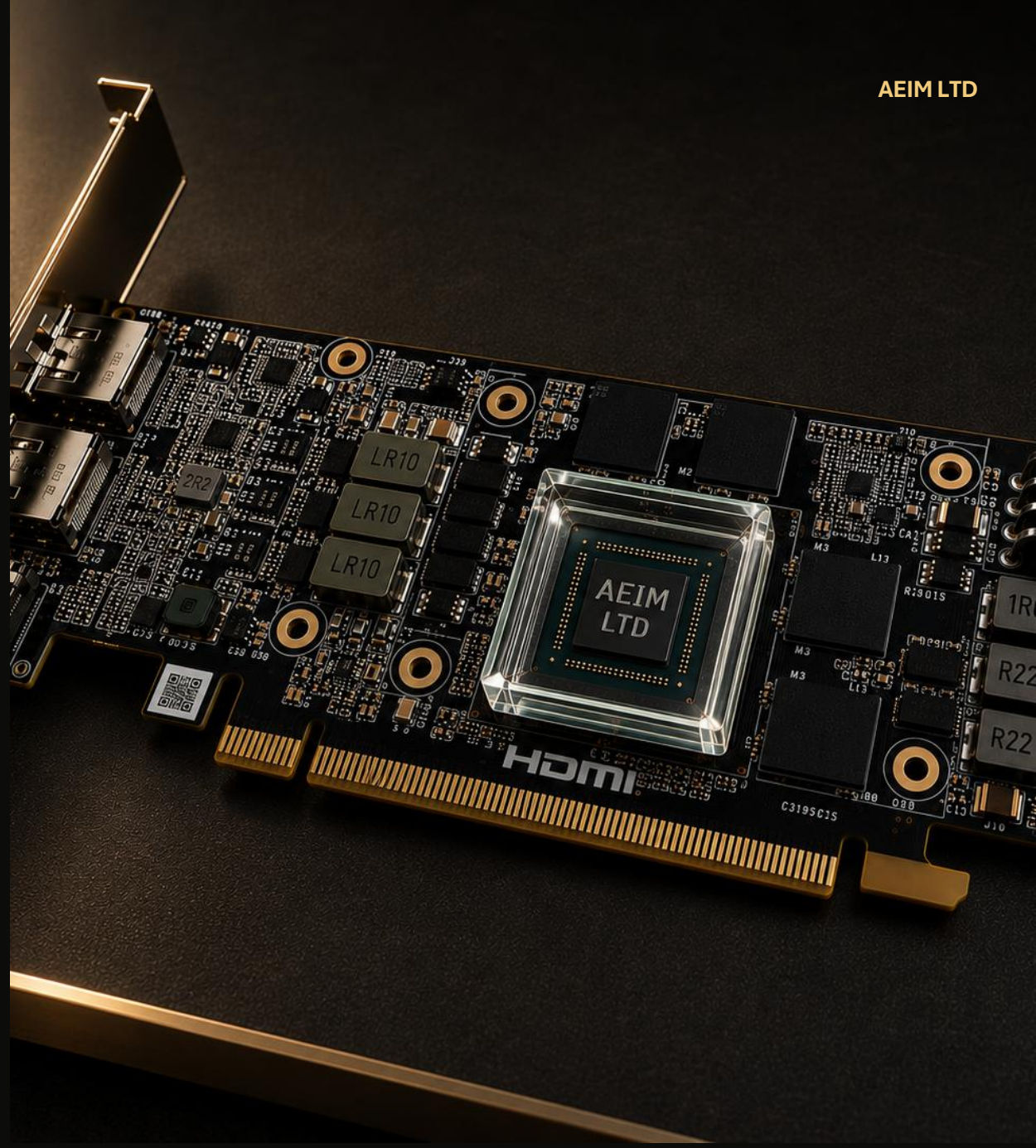
Single-Crystal Sapphire Thermal Spreader Blocks

Precision insulating interposers for GPU die protection and advanced thermal management.

