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Rechargeable Battery Technologies for Infrastructure Systems to Support Sustainable Recycling Society

SCiB™ Lithium-Ion Rechargeable Batteries Bringing Innovation to Social Infrastructure
EGUSA Shun

Trends in Rechargeable Battery Technologies and Applications to Create Sustainable Recycling Society, and Toshiba Group's Efforts in This Field
TAKAMI Norio / MOCHIKAWA Hiroshi
The movement toward the introduction of rechargeable battery systems has recently accelerated with the aim of realizing a sustainable recycling society in various spheres of social and industrial infrastructure such as energy systems, railway and traffic systems, and so on.
In response to these market needs, the Toshiba Group is continuing its efforts to develop technologies for its SCiB™ lithium-ion rechargeable batteries, which provide high-speed charging, a long lifetime, and high safety, and to deliver systems and services in a broad range of fields including electric vehicles (EVs), bus and railway systems, automated guided vehicles (AGVs), and stationary battery energy storage systems (BESS). From the viewpoint of economic efficiency and usability, we are also working toward the practical realization of the next-generation SCiB™ with the objective of achieving higher energy density as well as a further lengthening of the lifetime through the development of titanium oxide-based anodes, and are aiming to expand the range of application of SCiB™ batteries.

Energy Storage Solutions Utilizing SCiB™ Lithium-Ion Rechargeable Batteries Contributing to Realization of Sustainable Railway Systems
SATAKE Nobuhiko / IMAI Keiichiro
Reflecting the growing importance of the Sustainable Development Goals (SDGs) and environmental, social and governance (ESG) criteria, there has been an increase in demand in the field of railway systems not only for energy-saving solutions effectively utilizing regenerative electric power, but also for resilient systems allowing continuous operation even in an emergency such as a power outage.
In response to this trend, Toshiba Infrastructure Systems & Solutions Corporation has been developing power storage systems using SCiB™ lithium-ion rechargeable batteries and supplying them to a number of railway companies in Japan and other countries. Such systems comprise both ground facilities supplying electricity and on-vehicle driving equipment. As part of these efforts related to ground facilities, we have constructed a control system for Okinawa Urban Monorail, Inc. that makes emergency operations possible even in the event of a wide-area blackout through the interconnected operation of three sets of traction energy storage systems (TESS). In the area of on-vehicle equipment, we have developed a hybrid driving system to convert engine power and regenerative electric power into motor driving force using SCiB™ batteries and have delivered it to Central Japan Railway Company.

Integration Methods for Hybrid Systems to Reduce Life-Cycle Costs Using High-Power Battery Equipped with SCiB™ Batteries for Electric Power Systems
YAMAZAKI Shuji / MONDEN Yukitaka / KOBAYASHI Takenori
Battery energy storage systems and generators have been attracting attention in recent years as a means of regulating the frequency of power grids to which a number of renewable energy systems are connected. However, the short-term frequency fluctuations that tend to occur in such power grids shorten the lifetime of the batteries due to frequent charging and discharging cycles and increase the fuel consumption of the generators, leading to higher life-cycle costs. Hybrid systems combining a high-power battery specialized for frequency regulation with conventional high-energy batteries and generators have therefore been considered as a countermeasure against these problems.
The Toshiba Group has developed integration methods for hybrid systems applying a high-power battery equipped with its SCiB™ lithium-ion rechargeable batteries for frequency regulation, which have notable features such as long life and high power input/output performance, to conventional high-energy batteries and generators. These hybrid systems make it possible to reduce life-cycle costs through optimization of the equipment configuration and control method, taking advantage of the features of SCiB™ batteries.

Use of Simulation Technology to Evaluate CO_2 Emissions from 48 V Mild Hybrid Vehicles Equipped with 5 Ah-Class SCiB™ Battery Cell
SHIMAKAWA Shigeru / SEKINO Masahiro
There is a strong need in the automotive field for the reduction of carbon dioxide (CO_2) in exhaust gases, one of the main causes of global warming. In particular, increasingly stringent regulations to reduce CO_2 emissions will be implemented in Europe in 2021. Automobile manufacturers are therefore making efforts to further improve fuel consumption by developing technologies to enhance the performance of 48 V mild hybrid vehicles while suppressing increases in manufacturing costs.
Toshiba Corporation has developed a 5 Ah-class SCiB™ rechargeable lithium-ion battery cell as an auxiliary power source for automobiles in order to make effective use of energy generated by the engine as well as regenerative energy produced during deceleration. We have conducted simulation tests using two models of 48 V mild hybrid vehicles equipped with the 5 Ah-class SCiB™ battery cell in accordance with the World-wide harmonized Light duty driving Test Cycles (WLTC), and verified that this battery cell is effective in reducing CO_2 emissions.

