Chapter 4

Alloys for Sodium-Ion Batteries

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Abstract

Sodium-ion batteries (SIBs) are developing as a substitution for lithium-ion batteries (LIBs). Sodium is in great abundance in the earth's crust. By the used of selective carbon as an anode, the expansion of sodium ion batteries anode has been accomplished. Due to the contribution of the carbon-based materials, the sodium ion batteries anode has been improved. Moreover, more investigation is still required to get the appropriate carbon materials that specify anode qualities. Alloy materials have shown a high capacity anode with the combination of carbon-based or other carbon-based materials for the development of SIBs. This chapter highlights the expansion of carbon-based materials and their complexes with alloy materials as well as their challenges and problems for sodium-ion batteries anodes.

Keywords

Sodium-Ion Batteries, Anode, Alloying, Electrolyte, Challenges

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1. Introduction

In the present primary area of energy storage devices, the rechargeable ion batteries have been slowly working. It is because of the benefits of excellent capabilities, long cycling life, larger capacity, etc. [1]. The green and safe energy sources are in demand nowadays. Due to the fast automation and demand for energy sources, environmental pollution and energy crunch have elevated the rising apprehensions across the world in current years. Green renewable energy sources should be demoralized and promoted to solve these issues. In present years, high-performance energy storing devices developed a current study matter [2]. Rechargeable ion batteries have been used with the advantage of excellent energy density and good cyclability to bring that responsibility.

Lithium-ion batteries (LIBs) developed the primary energy storing procedures. Meanwhile, Sony was commercialized them in 1991. They gained incredible achievement as authoritative bases for convenient electric devices and vehicles (EVs) [3]. But the scientific enhancement of LIBs cannot report the shortage of lithium reserves, and it gives a risk for electric vehicles to motorized by LIBs, which is no longer reasonable with their general procedure. It is challenging to change battery bits of knowledge based on an earth-abundant element other than LIBs. Na is a promising candidate who is next to Li in the periodic table [4]. The sixth most abundant element in the earth's crust is sodium. It shows many comparable alkali metal reactivity with Li. It is extensively dispersed. The model of SIBs is not novel because they were examined together with LIBs in the 1980s. So, in the primary 1990s, researchers have lost their
interest because of the inferior energy density of Nickel-ion batteries (NIBs). Because of ambient temperature, NIBs have higher consideration for grid-level application.

SIBs contain more inferior electrochemical qualities than LIBs because of the better range of Na$^+$ (59 pm for Li$^+$ and 102 pm for Na$^+$) [5]. The big size Na$^+$ ion shows poor kinetic performance and significant volume variations. Lithium resources have been consumed heavily, and SIBs have fascinated the consideration due to large abundance and low price. Almost 6.8 million tons of lithium metal will be used up when 52% of gasoline operated vehicle is substituted by electric cars. The exclusivity of lithium resources increases the application of sodium ion batteries. The interest of researchers has been shifted towards SIBs. Figure 1 displays the charging and discharging mechanism of the sodium ion battery. During the mechanism, sodium ion from the cathode required to introduce and go through the electrolyte towards the anode. Through the external circuit, the charge evaluation electrons permit from cathode to anode at the same time. In the discharging process, different behavior occurs.

Figure 1. Diagrammatic representation of mechanism of sodium ion battery.
The exact energy density of SIBs is 18% inferior to LIBs. The anode constituents, graphite for LIBs do not work for sodium ion batteries with a low capacity [6]. It can be improved by solvent co-intercalation, but that method brings a set of challenges. Numerous efforts have been made to discover anodes for sodium ion batteries [7]. Sodium reacts with an extensive range of transition metal oxides. Several review articles have been published related to sodium ion batteries anode. Carbon-based and alloy included anodes for sodium ion batteries are the current topic for researchers. Thus, this chapter highlights the high recital hard carbon anodes and sodium ion-storing mechanism in hard carbon. The alloying type anodes such as phosphorous to prove some of the maxima stated capacities are discussed. Lastly, metal oxide, sulfide, and organic based anodes are explored [8].

