SCiB™ Technology and Its Potential Military Applications

Takeshi Yasuda, Kaoru Koiwa, Makoto Soda
Defense & Electronic Systems Division
Toshiba Infrastructure Systems & Solutions Corporation
Kawasaki, Japan, 212-8585
Contact Author Email: takeshi3.yasuda.wq@toshiba.co.jp / +81-44-331-1765

Abstract: *SCiB™ is Toshiba's Lithium-ion rechargeable battery developed adapting LTO (Lithium Titanium Oxide) technology to its anode. The LTO anode provides SCiB™ with six superior features: long cycle life, rapid charging, high input/output power performance, wide effective SOC (State of Charge) range, excellent low-temperature operation, and a high level of safety. SCiB™ is a proven technology and has already been applied to a variety of civil/commercial products/systems including EV/HEVs, trains, and large-scale stationary battery energy storage systems (BESSs). Using state-of-the-art manufacturing technologies, Toshiba has established a no-defect record for delivered SCiB™ cells. SCiB™ cell's unique characteristics and high reliability are beneficial not only for civil/commercial applications, but also for defense/military applications. Toshiba will present the operational advantages gained by applying SCiB™ for defense/military products/systems and introduce some possible applications, including drop-in-replacement for NATO 6T lead-acid batteries for ground vehicles.*

Keywords: Lithium-ion battery; Rechargeable; LTO; NTO; Long life; Safety; Rapid charge; Deep cycle; Low-temperature operation; Cranking Ampere; 6T battery; 24V Lithium-ion battery; Dual use; Silent watch; MIL-PRF-32565

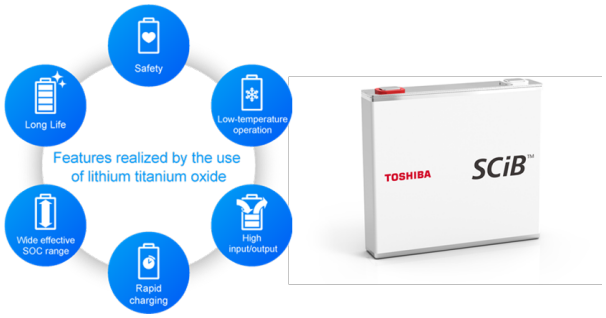
What is SCiB™? [1]

SCiB™ is Toshiba's Lithium-ion rechargeable battery originally developed for civil/commercial applications utilizing LTO (Lithium Titanium Oxide) technology. Use of an LTO anode provides SCiB™ with a unique and superior combination of six characteristics. (Figure 1)

Use of an LTO anode provides SCiB™ with a long life of over 15,000 charge/discharge cycles, rapid charging, high input/output power performance, wide effective SOC range, excellent low-temperature operation, and a high level of safety.

Safety

Use of an LTO anode provides safety protection against internal short circuiting. In case of short circuiting, instead of a rapid temperature rise associated with sudden discharges in carbon anodes, SCiB™'s LTO Anode exhibits a limited temperature rise due to its Phase Transformation.



- **Safety**: Uses highly safe lithium titanium oxide (LTO)
- **Long life**: Over 15,000 cycles*
- **Low-temperature operation**: Can be used at temperatures as low as -30°C
- **Rapid charging**: Rechargeable in 6 minutes*
- **High input/output**: Chargeable at large currents and provides large current output
- **Wide effective SOC range**: Provides a large available capacity

*Measured with a particular single cell under specific conditions

Figure1. Six feature of SCiB™

Specifically, upon an internal short circuit, LTO transforms from a high conductive material to a low conductive material, which results in a minimal discharge rate between the anode and cathode. This prevents rapid temperature rise in the cell and assures safety. (Figure 2)

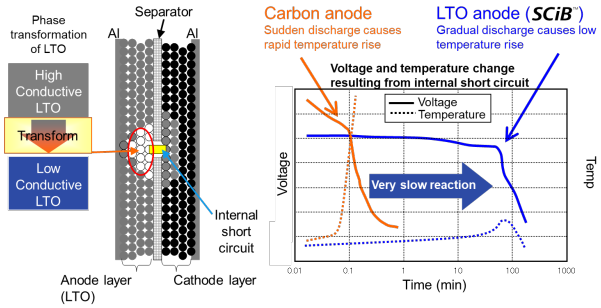


Figure2. Safety Protection against Internal Short Circuit

Additionally, the electrode potential of SCiB™'s LTO anode prevents Lithium-metal deposition, which could be a cause of internal short circuiting, even in cold conditions with high input power. (Figure 3)