SCiB™ Lithium-Ion Rechargeable Battery Cell with Stainless Steel Outer Package Offering Both High Shaping Flexibility and High Mechanical Reliability
MAMYODA Hirokiyo / KOBAYASHI Yoshiki / WATANABE Kenji
The market for lithium-ion rechargeable batteries has been rapidly expanding in recent years, particularly in the areas of on-board batteries for electric vehicles and battery energy storage systems for electric-load leveling in various distributed power supply systems. Although lithium-ion rechargeable batteries having different shapes are required to meet user needs, such as thin, low-height, and wide batteries with a large aspect ratio; large A4-size batteries, and so on, their packages can be roughly classified into only two types: can type packages made of deep-drawn aluminum, which have high mechanical reliability but low shaping flexibility, and pouch type packages sealed with laminated film, which have higher shaping flexibility but lower mechanical reliability compared with can packages.
With the aim of overcoming these issues, Toshiba Corporation has developed a new SCiB™ lithium-ion rechargeable battery cell with a stainless steel outer package, which offers both high shaping flexibility and high mechanical reliability by combining the advantages of can and pouch type packages. We have conducted evaluation experiments on key elements including the terminals, package materials, and gas release vent, fabricated a 27 Ah prototype cell based on a reference model, and confirmed that it can meet the requirement specifications.

High-Safety Aqueous Lithium-Ion Rechargeable Battery with Incombustible Aqueous Electrolyte Solvent
SEKI Hayato / MATSUNO Shinsuke / TAKAMI Norio
Lithium-ion rechargeable batteries used in fields of infrastructure requiring long-term operation and high reliability, such as electric power systems, industrial equipment, and automobiles, must provide high safety in addition to high energy density. In this context, Toshiba Corporation has been developing and launching various products in its lineup of SCiB™ lithium-ion rechargeable batteries using lithium titanate oxide (LTO) anodes instead of the commonly used graphite-based anodes. In order to enhance the safety of batteries by reducing the risk of fire accidents caused by extrinsic factors, we have been promoting the development of an aqueous lithium-ion rechargeable battery in which the conventional combustible organic electrolyte solvent is replaced by an incombustible aqueous electrolyte solvent, together with the use of our proprietary solid electrolyte separator to suppress electrolysis of water so as to prevent charging and discharging reactions with generated hydrogen and oxygen gases. Experiments on a prototype aqueous battery cell with the solid electrolyte separator have shown that it is effective in suppressing electrolysis of water. In addition to enhancing safety, this battery has the potential to decrease production costs through simplification of the manufacturing equipment.

Design Techniques Utilizing Numerical Thermal-Fluid Analyses to Appropriate to Control of Heat Transfer and Airflow in High-Temperature Aging Chamber for SCiB™ Cell Manufacturing Process
TOYA Kiminori / ITABA Keisuke / SATO Shingo
In response to the increasing demand for rechargeable batteries accompanying trends such as the growing dissemination of electric vehicles, Toshiba Corporation has been developing and supplying SCiB™ lithium-ion rechargeable batteries with high safety and rapid charging performance. Heat aging in a high-temperature chamber plays an important role in achieving consistent quality during the process of manufacturing SCiB™ battery cells. In order to realize both consistent quality and improvement of productivity to enable a large number of cells to be handled, a chamber that can provide uniform temperature distribution through precise temperature control is essential. However, a critical issue with the conventional chamber is the need for detailed measures according to the conditions inside the chamber.
In order to rectify this situation, we have developed a new high-temperature aging chamber for SCiB™ battery manufacturing utilizing numerical thermal-fluid analyses of the heat transfer and airflow from the initial design phase. As a result of improving the heating air supply and exhaust positions and the layout of equipment through these analyses, we have confirmed that the new chamber achieves a reduction of about 60% in cell temperature variations compared with the conventional chamber by increasing the velocity of the airflow in the chamber.

