“Thickness Optimization of Thermal Barriers Containing ENTERA® Aerogel Particles for Electric Vehicle Batteries,” (Cabot Corporation, Billerica, MA, USA. David Flannery, Xiaofeng Zhang, Peter Pescatore, Sean Sullivan, Jeffrey Gamble, Saeed Choudhary, Augustine Awuah; April 2024)

Silica aerogel, originally used as an insulating material in highly specialized applications such as those in NASA’s Space Shuttle and Mars Rovers Programs to insulate against the harshness of outer space, is now transitioning to mainstream markets. Due to its nanometer scale pore size (~20nm) and closed-pore structure, silica aerogel delivers superior thermal insulation at low density, ideal for space-constrained applications, like those in electric vehicle battery packs.These characteristics of silica aerogel particles enable extremely effective thermal insulation properties along with nonflamability and lightweight, have resulted in aerogel becoming the incumbent materials being used to mitigate the risk of thermal runaway and fires in lithium-ion batteries used in battery electric vehicles (BEV), having gained adoption in numerous global auto OEM and battery supplier platforms. As a leading producer of silica aerogel particles, Cabot Corporation can provide formulators with key building blocks to develop thermal insulation solutions for the EV market.

To demonstrate the performance gains that can be realized through the addition of aerogel particles, researchers at Cabot developed multiple prototype thermal insulation pads “with and without” aerogel particles and subjected these pads (shown in Figure 1a) to a series of tests for evaluation, including hot-cold plate testing. “Hot-cold plate tests” are commonly employed by auto OEMs to evaluate thermal barrier performance. A hot-cold plate test system is utilized to simulate thermal runaway conditions, where the hot plate is heated up to 650°C to work as a thermal runaway trigger cell, and the cold plate serves as a normal cell (Figure 1b). An insulation pad is inserted between the hot and cold plates to reduce thermal propagation and thermocouples are attached to both the hot side and cold side of the plates in contact with the aerogel pads. During the test, the hot plate is heated from room temperature to 650°C and the temperature is recorded on the cold plate for a predetermined length of time, ten minutes in our case. Cabot researchers utilized this test methodology to quantify the performance gains realized through the addition of ENTERA® aerogel particles to both glass-fiber and ceramic-fiber containing pad formulations. Relative to non-aerogel based thermal barriers, Cabot’s test results demonstrated that ENTERA aerogel enabled:

1. 40% reduction in barrier thickness required for a given level of insulation performance, measured by the temperature differential between hot/cold plates (Delta T), after 10 minutes of heating on the hot plate
2. 100°C improvement in insulation performance (Delta T) at a given thickness
3. And the potential of a 50% reduction in pad weight for a given level of insulation performance (Delta T)

Figure 1a. Insulation pad formulated with ENTERA® Aerogel Particles

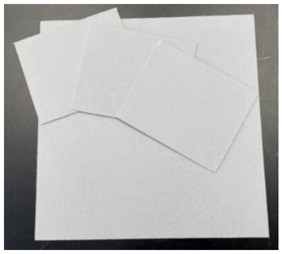


Figure 1b. A Schematic of Hot-Cold Plate Test

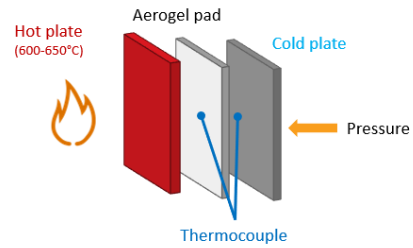
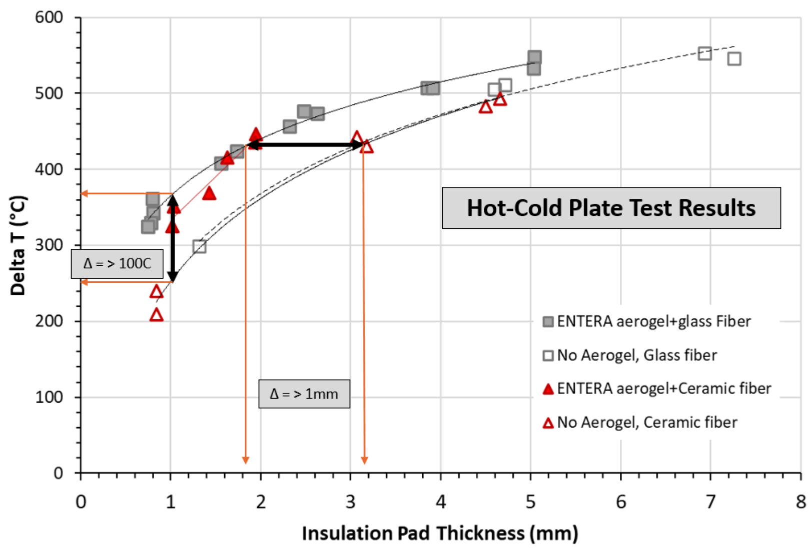


Figure 2 demonstrates the impact that aerogel particles have on hot-cold plate test results. This graph compares the performance of glass- and ceramic-fiber based blanket systems with and without aerogelparticles.