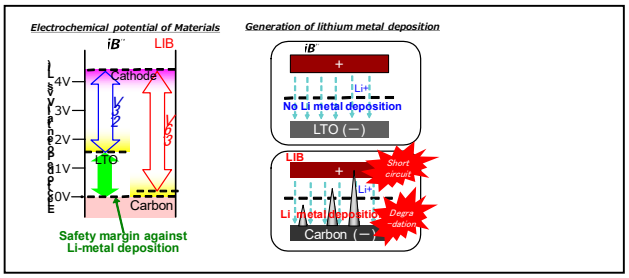


Figure 3. LTO prevents Lithium-metal deposition

Long Life

20Ah SCiB™ cell maintains over 80% of its initial capacity after 15,000 charge/discharge cycles with 3C charge/discharge condition at 25°C. (Figure 4) This superior Long Life characteristic of SCiB™ also stems from its LTO anode.

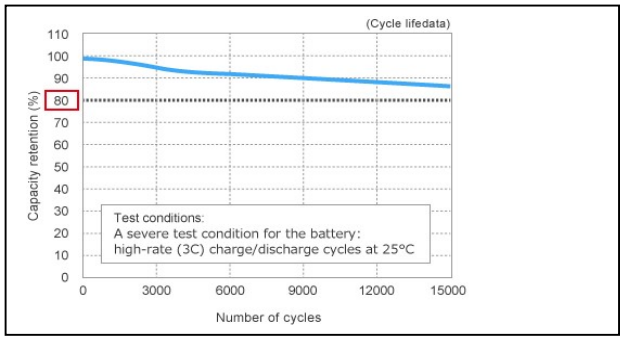


Figure 4. After 15,000 cycles, SCiB™ keeps 80% initial capacity

In most cells, the stress imposed on the anode structure by the changing thickness of the anode material caused by lithium-ion intercalation/de-intercalation accompanying charge/discharge influences battery life. In particular, relatively large increases in thickness of carbon/graphite anodes caused by repeated charges/discharges accelerates the capacity degradation of cells.

On the other hand, with SCiB™, the much smaller increase in thickness of its LTO anode with a solid crystal structure greatly reduces capacity degradation, despite repeated charge/discharge cycles. This helps ensure a long battery life. (Figure 5)

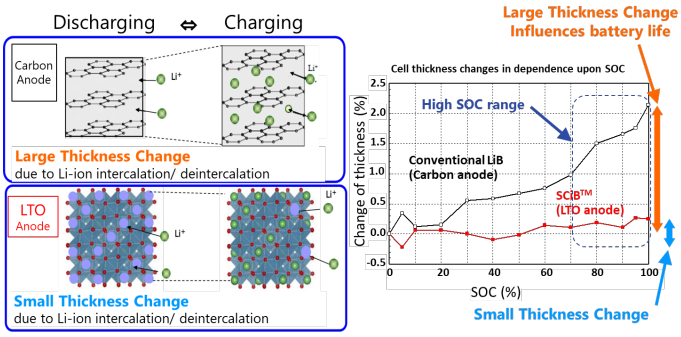


Figure 5. Small thickness change leads to a long life

SCiB™ Cell Types

SCiB™ cells can be categorized into two types. (Table 1)

The high energy type cell is suitable for applications requiring large capacity, such as electric vehicles and stationary storage systems

The high power type cell is suitable for applications requiring the charge and discharge of large currents in a short period of time, such as regenerative braking in automotive applications.