Wireless Charging Systems for SCiB™ Lithium-Ion Rechargeable Battery Modules
UBUKATA Naoki / OKUBO Takashi
The introduction of automatic guided vehicles (AGVs) to convey various loads, including materials and parts, in combination with robot arms and other such devices is being actively promoted at manufacturing sites in order to improve productivity. From the viewpoint of securing safety and maintainability, the need has arisen in recent years for wireless power charging systems to charge the battery modules mounted on these AGVs.
As a result of this trend, Toshiba Infrastructure Systems & Solutions Corporation has released wireless charging systems for the Type3-23 and SIP24-23 SCiB™ lithium-ion rechargeable battery modules, which are applicable to AGVs and offer high safety and high-speed charging. These systems consist of a power transmission unit, a power receiving unit, contactless power transmitting and receiving pads, and other equipment. The wireless charging system for the Type3-23 large-capacity battery module employs a constant power control method that makes it possible to continuously charge an AGV equipped with robot arms in operation, while that for the SIP24-23 small-capacity battery module employs a constant current control method allowing the charging time of compact AGVs to be shortened. Both systems also incorporate protection functions to ensure safety.

Battery Capacity Estimation Method Requiring Only Operation Data of Battery Energy Storage Systems
MIZUTANI Mami / KIUCHI Masako / MITSUMOTO Kenji
Battery energy storage systems (BESS), which play a key role in social infrastructure, are expected to provide stable long-term operation. Effective means of grasping trends in battery performance degradation so as to facilitate maintenance at the optimal time are therefore required. Estimation of the capacity deterioration of batteries in BESS systems connected to the power grid, which must respond to a wide range of state of charge (SOC) conditions, is a particular focus of attention.
The Toshiba Group has developed a battery capacity estimation method that requires only the data of BESS systems in operation as input data. This method allows users to optimize the timing of maintenance and reduce operating costs without the need for information on the specific characteristics of the batteries nor for data obtained by specific charging and discharging cycles during the interruption of normal operation. We have applied this method to both an actual BESS system to suppress power fluctuations caused by a photovoltaic (PV) power generation system and a virtual power plant (VPP) system in which multiple consumers' BESS systems are interconnected to an AC power system, and confirmed that the evaluation of battery capacity in both cases is in good agreement with the actual trends. From the results obtained, we have confirmed that the performance of this battery capacity estimation method is sufficient for practical application.

Technique to Sequentially Optimize Electric Power Charging in Demand-Side Rechargeable Battery Systems for BCP Functions
MURAI Masahiko / SAKATA Masanori
Electricity markets are experiencing an increasing tendency toward the installation of rechargeable battery systems by electricity consumers in order to enhance their business continuity plan (BCP) functions in the event of an emergency and to utilize renewable energy generation including photovoltaic (PV) power generation for self-consumption. The capacity of such rechargeable battery systems allows them to be used not only for BCP functions but also for multiple purposes including peak shaving and shifting functions, as well as demand response (DR) when the residual capacity is available. In the case of PV power generation systems, attention is being focused on the effective utilization of battery capacity for the reduction of electricity costs by compensating only for any insufficiency in the PV power generation capacity to cover the BCP functions. With this as a background, the Toshiba Group has developed a calculation technique to sequentially optimize the amount of electric power charged in the rechargeable battery system to cover the BCP functions. We have conducted simulation experiments using actual solar radiation data and confirmed that this technique can suppress the peak value of power demand received from the commercial power system and cut electricity costs for the day-to-day operations to as little as one-tenth compared with the conventional style of operation assigning a fixed amount of capacity to BCP functions.