2. Sodium ion batteries anode materials

In the growth of sodium ion batteries, the anode material is expended with hard carbon. But their uses were restricted due to difficulties. Transition (d-block) metal oxides were used as an anode in LIBs because of the complexity of carbon resources. It was strained to sodium ion batteries as a substitute for carbon material [9]. Higher specific capacity is the factor in this substitution. So more considerable volume extension or reduction related to alkaline ion addition or removal to create remarkable loss to electrodes, which primary damage of electrical interaction with fast capacity is failing. Since these factors that delay metal-based anode considers the expansion of components that can be alloyed with sodium called alloy materials. For example, in the periodic table group IVA and VA such as Ge, Sn, Sb, P, etc. give alloy with sodium to make NaGe, Na\textsubscript{3.75}Sn, Na\textsubscript{3}Sb, and Na\textsubscript{3}P, respectively [10-14]. Such type of alloying reaction was capable of reaching tremendous capabilities to a great extent, but difficulties were escorted with a massive increase in the volume of the host materials. It occurs because of the nonstop reduction of the electrode materials. It was studied by designing the novel nanostructures, defending the volume variation of the alloy anodes through sodium extension and reduction reaction. During the analysis of sodium ion battery anodes, carbon-based materials remain inspiring like lithium ion battery due to excellent conductivity and more abundance on earth [15].

3. Hard carbon

Experimentally and theoretically, various carbon-based resources were examined as an electrode material for energy storing. Cyclic efficiency, lifetime, and power of energy saving devices, supercapacitors, and lithium-ion batteries enhanced to improve specific
capacity. In the 1980s, the electrochemical addition of sodium ion in carbon materials began initially [16] because of the arrangement of chemical and physical properties like price efficiency, high abundance, and high surface area. Hence, researchers began work on carbon-based electrode resources to recover the enactment of energy storing devices electrodes.

Some studies have been reported for the comparison of the functioning of carbon in Na and Li batteries. While the additional outcomes may construe for SIBs since the intercalation mechanism has appeared very close to that of lithium. The significant work has been reported for the electrochemical, microstructural properties of automated crushing on graphitized petroleum coke for SIBs and LIBs [17]. The storage capacity of sodium rises with elongated ball milling time. With three black carbon samples, the electrochemical reaction was reported for Na and Li. The lower nature of sodium for the productivity of the passivating sheet in sodium unit reduces irreversible capacity. A cost of a reversible function in carbon black SIBs was reported around 201 mAh/g [18]. This higher reversible capability was initiate to vary on the external surface of carbon black. This comparison was studied at different pyrolyzing temperatures. In hard carbon precursor, a high reversible capacity was observed around 210 mAh/g [19]. The structure of hard carbon easily allows sodium insertion with potential below 0.1V. PAN-based carbon fibers provided different carbon host samples. Solid coals possess excessive unalterable capabilities, almost 310 mAh/g. A saccharose coke carried out an extreme ability above 910 mAh/g and decreased with 202 mAh/g as a sample, which gives result in an unalterable capacity of 710 mAh/g [20]. It shows the high reversibility loss of hard carbons. This loss depends on a few factors like particle size, additives, electrolytes, and porosity capacities. The short opening volume and surface region of hard carbon substantial was studied to provide high reversible capacities around 345 mAh/g. Size of the stiff carbon offers good impression on capability [21].

4. **Carbon nanostructures**

In the fact of attainments, a growth of carbon anodes for sodium ion batteries (different means like developed methods, the calculation of electrolytes, etc.), the capability was barely cited. The energy storage devices with a suitable electrode have an attractive rate capability. The details of the size of the hard carbons as SIBs anodes are not sufficient to mention the rate abilities of the hard carbons [22]. Nano-sized materials are useful for the accomplishment of extreme rate capabilities, morphology, and size. They open opportunities to increase mass transportation and storage to recover the electrochemical performance of sodium. To regulate the morphology and size of electrode materials, the
synthesis of nanomaterials was a hopeful design. The development of electrochemical properties of electrode materials depends on different types of nanostructures [23].