GPU die → TIM → Sapphire → TIM → Heatsink



The opportunity

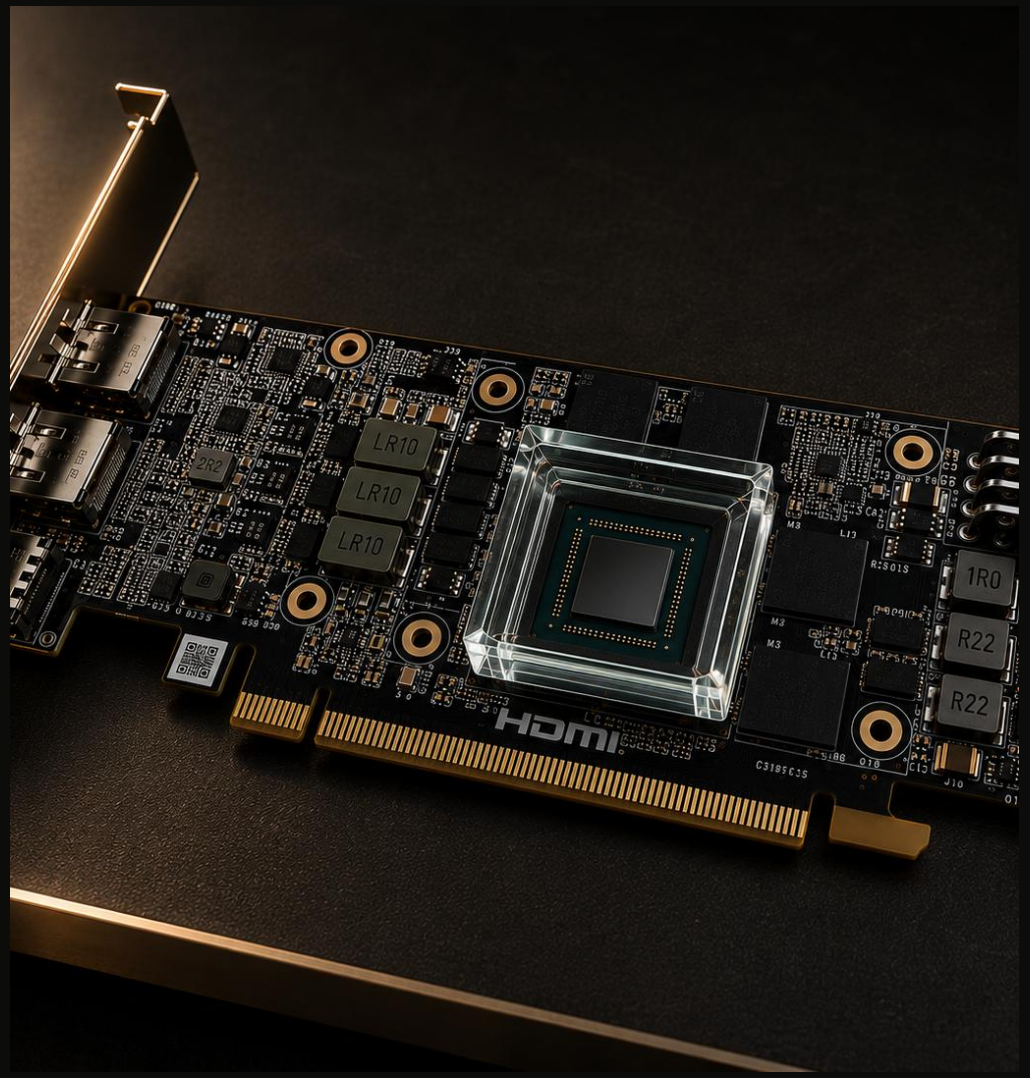
A precision material layer between chip and heatsink can improve reliability and design freedom.

Why sapphire?

- Electrically insulating interface for dense packages and bare dies.
- Hard, stable contact surface that can protect fragile silicon.
- Thermally useful compared with glass or polymer pads.
- Premium transparent material enables inspection and branding.

Design rule

Keep it thin, flat, polished, and pressure-controlled.



Thermal stack architecture

The concept works only when the sapphire and both TIM interfaces are engineered together.

GPU / ASIC die	TIM 1 10–30 µm	Sapphire 0.5–1.5 mm	TIM 2 10–50 µm	Copper cold plate

Key engineering target

Minimize total thermal resistance. Interfaces often dominate real-world performance.