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Heat Pump Technologies Advancing toward Realization of Decarbonized Society

Expansion of Products Applying Heat Pumps Responding to Diversified Needs of Global Market
SATO Takehiko

Situation Surrounding Products Applying Heat Pumps and Toshiba Carrier's Approach
SHIMIZU Katsuhiro / SATODATE Koji / ENDO Takahisa
Heat pumps for air-conditioning systems are positioned as renewable energy utilization technologies in Japan and Europe, and are therefore expected to play a key role in enhancing energy conservation, particularly in systems that consume large amounts of energy such as heating and hot-water supply systems. Moreover, the trend toward the prevention of global warming by reducing emissions of greenhouse gases such as carbon dioxide (CO_2) and chlorofluorocarbons (CFCs) has intensified the need for technologies for air conditioners that comply with strengthened environmental regulations related to energy conservation and refrigerants throughout the world.
In response to these circumstances, Toshiba Carrier Corporation is developing and supplying air-conditioning products with high environmental performance utilizing its proprietary heat pump technologies suitable for various purposes, fields of application, and regions, while actively focusing on the development of technologies that can improve and maintain environmental performance throughout the life cycle of products.

High-Efficiency Air-Conditioning Systems Providing Solutions to Meet Diverse Needs of Small and Medium-Scale Buildings in Japanese and Overseas Markets
MORI Katsutoshi / KUBOTA Hikaru / HAMASHIMA Tetsuma
Variable refrigerant flow (VRF) air-conditioning systems, which make it possible to air-condition multiple spaces individually, have been widely adopted for small and medium-scale buildings due to their advantage of easier design and construction compared with central air-conditioning systems. As their range of application has expanded from office buildings to various other types of buildings in recent years, the requirements of designers, owners, and tenants of buildings with respect to such systems have also been rapidly diversifying.
Toshiba Carrier Corporation has developed the Super Multi u series high-efficiency VRF air-conditioning systems for the Japanese market as comprehensive platforms capable of offering increased flexibility and adaptability in order to respond to such diversified needs. The Super Multi u series has been achieved through the application of the latest technologies to the systems' hardware, software, communication equipment, and peripheral devices. This is also available in overseas markets as the SMMS-u series.

A3 and A4 Series Compact Large-Capacity Rotary Compressors for VRF Air-Conditioning Systems
SHIDA Shogo / SHISHIMOTO Tomohide / TODA Hayato
As the outdoor units of variable refrigerant flow (VRF) air-conditioning systems are often installed on the rooftops of buildings, it is necessary to reduce their casing size in order to make effective use of the limited space available. Demand has therefore been increasing for compressors offering both large capacity and compactness so as to decrease the number of compressors used in outdoor units, thereby allowing them to be installed in locations with limited space without any decrease in product specifications.
Toshiba Carrier Corporation has developed the A3 and A4 series rotary compressors for VRF air-conditioning systems that have achieved the largest class of capacity in the industry, about 20% higher than conventional compressors with same shell diameter, as well as high efficiency, low vibration, and low noise. These features were realized by applying a triple-rotary structure consisting of three compression chambers, a multivalve structure with discharge valves located on both the top and bottom sides of the compression chambers, and the world's first open-winding motor for air conditioners.

Universal Smart X EDGE Series Air-Cooled Heat Pump Chilling Units Equipped with Large-Capacity Rotary Compressor Adopting R32 Refrigerant
TOYAMA Shingo / MATSUMOTO Yuki
As a measure toward solving global environmental issues related to refrigerants for air-conditioning products, hydrofluorocarbons (HFCs) have been widely used as a replacement for chlorofluorocarbons (CFCs), which cause destruction of the ozone layer in the stratosphere. From the standpoint of global warming, however, there is a need to reduce the production and consumption of HFCs in stages through regulation due to their higher global warming potential (GWP) compared with carbon dioxide.
Toshiba Carrier Corporation is the leader in the air-cooled modular chiller market, with a share of more than 40%. We are now promoting the development of the Universal Smart X (USX) EDGE Series air-cooled heat pump chilling units equipped with a newly developed rotary compressor that realizes the world's largest class of capacity employing R32, a low-GWP refrigerant, through the improvement of elemental technologies including a liquid injection function to suppress increases in the temperature of the discharge gas peculiar to R32. As a result of these technologies, the USX EDGE Series achieves the industry's highest class of operating efficiency and expansion of the allowable temperature of the outside air taken in by the system from 43°C to 52°C, allowing it to handle extremely hot summer conditions while reducing the burden on the environment.