Subsequently, the unique structure can increase the mass transference by proposing an excellent surface area and a small diffusion distance. And nanostructure design is a smart area of interest in LIBs. But nanostructure engineering has been prolonged toward sodium ion batteries and provides countless achievement. For the SIBs anodes, different types of nanostructured materials like hollow nanostructure, nanofibers, nanobubbles, nanosheets, and mesoporous carbon have been studied [24-26]. The rateability for hollow carbon nanospheres was established. The hollow carbon nanospheres distribute a discharge capacity of 100 mAh/g at the existing thickness of 2 A/g, which is 80% more than carbon spheres. The discharge ability of 120 mAh/g at density 100 A/g was also reported for carbon nanobubbles [27]. It was demonstrated by receiving the distinctive structure of peat moss leaves. A subsequent constituent is comprised of a 3D macroporous consistent network of carbon nanosheets. It provides an alterable capability of 299 mAh/g and 855 capability retention at 60 mAh/g over 211 cycles [28]. With 510 mA/g, the capability was observed 204 mAh/g. It has been studied that materials maintain a resonating nanowire arrangement with a plane surface which increases the particular area and connection area with electrolyte. The hollow carbon nanowire structure keeps the capability of 216 mAh/g after 330 rotations [29]. Retention was 82% because of the resonating structures. It gives a defending region for the discharge of mechanical stress by sodium ion addition or removal. The electrode was observed to the delivered alterable capacity of 150 mAh/g at density 500 mA/g [30]. The hollow carbon nanowire structure provides an increased rate of proficiency and long cycle immovability. This insertion property is accredited to small transmission space in resonating carbon nanowires, and it is interlaying space among the graphite areas. It provides excellent cycling immovability with rate ability of carbon nanomaterials on solid carbons.

5. Carbon and alloy-based material composites

Electrode resources provide great capability and extensive steering life, but still, there is a need for excellent rate capability. It is hard to get all the purposes to a single-phase substantial, and dimensions to decrease simultaneously. The combination of separate nanostructures and perhaps synergistic effect has attracted the attention for energy storage devices as an electrode material [31]. Recently it has been studied in sodium ion batteries that metal oxides, metal Sulfides, elements of group IVA, VA, VIA (alloy-based constituents) and certain SIBs cathodes react with carbon to form compounds. Several alloy substantial components like Sn, Sb, Ge, Se, and P can alloy with sodium and produce the alloy phase like Na₃.₇₅Sn (857 mAh/g), Na₃Sb (670 mAh/g), Na₂Se (688
mAh/g), and Na₃P (2660 mAh/g) [32-37]. These materials provide appropriate implanting potential with high hypothetical specific capacities. So, the significant volume change of these materials delays their utility to SIBs. The development of composite alloys has been the only solution. Intermetallic or alloyed materials are being combined selenium with mesoporous carbon to give energy storage devices. After 380 rotations, the discharge capacity of 480 mAh/g to an ability of 340 mAh/g was delivered [38]. The selenium with mesoporous carbon showed a good result with capacity retention of about 35%. Some researchers showed the effect with phosphorous/carbon (P/C) composite materials for maximum Na ion-storing capability to 1765 mAh/g after 100 cycles [39]. The amorphous red p/c compound had released capability around 2400 mAh/g. With stable cycle performance, the high reversible capacity was recorded around 1880 mAh/g in some studies. The composites give excellent rate capabilities 1530 mAh/g at density 2.85 A/g [40]. Such rate capabilities are rarely present for some alloyed carbon complexes. The electrochemical implementation was accredited for carbon accumulation, which can play a role to increase the electrical conductivity of the conductor and provide support to expand the stability of the electrode. The elements of group IVA and VA like Sn/carbon and Sb/carbon compounds attract the attention towards SIB anode substantial [41]. The liberation capability of 547 mAh/g was studied for the composite of Sn and graphite. After the 100 cycles, there was less than 1% reduction in size. Sb nanomaterials are also reported with an ability of 420 mAh/g at the degree of 101 mA/g [42]. These materials are uniformly encapsulated in carbon fibers. After the 310 cycles, the capacity was 350 mAh/g. Such property provides the conductive way and intermediate carrier for the active discharge of mechanical pressure due to the addition or removal of Na ion. It avoids the aggregation of Sb nanoparticles [43].

