication & Assembly (M4-M12)

Fabrication of metal/ceramic components; reactor build; procurement/tuning of Ga_2O_3 feeders and tools; cold tests (feed mixing, transport gas → Ga_2O_3 optimization); assembly for integrated trials.

Outcomes: *TRL 5–6* *TRL 7 (pilot)* *TRL 8–9 (industrial)*

DELIVERABLES

Key Deliverables:

- Operational N_2 (≥180 kg/h) and H_2 (≥0.72 kg/h) systems; safe dilution unit
- Experimental data on high-H_2 N_2–H_2 plasma (APT-100)
- Complete CAD of pilot Ga_2O_3 reduction system; production budget
- RFQs: tundish, heated crucibles, ceramic filters
- Fabricated & assembled system; optimized feed mixing regime

Outcomes & TRL Progress:

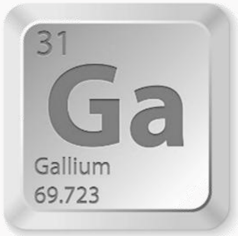
- Validated Ga_2O_3 → Ga / GaN process data for industrial scaling
- Industrial Deployment Unit (IDU) ready for integrated tests
- Path to TRL 7 at end of M5; TRL 8–9 in M12 via Ga_2O_3 pilot integration

M5: H_2/N_2 systems operational; dilution system ready

M7: Complete CAD; RFQs issued

M12: System fabricated & assembled; ready for tests

CLOSING & CALL FOR PARTNERSHIP



Next-generation clean Gallium production

Our RF plasma process offers emission-free, modular, and scalable Gallium (powder) production for the net-zero era.

Zero-emission, modular, scalable process

No CO_2. No Cl-chemistry. No nitrate or SX waste — only Gallium (powder), water. Fully aligned with ESG and decarbonization goals.

Strategic partnership opportunity

By joining forces, we can pioneer the future of Gallium (powder) production and set a new global benchmark for green metallurgy.

THANK YOU

Follow us and learn more about our recent development

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OUR CONTACT

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