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Battery Technologies: Look beyond the obvious

How Lithium Titanium Oxide (LTO) Technology can reduce the total cost of ownership for applications such as AGV

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Introduction

Battery technology is developing rapidly, and, at a first glance, the goals may seem obvious – simply squeeze as much capacity as possible into the smallest space, at the lowest cost. While, in some applications such as electric road vehicles, this may hold true, other applications require a different way of thinking and alternate approaches may achieve even greater performance at lower cost.

In this technical article, Toshiba will look at LTO battery technology and consider how it can bring significant advantages in terms of both performance and cost in heavy-duty applications where batteries are charged and discharged frequently. Automatic guided vehicles (AGVs) are used as an example to show how LTO technology can help to optimize the battery and reduce the total cost of ownership.

As environmental pressure and dwindling fossil fuel reserves drive the automotive industry to replace the internal combustion engine (ICE) with electric propulsion, the battery pack becomes the defining element in terms of vehicle range. Designers are being driven to produce batteries that offer ever more capacity per unit volume while continuing to reduce the cost, measured in Euro/kWh.

In fact, that is exactly the correct approach for vehicles that are required to cover long distances but are charged relatively infrequently. However, for other applications including railway, marine or off-road heavy-duty vehicles, careful consideration of alternate technologies can yield lower costs and greater performance. Instead of maximising the battery capacity at the lowest cost, it is often more beneficial to optimize battery capacity by regular fast re-charging - as enabled by the use of LTO technology.

Lithium Titanium Oxide (LTO) battery technology

LTO technology has a fundamentally different chemical structure to other batteries, making it the most powerful and robust Lithium-Ion (Li-Ion) technology that is available anywhere. In LTO batteries, the anode is formed from Lithium Titanate Nanocrystals (Li4Ti5O12) instead of the more common graphite powder.

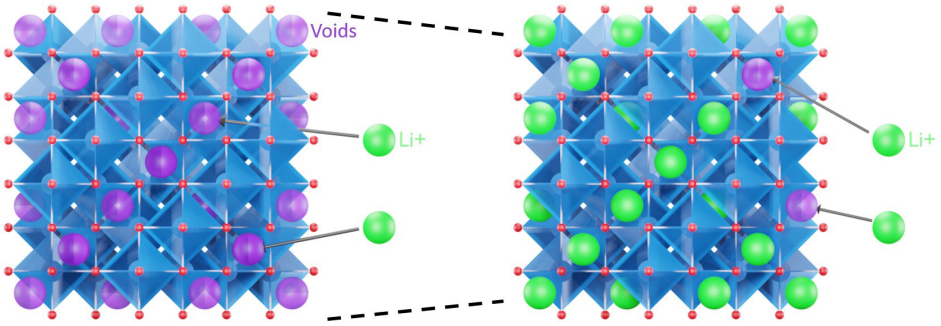

Figure 1: Li Ions can easily enter voids in the LTO spinel structure

The surface area of this material is thirty times higher than carbon. It avoids the challenge of fast reversible intercalation of lithium ions into the carbon. Instead, the ions can easily occupy the voids in the crystal structure during charging, giving an LTO battery a much-reduced internal resistance that can support higher currents.

The spinel structure of an LTO anode is considered to be “zero-strain”, showing little (if any) volume change as lithium ions are inserted and extracted. This gives excellent cycling stability of the battery. Even after 8000 cycles of continuous charge and discharge at 5C from 10 to 90% of the full SOC range Toshiba’s latest high-power LTO cell maintained almost 100% of its nominal capacity and showed no discernible degradation.

LTO gives a lower cell voltage of 2.3 V compared to the 3.6 V that is found in other Li-Ion cells. This does lead to a lower specific energy although LTO batteries remain capable of exceeding 100 Wh/kg – albeit lower than a comparable state-of-the-art NMC or LFP cell.

However, the positive impact of this reduction in cell voltage is to give a safety margin that eliminates the risk of Li-metal plating. As a result, 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. This is crucially important in applications such as marine.

LTO cells in AGV applications

As businesses seek to be more efficient, automation is being added throughout factories. One particular area of focus is AGVs – small electrically-powered vehicles that are used to move raw materials and goods around the factory and warehouse. Often AGVs are operated around the clock sometimes in demanding environments such as refrigerated warehouses or clean rooms.

If we consider the typical working profile for a small AGV, we can begin to understand the benefits of LTO battery technology in these applications. Around 75% of the time is spent driving with low power consumption.

Raising cargo up uses the most power while energy is recuperated and returned to the battery when lowering goods. In a typical 20-hour day, such AGV will use about 4.8kWh of energy – assuming around 1,200 runs are made.

When considering the charging strategy and selecting the optimum battery there are two options. The AGV can run for its full working day and deplete a large battery which can then be recharged in about an hour, or regular recharges can be used to keep a much smaller battery topped up during the day. In terms of working time, the two scenarios are the same, with 60 minutes of each day being dedicated to charging.

The first option for daily recharging requires a battery with a capacity of 165 Ah. So even when using NMC technology with a very high energy density of 200 Wh/kg the battery would still weigh almost 40 kg. In the second option, a battery with much smaller capacity of around 16.5 Ah is recharged during operation for six minutes, ten times per day. The challenge is that to operate in this way, much faster charging is required – the relative charging power is ten times higher (6C). However, this is entirely within the capability of LTO technology that can be recharged more quickly (even in low temperatures) without any risk of Li-metal plating. As a result, despite the lower energy density, this solution weighs under 10 kg and, assuming a factor of two for the Euro/kWh, the cost for the cells would still be only one fifth.

Apart from the lower initial cost of the battery, its smaller size and weight will ease the design and reduce the cost of the AGV. The operation will be much more efficient and new use cases such as shuttles connected to the warehouse shelves become possible.

From the perspective of robustness and ruggedness, the LTO solution is best. Not only is any risk of fire minimal, the LTO batteries do not require a warm environment for charging and during its long lifetime it is likely that two or three sets of NMC batteries may be needed.

Toshiba SCiB battery pack solution

Toshiba's range of Super Charge Ion Batteries (SCiB) feature a 24 V / 22 Ah LTO battery designed specifically for industrial applications such as AGVs. The pack can operate from -30°C to +45°C and is capable of delivering up to 125 A for 200 seconds.

Measuring just 247 x 188 x 165mm and weighing a mere 8kg, the SCiB batteries can be joined in parallel or in series (for 48 V operation). Status and diagnostic data is provided via CAN bus.

Summary

AGVs are becoming very common and, to be successful, they need to be small, manoeuvrable, reliable, and low cost to acquire and operate. Selecting the right battery is key to achieving this and while the mantra for batteries is generally "more capacity for lower cost", a choice of an LTO battery can dramatically reduce costs while delivering a safer and more robust solution.

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Volker Schumann, Vice President Battery Division at Toshiba Electronics Europe

Volker Schumann joined Toshiba in 1999 and held various positions throughout his time with the company. In the past, he was responsible for the Automotive Systems Marketing Group and headed the Automotive and Industrial sales teams for semiconductors before he moved in 2021 to the battery division of Toshiba.

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