Breaking the Heat Barrier

Exploring thermally conductive materials for enhanced battery performance

Overview of thermally conducting materials

The increasing demand for higher energy and power density, as well as quick charging capabilities, has driven the battery industry to explore new cell chemistries and other innovations in energy storage. However, many of these developments have led to increased heat generation in battery cells, which limits performance, longevity and negatively impacts safety of the battery pack. To address these challenges, efficient battery thermal management systems are required. Recently materials with compelling thermal properties have emerged as one crucial component to mitigate heat within energy storage systems.

Within the class of materials for effective thermal management, so-called “gap fillers” play a critical role in dissipating and / or absorbing the heat, generated during battery discharge and fast charging. By filling the unused space between battery cells and the heat exchanger, or the cells and the casing, gap fillers serve as thermal interface materials (TIMs). They improve equal thermal conductivity throughout the system by facilitating heat conduction. Additionally, gap filler materials also provide electrical insulation, dampen vibrations, and can act as fire retardants.

With the growing emphasis on sustainability of the battery pack production process, use phase and finally the disposal, the request of easy dismantling and disposal of these materials has gained strong attention. In the fast-paced world of TIM materials for battery solutions, it's no longer enough to deliver outstanding performance and safety. Such materials are expected to also meet sustainability and recycling standards while also satisfying manufacturability requirements.

Understanding and testing these arrays of KPI’s is crucial to select the right materials for a given battery application. Despite the massive demand in high-performance gap filler materials for automotives, power tools and micro mobility applications alike, we have seen limited holistic overviews and benchmarks that support this selection. Sphere Energy therefore took on the mandate to conduct a comprehensive evaluation of 10 leading gap filler materials and analyze their maturity regarding enhancement of cell performance and sustainability.

This report offers a glimpse into our findings. **Please reach out if you are interested in more detailed data points**!

Improving battery performance: Our results reveal significant performance increase for battery cells

We have conducted comprehensive model evaluations using a single battery cell type to assess the performance of different gap filler materials. Here, two parameters significantly influence the behavior and performance of the battery cell: a) the specific heat capacity, which measures the material's ability to absorb thermal energy, and b) the thermal conductivity, which measures its ability to dissipate thermal energy (see Figure 1). Depending on the specific application and the configuration of the battery thermal management system, the importance of either parameter may vary.

Thermal conductivity and heat capacity: two unrelated, yet essential concepts to be understood when looking for the right gap filler material for your application

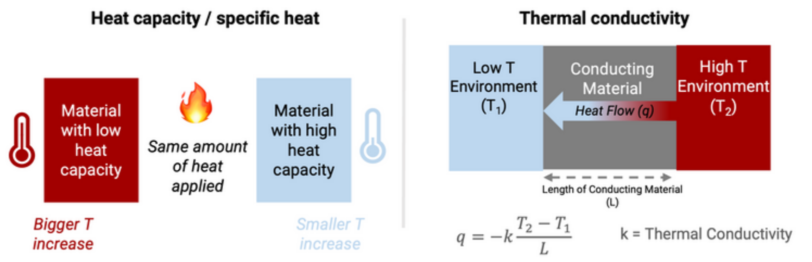

Fig. 1 - Differentiation between thermal conductivity and heat capacity

In our study, we compared gap filler materials from various manufacturers, each with different thermal conductivities ranging from 1.5 W/mK to 3.0 W/mK. To isolate the thermal conductivity effects from the specific heat capacity, we varied the thickness of the gap filler applied around the battery cell. This method allowed us to gather valuable insights into these two phenomenon.

In the experiment we performed a full 10C discharge (45A) from 100% state of charge (SOC) to 0% SOC, followed by a resting phase. To compare the surface temperatures of the battery cell to the one of the gap fillers, two separate temperature measurements were performed, using an embedded PT100 temperature sensor and an infrared camera (IR) (Figure 2). Measurements were conducted both with and without forced convection in a controlled atmosphere at 25°C.

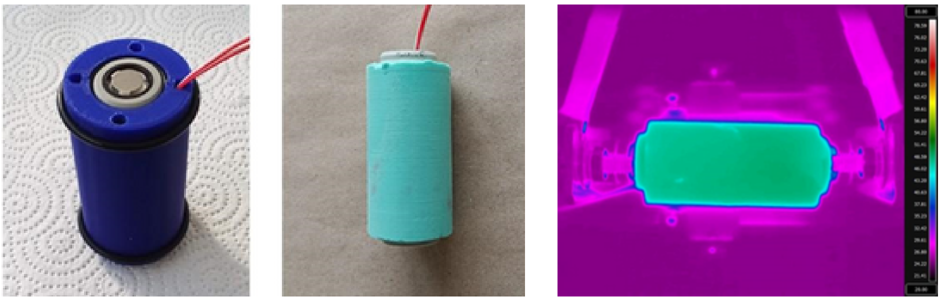

Fig. 2 - Left/Middle: Integration of Pa T100 sensor for temperature monitoring in gap filler encased battery cells.
Right: IR-Picture of a cell coated with gap filler material.

