TOSHIBA

Battery

Batteries for boats – think differently

How lithium titanium oxide (LTO) technology can reduce the total cost of ownership for applications such as ferries

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Article

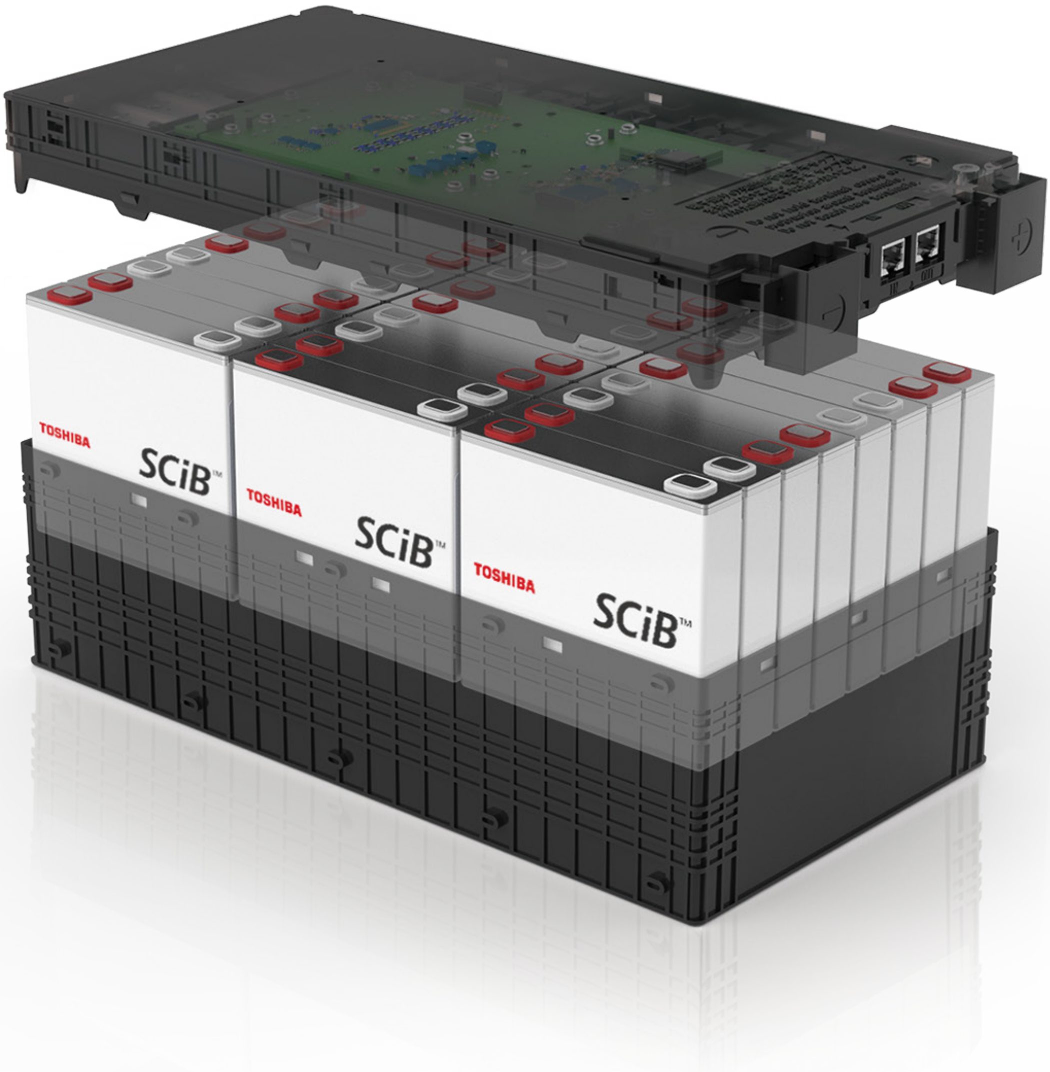

Figure 1: Battery module Type3-23

Introduction

If you were to ask an automotive engineer, the goals for battery design are simple – create the most capacity you can, for the lowest cost, with the smallest volume and weight. While that is intuitively true, it works because of the way electric road vehicles are used. Other applications, such as water ferries are somewhat different, travelling the same route with frequent stops and this opens up battery choices.

In this technical article, Toshiba will discuss LTO batteries and consider how they can support applications where batteries are charged and discharged frequently, delivering advantages above and beyond 'normal' automotive-style batteries. Marine ferries will be cited as an example to demonstrate how what may appear at first to be a more expensive option can, in fact, save significant costs during the lifetime of the application.

Batteries are taking on greater importance as many see them as a significant contributor to meeting the environmental goals, we have set ourselves. One of the key applications is to store energy that can be used to propel many types of electric vehicles including cars, vans and boats. As all of these applications are space-constrained and cost sensitive, battery designers are challenged to produce batteries that offer ever more energy per unit volume while continuing to reduce the cost, measured in Euro/kWh.
In applications where vehicles must cover long distances but are charged relatively infrequently then the 'low-cost and high capacity' approach is the right one. However, where a defined route is followed and in-journey stops are made as part of normal operating procedure, the battery needs can be reviewed and changed. This includes applications such as buses and ferries where the route is pre-planned and there are multiple stops to allow passengers to get on and off. Here, there is the chance to recharge in-journey without inconveniencing the operator or passengers. However, a pre-condition is that the battery can be re-charged very quickly multiple times and this is where LTO technology appears very attractive.

The technoloy behind LTO batteries

As the most robust and powerful Lithium-Ion (Li-Ion) battery technology currently on the market, LTO technology employs a significantly different chemical structure. Here, the more common graphite is replaced, and the anode is formed from Lithium Titanium Oxide (LTO).