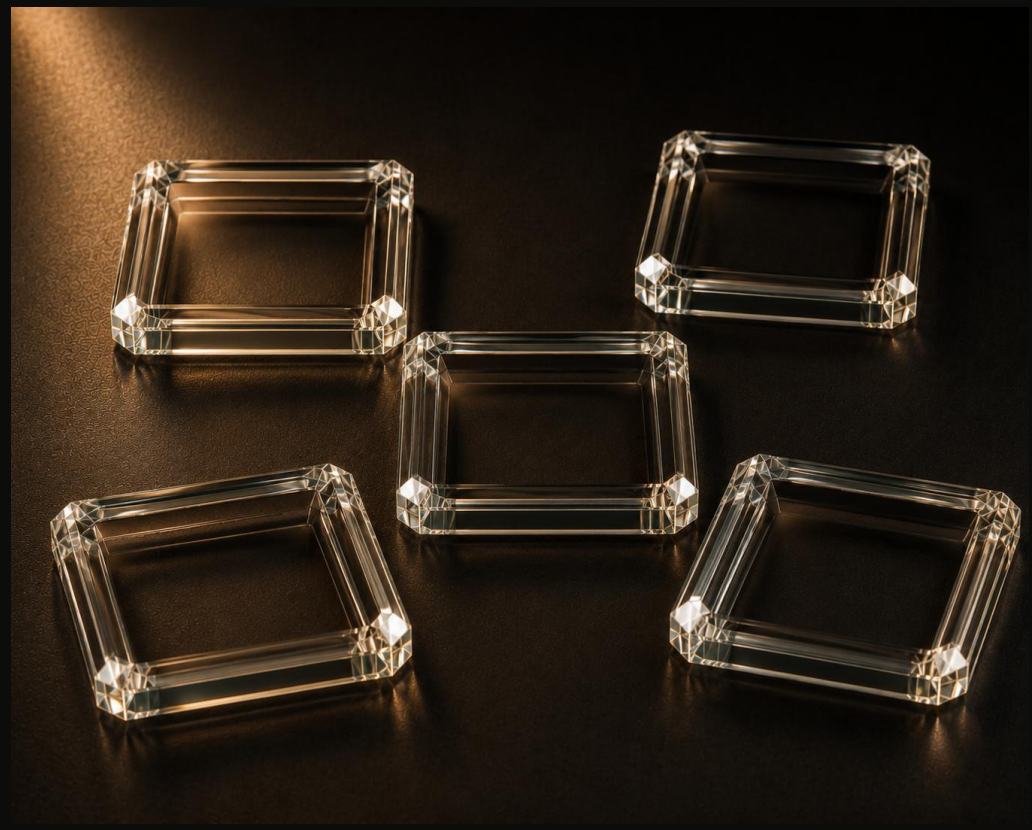
$$R = \text{thickness} / (k \times \text{area}) + \text{interface resistance}$$

Single sapphire block: transparent, polished, and edge-beveled for safe contact.

Recommended first product specification

Start with a GPU-grade sapphire thermal spreader family.

Material	Synthetic single-crystal sapphire, α-Al_2O_3
Growth	Kyropoulos or HEM; 5N Al_2O_3 preferred
Orientation	C-plane (0001), ±0.5°
Thickness	0.5 / 0.75 / 1.0 / 1.5 mm
Flatness	≤3 µm over active die contact area
Surface	Double-side polished; Ra ≤5–10 nm
Edges	0.1–0.3 mm bevel or radius
QC	XRD orientation, flatness, stress, inclusions, thickness report



Block family: multiple sapphire interposer sizes for GPU, VRAM, and power devices.

Manufacturing flow

From crystal growth to packaged thermal components.

1 **Grow boule**

KY / HEM sapphire

2 **Anneal**

reduce stress

3 **Orient**

XRD / Laue

4 **Slice**

C-plane wafers

5 **Lap**

flat + parallel

6 **Polish**

Ra ≤5–10 nm

7 **Dice + bevel**

custom sizes

8 **Clean + QC**

traceable reports

Manufacturing focus: low stress + high flatness + excellent surfaces + clean interfaces.