The results of our study reveal the benefits on the performance of a battery cell when applying gap filler materials, as they significantly reduce the maximum temperatures during discharge, compared to pristine cells. While the pristine cell could not be fully discharged (only 80% of the max. energy) due to a safety cutoff at 80°C cell temperature, this threshold value has not been reached with gap fillers applied. We were able to achieve a complete cell discharge for all the materials tested, with maximum recorded temperatures ranging from only 65°C to 70°C.

These findings hold exciting implications: By utilizing such TIMs, we were able to extend the average discharge time by an impressive 85 seconds which resulted in a remarkable 25% increase in energy throughput per cycle (Figure 3) - as it prevented the cut-off temperature from being reached. Adding a forced convection, further decreases the peak temperature while also securing faster cooling, after discharge. When we consider these results on the cell-level for battery modules or entire packs, the added value of these materials in battery engineering becomes evident. Interestingly, despite varying thermal conductivity values, we found no significant difference between the single materials in terms of discharge performance (Figure 4).

Fig. 3 - The 5mm gap filler jacket enables a 25% capacity gain within a 10C discharge process.

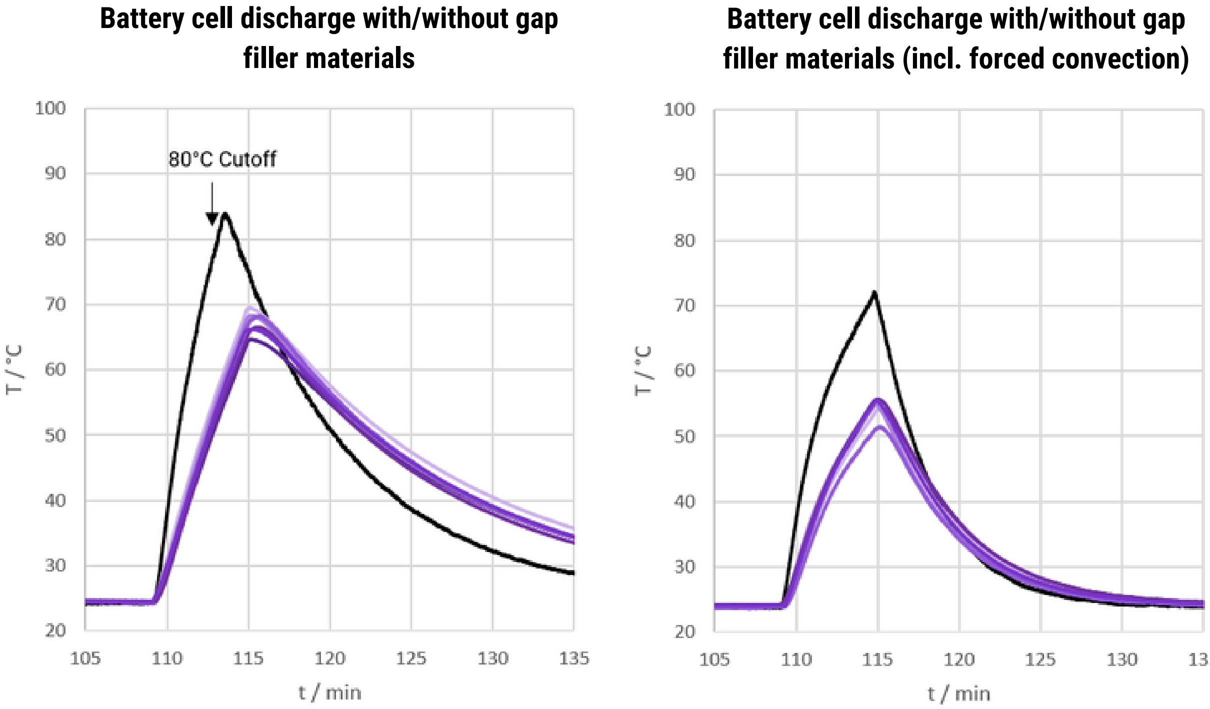

Fig. 4 - Peak temperatures are significantly reduced with gap filler materials (purple) compared to pristine battery cells (black). Left: Full discharge was achieved with applied gap filler material, whereas the pristine battery cell was shut down due to the safety cut-off temperature. Right: Improved performance is also observed when additional forced convection was added to the experimental setup.