Table1 SCiB™ Cell lineup

	High Power Type		High Energy Type	
Cell Type				
Nominal voltage	2.4V		2.3V	
Nominal capacity	2.9Ah	10Ah	20Ah	23Ah
Dimension	W63 x D14 x H97 mm	W116 x D22 x H106 mm		
Weight (Approx.)	150g	510g	515g	550g

Civil / Commercial Applications

SCiB™ cells and modules have already been adopted in a variety of highly reliable systems and products, such as the following: [1]

- EVs/PHEVs, EV-Buses, Hybrid electric boats, Emergency-Running Battery System for metro, Battery powered locomotive, General battery-driven industrial equipment
- World-largest class (40MW/40MWh) stationary battery energy storage systems (BESS)

Advantages for Military Operations

SCiB™'s unique combination of six characteristics provides beneficial features for not civil/commercial applications, but also defense/military one. (Figure 6)

Figure 6. Advantages for Military Operation

SCiB™ 24V Lithium-ion 6T battery

Toshiba is currently finalizing development of a "dual (i.e., both military and civil) use" 24V Li-ion battery with a 6T form factor in accordance with STANAG 4015. (Figure 7) The battery is intended for use as a power source for in automotive starting, lighting, and ignition (SLI) and auxiliary electronics (deep cycle, engine off / silent watch). It can also potentially be used for a wide variety of air and naval platforms and ground-based energy storage systems. The battery incorporates SCiB™ commercial cells inside the battery package, along with a Battery Management System (BMS). Toshiba plans on qualifying the battery with MIL-PRF-32565A by 2019. Targeted specifications of the SCiB™ 24V Lithium-ion battery are represented in Table 2.

Table 2 Targeted Spec. for 24V Lithium-ion 6T battery

Items	Specifications
Dimension	256 x 269 x 208 mm
Weight	Aprox. 28 kg (61.7 lbs)
Nominal Voltage	25.3 V
Nominal Capacity	64 Ah at 22 °C
Energy	1.6 kWh
Cranking Amperes (No pre-heating)	1,100A for 30 sec at 55°C 600A for 30 sec at -18°C
Cranking Amperes (with pre-heating)	1,100A for 30 sec at -18°C 600A for 30 sec at -48°C
Deep Cycle Life (1C/1C)	4,000 at 38 °C 2,000 at 50 °C 500 at 65 °C
Rapid Charging (SOC 90% and more)	20min at 180A (Maximum charge: 300A)
Charging below 0 °C	Available (No heating necessary)
Operational Temp.	-46°C to +71°C

Figure 7. SCiB™ 24V Lithium-ion 6T battery

Configuration

A single SCiB™ 24V Lithium-ion 6T battery can replace two current 12V 6T lead acid batteries to securely provide vital power for various military vehicles. (Figure 8)

- Power for engine start
- Power for Mission Equipment under "Silent Watch"

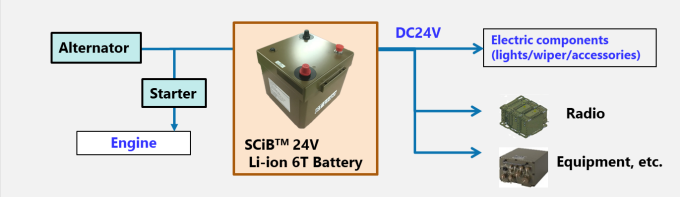


Figure8. Configuration for use on the military vehicles

Silent Watch Operation

To minimize the risk of being detected by enemy forces, the batteries can provide power to the vehicle equipment while the engine is turned off. Toshiba's Li-6T battery provides long Life, wide effective SOC range, and rapid charging suitable for repeated long-duration Silent Watch operations. (Figure 9).

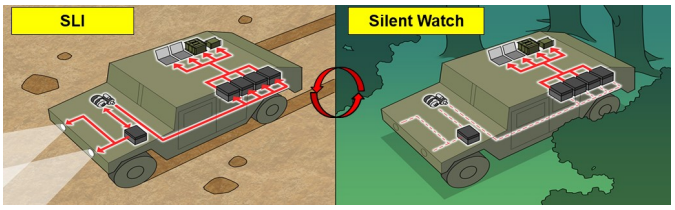


Figure 9. Silent Watch Operations

Test results of SCiB™ Cell and 24V Lithium-ion 6T battery

Some in-house test results of SCiB™ 24V Lithium-ion 6T battery prototype are shown below.