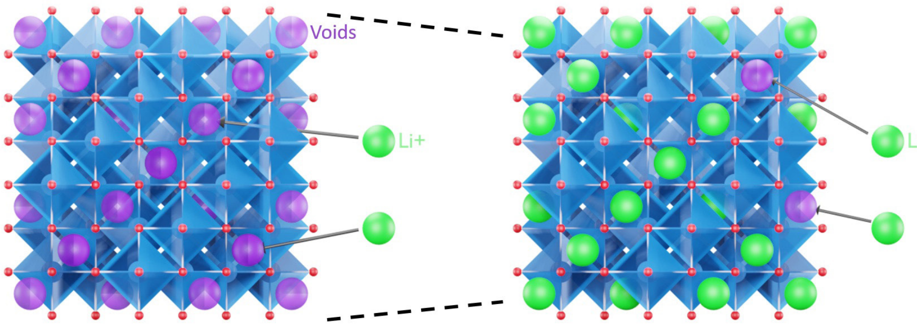

Figure 2: Li Ions can easily enter voids in the LTO spinel structure

When conventional Lithium Ion chemistries are charged the ions have to squeeze between the layers of graphite. If they cannot intercalate into the layers fast enough then, instead, they will form metallic Lithium at the interface to the electrolyte. This plating will occur if the battery is charged too fast and is even more of a concern at temperatures below freezing or if the battery is already in a high state of charge (SoC). The risk of metal plating instead of intercalation into the graphite is a key limiting factor for fast charging and leads to capacity degradation. In contrast to the layered material of graphite the LTO in the anode of LTO battery cells is a crystalline spinel structure. In this structure there are voids in which the Lithium ions can be inserted and extracted much more easily, reducing the internal resistance of the cell and supporting higher current charging.

The spinel structure of the anode in an LTO cell is "zero-strain", meaning that there is negligible change in volume as ions are inserted and extracted, thereby enhancing the cycling stability. In tests, Toshiba's high-power LTO cells retain more than 90% of their initial capacity after more than 20,000 cycles of continuous charge and discharge at 5C (meaning the cell is fully charged/dis-charged within 12 minutes).
The cell voltage for LTO is 2.3 V which is slightly lower than the 3.6 V that is common in other Li-Ion cells. Even though this produces a lower specific energy, LTO batteries remain capable of exceeding 100 Wh/kg.
However, the lower cell voltage delivers a safety margin that eliminates the risk of Li-metal plating. Consequently, LTO cells are extremely safe and no Li dendrites are formed, even when fast charging at low temperatures. In the unlikely event of an internal short circuit, LTO cells will discharge much slower than cells with a carbon anode. The slower chemical reaction means less heat is generated, so any risk of thermal runaway or thermal propagation is much lower than with other types of Li-Ion cells

LTO as solution for ferries

Electrically propelled ferries are increasing in popularity as they are much more environmentally friendly ter to operate, and their operating profile is well defined and repeated regularly. Typically, this will consist of a round trip, between two (or several) points, perhaps along the length of a river or around a lake or harbour with relatively frequent stops to allow passengers to join or disembark.

With a little adjustment for payload, currents and wind, the energy needed to complete each leg of the journey is known, and consistent. Given this, it is not necessary to deploy a battery that will provide energy for the entire day's operation, on the basis that the battery can be conveniently replenished at each scheduled stop, without lengthening the journey.

However, charging for the next leg will have to take place within minutes. If this is tried with a conventional LIB, its capacity needs to be many times bigger than the energy delivered during rapid charging. Otherwise, the charging current per cell would be too high leading to metal plating, capacity degradation and the risk of dendrites. If an LTO battery is used, its capacity can be much smaller probably around 10x smaller in capacity - while still enabling sufficient fast charging.
The ferry will benefit from a physically smaller and lighter battery which, consequently, will cost far less than the conventional LIB. Even with the lower energy density and higher cost-per-Watt, the LTO battery will only cost around 20% of the conventional solution because of its optimised energy size. However, over the lifetime of the ferry (say 15 years) the savings will be far higher as the NMC or LFP batteries may have to be

replaced while LTO batteries are unlikely to need replacing on this timescale.
LTO is the safest Li-Ion technology with characteristics that virtually eliminate the risk of fire or explosion. Obviously, on a boat, fire is a more serious issue than with a land-based vehicle.

Toshiba's SCiB™ LTO battery solution

Toshiba offers a wide line-up of battery cells ranging from small high-power cells with 2.9Ah capacity up to a new 26Ah cell with more than 100Wh/kg energy density. An innovative 20Ah-HP cell with very high-power capability was recently launched, reducing the internal resistance of the previous 20Ah-HP cell by approx-imately 40%. This allows 70% higher input and 60% higher output power as well as achieving a longer life and retaining nearly 100% of its capacity after 8,000 charge/discharge cycles at 5C (@25°C with 10~90% SOC).

Toshiba also offers complete modules consisting of 24 cells, 12 in series and two in parallel. Depending on the load profile they can be delivered with different cell types either for high power or for high energy. These modules are already used in various marine projects and were the first batteries in Japan to win approval from Nippon Kaiji Kyokai (ClassNK) for use in marine vessels.

Summary

For many heavy-duty marine applications, fast charging, lifetime, and safety are key points to select the best battery technology. The possibility to reduce the size of the battery and to avoid replacements during the lifetime of the application are more important factors for the total cost of ownership than energy den-sity. LTO is the most powerful, robust and safest Lithium-Ion technology available and offers many benefits for such marine applications.

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