GUIDE BATTERY STORAGE · 8 MIN.

Barriers at Cell and Module Level: Fibre Paper, Microporous Laminates and Aerogel Compared

Which barrier material prevents propagation between cells and modules most reliably? A technical comparison of fibre paper, microporous laminates and aerogel composites for stationary battery energy storage systems.

Why the First Line of Defence Starts at the Cell

A thermal runaway always begins in a single cell. Whether it remains a locally contained event or turns into a full fire of the entire storage container is decided in the first seconds and minutes — specifically by the question of whether the neighbouring cell has to absorb the heat input or not. This is exactly where thermal barriers at cell and module level come in: thin separating layers between the cells and separator plates between modules that limit the heat flow until the released energy has been dissipated or distributed.

For designers and installers of stationary battery storage systems the topic is doubly relevant. First, test procedures such as UL 9540A evaluate propagation behaviour from the cell through the module up to the unit — an effective barrier at cell level improves the result at every level above it. Second, packaging space in modern racks is extremely tight: every millimetre of barrier material competes with energy density. Material selection is therefore always a compromise between thermal performance, thickness, mechanical behaviour and cost.

Note: The Requirements List for a Cell Barrier — A barrier between cells has to do more than insulate: it must briefly withstand the hot particles and gases of a cell failure, provide electrical insulation, mechanically accommodate the cyclic breathing of the cells (swelling) over their service life, and remain dimensionally stable while doing so. No single material fulfils all these points perfectly — which is why compromises and multi-layer assemblies dominate in practice.

Fibre Paper: The Robust Classic

Papers and blankets made of high-temperature fibres — classic aluminium silicate wool or bio-soluble alkaline earth silicate wool — have been established in industrial furnace construction for decades. Their strengths: very high classification temperatures (typically in the range of about 1,100 to 1,400 °C depending on fibre type), good availability, easy fabrication by die-cutting or slitting, and a moderate price. As a separating layer between modules or as a lining for module housings they perform reliably.

Their limits lie in thermal conductivity and mechanical behaviour. Fibre papers insulate considerably less well than microporous materials or aerogels, so they need more thickness for the same protective effect. Under sustained compression they also lose resilience — for positions where the swelling of the cells must be absorbed elastically, they are therefore only of limited suitability on their own. With classic aluminium silicate fibres, the classification as potentially carcinogenic must also be considered, which entails special protective measures during processing and dismantling; bio-soluble fibres avoid this issue.

- Typical use: separating layers between modules, lining of module and rack housings, backing for gas discharge ducts
- Strengths: high temperature resistance, easy processing, inexpensive
- Weaknesses: higher thermal conductivity, limited resilience, fibre dust issue depending on fibre type

Microporous Laminates: Maximum Insulation per Millimetre of Heat Protection

Microporous insulation materials consist of fumed silica with opacifiers and achieve pore sizes below the mean free path of air molecules. The result is a thermal conductivity that at high temperatures lies below that of still air — no other material in common use insulates better per millimetre under hot gas contact. Classification temperatures, depending on the product, are mostly in the region of 1,000 °C. Exactly this combination makes microporous boards and laminates the first choice where a steep temperature gradient must be maintained within the tightest of spaces.

The price for this is mechanical sensitivity: the material is pressure-sensitive and prone to dusting, which is why it is practically always processed with a facing — welded into films, wrapped in glass fabric, or as a laminate with facing layers of mica or metal foil. Such laminates combine the insulating performance of the microporous core with the puncture resistance and particle erosion resistance of the facing layer. For positions with cyclic compression — directly between breathing cells — the material is unsuitable, however, as it can compact under alternating load and lose its structure.

Note: Mica as a Partner — Mica boards bring exactly what microporous cores lack: high mechanical stiffness, excellent electrical insulation and resistance to hot particle streams. In multi-layer barriers, mica frequently takes the hot, particle-loaded side while the microporous core maintains the temperature gradient.

Aerogel Composites: Thin, Flexible, Compression-Stable

Silica aerogels are among the least thermally conductive solids of all; fibre-reinforced aerogel composites achieve thermal conductivities in the order of 0.015 to 0.02 W/(m·K) at room temperature. What makes them interesting at cell level, however, is above all the combination of insulating performance, low thickness and mechanical compliance: aerogel pads only a few millimetres thick can briefly withstand very high flame temperatures while elastically absorbing the breathing and swelling of the cells over thousands of cycles without building up any significant compression set.

Aerogel composites thus occupy the position that fibre paper and microporous laminates do not cover: the direct cell-to-cell barrier in prismatic modules and between pouch cells, where barrier and compression pad coincide in a single component. Disadvantages are the higher price, the continuous service temperature that is limited compared with ceramic fibre depending on the product, and possible dust release, which is likewise controlled by facings. For large-area module separations or housing linings they are often not the first choice economically.

- Fibre paper: plenty of temperature reserve, needs thickness — good for module separation and housings
- Microporous laminate: best insulation per millimetre, pressure-sensitive — good for static barriers where space is tight
- Aerogel composite: insulates very well and cushions swelling — good for the cell-to-cell position
- Mica: mechanically and electrically strong, hardly insulates — good as a facing layer in a composite

Selection in the Project: From Load Case to Verification

Material selection does not start with the datasheet but with the load case: how much energy does the cell release, how long does the venting last, what temperatures and particle streams occur at the barrier, and what maximum temperature may the cold side reach so that the neighbouring cell does not run into the critical range? From these boundary conditions, thickness and build-up follow — frequently as a multi-layer composite combining insulating core, particle protection and electrical insulation.

Effectiveness is ultimately verified by testing: propagation tests at cell and module level, standardised in North America via UL 9540A, show whether the barrier actually stops propagation or merely delays it. Important for operators: a material change during the product's life — for cost or supply reasons, say — can call the validity of existing test evidence into question. Barrier materials therefore belong in the change control of the safety concept, not in unrestricted procurement.

Frequently asked questions

Is a barrier at cell level sufficient to dispense with measures at container level?

No. Cell barriers reduce the probability of propagation, but they replace neither the fire compartmentation of the container nor gas detection, explosion venting or suppression systems. Effective protection only arises from the interplay of all levels — cell, module, rack and room.

If aerogel insulates best, why is it not used everywhere?

Aerogel composites are considerably more expensive than fibre paper and play out their advantages above all where low thickness and compression behaviour are required at the same time — that is, directly between the cells. For large-area, static separations, fibre products or microporous laminates are frequently the more economical and equally effective solution.

What does the breathing of the cells mean for barrier selection?

Lithium-ion cells expand during charging and with ageing. A barrier between the cells must absorb this change in thickness elastically without permanently compacting — otherwise it loses insulating performance and the cell stack loses its defined preload. Materials with a low compression set have a clear advantage here.

Let us talk about your project

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