Outdoor Condensing Units Handling Five Refrigerants Including R448A and R449A with Low GWP
SHIRAI Koji / UCHIDA Shunsuke / KUSUNO Masaharu
R404A has been widely used in the refrigeration and air-conditioning fields as the main refrigerant in condensing units. Due to its high global warming potential (GWP) value of 3 920, however, demand has been increasing in recent years for condensing units using lower GWP refrigerants as a means of contributing to the prevention of global warming.
Toshiba Carrier Corporation has developed 0.75–2.2 kW outdoor condensing units capable of handling five refrigerants; namely, the low-GWP and nonflammable refrigerants R448A (GWP = 1 386) and R449A (GWP = 1 396), and the conventional refrigerants R404A, R410A, and R407C. These products allow customers to flexibly select the optimal products to meet various business objectives during the transitional phase of shifting to lower GWP refrigerants.

New Air Conditioners for Stores and Offices in Cold Regions Offering Both High Heating and Energy-Saving Performance
SANO Mitsukuni / UESHIGE Jun / SUITO Shoichiro
Oil refrigerant type heaters have been widely used for air conditioners installed in stores and offices in cold regions due to their heating performance and capability to continuously operate without the need for defrosting, and the use of energy-saving heat pumps has also been expanding. Such equipment is now aging, necessitating its replacement with new air conditioners to achieve a balance between high heating and energy-saving performance.
With this as a background, Toshiba Carrier Corporation has developed and released the Super Power Eco DANTARO HRP1 series air conditioners for stores and offices in cold regions. In order to improve heating performance and realize stable continuous operation even in extremely cold regions, the HRP1 series is equipped with a heat pump with high energy-saving efficiency and also incorporates the following features: (1) improved heating capacity at extremely low temperatures, achieved by a liquid injection compressor, (2) prevention of freezing of the outdoor heat exchanger and suppression of icicle formation on the underside of the outdoor unit, achieved by an anti-icicle defrosting control method and an antifreezing plate, (3) effective operation in high-humidity regions, achieved by a low-frost mode, and (4) prevention of chilling in unoccupied rooms, achieved by an 8°C heating control method.

Energy Consumption Simulator Promoting Efficient Energy Saving for Individual Stores of Retail Chains
KANAGAWA Keiko / SUYAMA Akihiro
Retail chains operating retail outlets such as convenience stores in Japan have recently been facing various management issues, including how to reduce their environmental burden and operating expenses through saving energy in each of their stores. In this context, attention is being increasingly focused on tools to estimate energy consumption according to the actual situation of individual stores, taking differences in the regional climate and installed equipment into consideration.
The Toshiba Group has developed an energy consumption simulator for convenience stores that can simulate the energy consumption of store equipment, including air-conditioning, ventilation, heat source, and condensing units, considering the seasonal and daily variations in the climate of each region. We have conducted accuracy verification tests using data obtained in a test room and at various actual convenience stores and confirmed the effectiveness of this simulator. The results of an investigation into reducing the energy consumption of air-conditioning equipment in the summer season have shown that an optimal air-conditioning setting temperature exists for each store according to the conditions of each region.

Feature Articles

LED Location Light for On-Location Venues Featuring Compactness and High Intensity
KONDO Kazuya / MURATA Junya
Location lights are portable lighting fixtures providing sufficient illuminance for photography and filming in on-location venues, even under sunlit conditions. Metal halide lamps with high intensity and high color rendering are commonly employed as the light source of location lights. Due to the use of mercury in the light-emitting tube of these metal halide lamps, however, demand is increasing for the replacement of such lights by location lights using a light-emitting diode (LED) module.
Toshiba Lighting & Technology Corporation has developed a small and lightweight LED location light equipped with a high-power chip-on-board (COB) LED module that can withstand higher temperature operation compared with conventional LED modules. This has been achieved by making efforts to reduce the size of the heat sink to cool the LED module and by considering the tradeoff relationships among the lifetime, performance, and attachment structure of the LED module. As a result, the newly developed LED location light has a power consumption of 225 W while outputting light equivalent to that of a location light equipped with a 575 W metal halide lamp. We have now launched a light source exchange service that allows users to change only the new LED module while continuing to use their usual lighting equipment and power supply units.

Frontiers of Research & Development

Method to Estimate Heat Stress Using Data from Wearable Sensors on Worker