We conclude that, at least for this experimental setup, the effect of the specific heat capacity, heat uptake in the TIM, is the overwhelming effect. Surely, when an efficient active cooling is applied to the system, the heat thermal conductivity gains in importance.

New regulations. New opportunities

As the demand for sustainable practices continues to rise within the battery industry, the demand on gap filler materials extends beyond performance and safety considerations. Environmental friendliness throughout the entire life cycle (incl. production and disposal) of these materials has become central. In order to demonstrate the environmental impact of electric vehicles (EVs), conducting Life Cycle Assessments (LCAs) for various components, including gap filler materials, is on its (slow but steady) way to becoming standard practice. Thus, providing comprehensive LCA studies can serve as a crucial differentiator for gap filler manufacturers, enabling EV manufacturers to align with their sustainability goals.

In the ever-changing landscape of battery recycling and second-life applications, gap filler manufacturers are confronting a non-trivial challenge. The need for recyclable and adaptable gap filler materials has risen as new regulations come into play. The pressure is on for manufacturers to think creatively and find practical solutions to meet these demands. Ideally, gap filler materials should exhibit strong adhesion throughout their lifespan while also being easily removable at EOL to facilitate disassembly, one of the first steps of the overall recycling process.

In our experiments, we discovered significant variations in the adhesive properties, hardness, elasticity, and plasticity of gap fillers. These characteristics are essential when considering the ease of serviceability and recyclability. Simply put, the faster the battery cell can be removed from the surrounding gap filler materials, the better. Based on this principle, we categorized all the materials into three distinct groups:

1. The first group consists of gap fillers that are easily removable. They maintain their elasticity and can be peeled off with minimal residue, requiring little mechanical force. (Figure 5, left)

2. The second group includes gap fillers that can be removed with relatively low mechanical force, but they leave behind stubborn residue on the battery cell surface that is difficult to remove. (Figure 5, middle)

3. The third group comprises gap fillers that are very hard. These materials cannot be easily removed and necessitate considerable mechanical force for disassembly. (Figure 5, right)

Fig. 5 - The simplicity of the removal of gap filler materials strongly varies among different products. This removal step from battery cells must be considered for 2nd life applications or recycling to reduce processing cost.

Next-generation cell technologies will further change requirements

The battery industry is going through a rapid transformation, with new types of batteries emerging to revolutionize energy storage. While NMC and LFP batteries currently dominate the market, there are exciting technologies on the horizon that will ask for specific TIM materials. One such technology is silicon-rich anodes, which enhances the energy density of batteries. Also Sodium-ion batteries, which use sodium instead of lithium, offer a more sustainable and abundant resource for battery power. Additionally, solid-state batteries, with their solid electrolytes, provide improved safety and higher energy densities.

These new battery chemistries bring along various challenges, such as battery swelling and heat generation. As a result, TIM materials need to adapt to meet these evolving requirements by offering greater flexibility and higher heat dissipation capabilities. Continuous innovation in TIM materials is vital to support the successful implementation of advancements in battery technology and optimize performance and safety in the dynamic landscape of energy storage.

About Sphere Energy

Sphere Energy employs an international team of scientists, engineers, and data experts with over 15 years of experience in developing and assessing innovative battery technologies. With three locations across Europe and a dedicated 500 m2 hands-on battery technology center in Germany, our team brings global expertise in electrochemistry, analytics, electrical engineering, and battery technologies. Our tech-focused offerings span the whole battery value chain - from early R&D support to strategic and organizational implementation of newest battery technologies.

Disclaimer

The information given by the article is for general guidance on matters of interest only. Even if Sphere takes every precaution to ensure the article's content is current and accurate, errors can occur. The article contains publicly available information only and provides further analysis and conclusions based on public information. Sphere does not have access to proprietary information, which would be required for an appropriate study. Sphere has consulted several of the cited companies to ensure accuracy. We will not hold any responsibility for any missing or wrong information. All conclusions are the sole opinion of Sphere and could be inaccurate given the limited scope of the article.

Take your TIM / gap filler solutions to the next level by partnering with us to understand and evaluate the changing battery requirements. Our expertise in battery thermal management and extensive knowledge of evolving cell technologies and industry demands will help you navigate the shifting landscape and optimize your gap filler materials accordingly. Let's together create innovative solutions that meet the dynamic needs of the energy storage market. Contact us today to explore the possibilities of a collaborative partnership.

www.sphere-energy.eu ☎ +41 79 278 57 87 ✉ info@sphere-energy.eu