Charge/ Discharge test in Cold Environment

The test results of repeated charge/discharge cycles without heating in a cold environment is shown on Figure 10. The condition is set as 1C Charge /1C Discharge at a starting temperature of -30°C. The result shows that the battery is capable of being charged to around 45% SOC in that condition without cell heating.

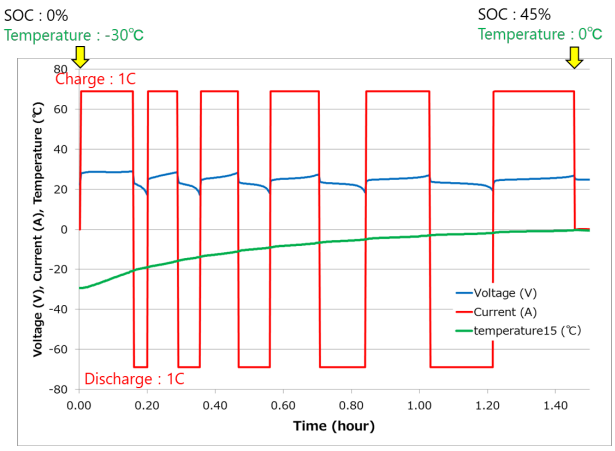


Figure10. Result of Charge/Discharge in cold environment.

Bullet penetration test result

In-house Bullet Penetration Testing that targeted fully charged 20Ah cell resulted in No Fire / No Rupture (EUCAR Hazard Level 3).

Cranking Characteristics

The result of repeated cranking of a 4-ton class dump truck with a diesel engine using a SCiB™ 24V Lithium-ion 6T prototype battery is shown on Figure 12. Cranking was repeated 180 times during 1,800 seconds in a normal temperature environment.

This figure shows that SCiB™ 24V Lithium-ion 6T battery maintains about 90% of its capacity, even after conducting 180 consecutive crank starts.

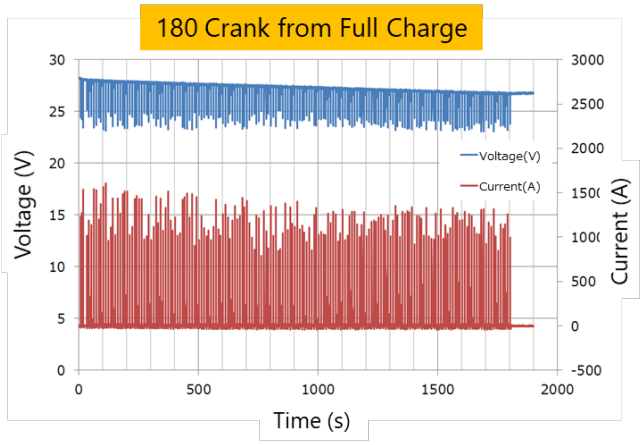


Figure11. Result of 180 consecutive crank starts

Next-Generation SCiB™[2]

Toshiba plans on making available to defense and commercial customers its SCiB™ 24V Lithium-ion 6T battery in 2019. All the while, Toshiba continues its commercially-based cell and battery development. It has announced development of a Next-Generation Lithium-ion Battery with a New Anode Material, as shown on Figure 12. This new battery will offer even better performance characteristics (in particular higher energy density while maintaining safety) for a wide-range of military applications.

- New Anode Materials: Titanium Niobium Oxide (NTO)
  - Doubles the capacity by volume of the graphite-based anodes generally used in lithium-ion batteries.
  - Excellent characteristics, such as Safety and Long life are same as current SCiB™
- 50Ah prototype
  - The energy density by volume of battery is twice that of the current SCiB™
  - Maintains over 90% of its initial capacity after being put through 5,000 charge/discharge cycles.
  - Ultra-rapid recharging can be done in cold conditions, with temperatures as low as -10°C, in only ten minutes

Prototype of 50Ah next-generation SCiB™
111mm x 194mm x 14.5mm

Figure 12. Next-Generation SCiB™

References

1. TOSHIBA SCiB™ Web site
   http://www.scib.jp/en/index.htm
   http://www.scib.jp/en/applications/index.htm
2. News release
   https://www.toshiba.co.jp/about/press/2017_10/pr0301.htm