Mechanical integration rules

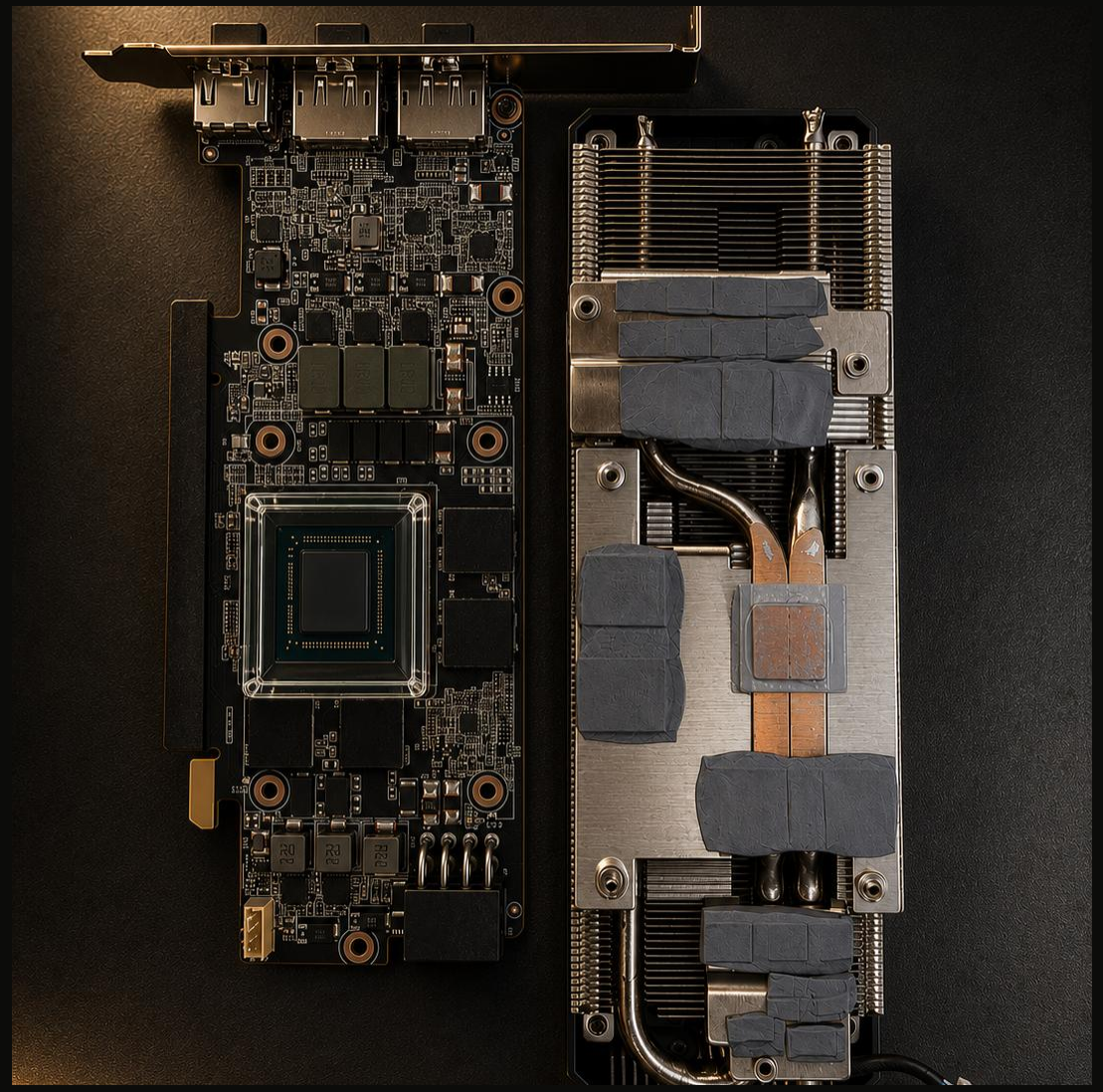
Protect the die and avoid hidden thermal resistance.

Must-have rules

- Use spring screws or Belleville washers for controlled pressure.
- Keep sapphire slightly larger than the die, not much larger.
- Chamfer corners to prevent chipping and stress concentration.
- Avoid tilt; a single high corner can crack the die or sapphire.
- Use thin, uniform TIM on both sapphire faces.

High-risk failure modes

Thick paste, rough surfaces, excessive thickness, uneven mounting, and unqualified liquid-metal containment.



Prototype validation plan

Compare sapphire against direct heatsink and copper shim references.

Build matrix

- 0.5 mm C-plane sapphire + paste
- 0.75 mm C-plane sapphire + paste
- 1.0 mm C-plane sapphire + paste
- 0.5 mm C-plane sapphire + phase-change TIM
- 0.5 mm copper shim reference
- Direct heatsink reference

Measure

- GPU core and hotspot temperatures
- Heatsink / cold plate temperature rise
- Thermal throttling and power limit
- Thermal cycling: -40 °C to 125 °C
- Pressure test and crack inspection
- 500-hour pump-out / reliability screening

Go / no-go: sapphire must win through safety, electrical isolation, die protection, reliability, or manufacturability - not only raw conductivity.

Commercial path

Turn the concept into a manufacturable sapphire thermal product.

Launch package

- GPU-grade sapphire blocks in standard thicknesses.
- Custom die-size blocks with lot-specific QC certificates.
- Evaluation kit: sapphire variants + TIM recommendations + pressure guidance.
- Customer validation workflow against copper shim and direct heatsink baselines.

Positioning

A precision single-crystal insulating thermal interposer - not decorative glass.

Sapphire blocks can become a premium thermal-management component when engineered for flatness, cleanliness, pressure control, and real-world reliability.