Figure 2: Hot-Cold Plate Test Results with ENTERA® Aerogel Thermal Barriers (ΔTemp. vs. Thickness)



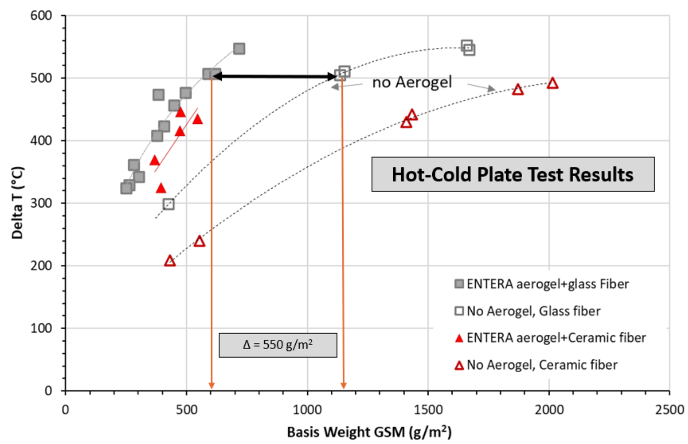
Cabot's performance testing results provide auto OEMs and battery manufacturers with four practical insights and take-aways. First, the addition of ENTERA aerogel in the formulation of the pads can improve insulation performance by 100°C versus either glass or ceramic fiber pads of the same thickness that do not contain aerogel. This is demonstrated on the graph above with the black vertical arrow at 1 mm thickness. This 100°C difference is critical, as it can mean the difference between containing thermal propagation to one cell, or a thermal runaway event spreading to many adjacent cells.

Second, we discovered that to achieve the same thermal insulation performance delivered by aerogel thermal barriers, non-aerogel thermal barriers need to be greater than 1 mm thicker. This is demonstrated on the graph above with the black horizontal line corresponding to a y-axis value of 440°C (Delta T) between the curves with and without aerogel. As there are many cells and thus many thermal barriers between cells in a battery pack, aerogel-based thermal barriers can free-up valuable space in a pack that can be re-allocated to additional cells to extend the driving range of the vehicle. Without aerogel, thermal barriers for BEVs need to be much thicker and it is difficult for battery module and pack designs to accommodate thick product forms in this application.

Third, our results did not reveal any meaningful performance differences between glass fiber-based and ceramic fiber-based formulations with our ENTERA® aerogel particles. This is shown in Figure 2 by the overlapping curves corresponding to glass fiber aerogel pads (solid gray squares) and ceramic fiber aerogel pads (solid red triangles). Cabot ENTERA aerogel particles provide tremendous formulation flexibility for companies developing thermal barriers for battery electric vehicles as they are compatible with glass, ceramic and polymeric fibers.

Fourth, ENTERA aerogel thermal barriers enable vehicle lightweighting (Figure 3). At an equivalent insulation performance, a pad containing aerogel particles has a much lower basis weight, or grams per square meter (GSM) than a pure fiber-based pad.

Figure 3: ENTERA® Aerogel Thermal Barriers enable lighter weight thermal barriers (ΔT vs grams per square meter (GSM))



For the same level of performance, aerogel solutions are significantly lighter than non-aerogel solutions. At a Delta T of 500°C, glass fiber-based aerogel thermal barriers have a basis weight of 600 g/m²compared to 1150 g/m² for non-aerogel barriers. As a battery EV can use between 4-8m² of thermal barriers for thermal management, the lower density associated with the aerogel solution would result in approximately 2-5 kg (~5-10 lbs.) of weight reduction per EV. The light-weighting effect is even greater when compared to ceramic fiber-based thermal barriers. Thus, aerogel insulation materials enable lighter thermal barrier solutions. This reduces overall battery pack weight, thereby extending driving range and reducing emissions associated with powering BEVs.

In conclusion, auto OEMs and battery manufacturers for BEVs have two levers for delivering the insulative and safety performance required by their thermal barriers used to mitigate the risk of thermal runaway and fires: 1) material choice; and 2) thickness (or, weight) of the barrier. Non-aerogel-based thermal barriers can deliver equivalent insulation performance to aerogel-based barriers, but they would need to be much thicker (and heavier), and this comes at a significant cost – much more of the volumetric space in a battery pack would need to be allocated to passive thermal barriers if aerogel is not used. Based on our estimates aerogel based insulation can result in 2-3%spacesaving in battery pack, which can be allocated to additional battery cells for extended range. ENTERA aerogel-based thermal barriers can enable the insulative and safety performance demanded in this application in the thinnest product forms possible.