Combinations of alloy constituents with further electrodes have been described for SIB anodes, which were named bimetallic. During sequential electrochemical reactions, the parallel electrode rich phase in the complex was designed, and it can serve to support each other. The composite SnSeSnSeC with sodium storage provides the capacity 660 mAh/g at 22 mA/g, and afterward, long cycling, the capability will retain 400 mAh/g [44]. During electrochemical cycles, the storage functioning of SnSeSnSeC compound can be connected to the self-supporting carrier. The sodium alloying reactions with SnSb/C was demonstrated as a connection for NIBs [45]. The charge or discharge behavior was studied due to the development and presence of Sn and Sb-rich stages during consecutive sodiation or desodiation. It provides the capability of around 720 mAh/g at 110 mA/g, which retain 85% of original capability afterward, 55 rotations of sodium ion storage [46]. The alloy composition optimization is the factor for the notable functioning of the SnSb/C electrode. The alloy phase basic change occurs during the results and carbon
accumulation in the electrode. A multicomponent alloy reaction provides the track for the progress of extraordinary capability anode constituents for SIBs [47].

6. Alloying reactions-based anode materials

6.1 P-based materials

Phosphorous has the maximum theoretical capability of 2500 mAh/g and 0.4 V redox potential. Phosphorous is classified into three allotropes due to crystalline structure:

1. White phosphorous
2. Red phosphorous
3. Black phosphorous

White phosphorus contains more harmfulness and reactivity with air, so it is unsuitable to use as an anode material. Red phosphorous is used as an anode because of immovability. It has abundant properties. Black phosphorous has been studied because of extraordinary electrical conductivity (290 S/m) and encrusted arrangement [48]. The tool [49] of sodiation with red and black phosphorous is P/Na\textsubscript{x}P/Na\textsubscript{3}P (0 < x < 3).

6.1.1 Red phosphorous

Red phosphorous contain chain-like structure, which is a byproduct of P\textsubscript{4} in which one P-P bond is wrecked, and extra bond is created with the neighbor tetrahedron. Due to the high hypothetical capacity and environmentally friendly nature make it more useable as anode substantial for Na ion batteries. So, exploitation of red P for sodium ion batteries is significantly delayed by great capacity variations and electrical conductivity (9\textsuperscript{14} S cm\textsuperscript{-1}) [50-55]. In the reduction of active materials, big volumes causing the attention of the shell of active materials by thick SEI layer. Every part of these subjects has important influence like capability and cyclability on electrochemical performance. Different tactics have been observed to report these contests with building carbonaceous materials and decrease the element extend to the nanometer balance. Combination of red phosphorous with carbon-based constituents raise the electrical conductivity and reduce automated pressures in sodium ion approval or issue procedure. Different kinds of carbon constituents were verified like carbon nanotube, carbon black and graphene, etc. [56].

With uniform distribution between single-layer carbon nanotubes, the red phosphorous based electrode gives result in loose rate proficiency (~310 mAh/g at 210 mA/g) after 300 cycles the capability retain with 0.01% average [57] — a fitted interaction of active substances with electrolyte promoted by a huge quantity of interconnected and continuous pores. Unstructured red phosphorous in regular passages of mesoporous
carbon medium CMK-3 (as P @ CMK-3) was confined in some studies [58]. The surface area for CMK-and P @ CMK-3 was observed 1138 and 16.02 m²g⁻¹ with pore volume 1.51 and 0.07 cm³g⁻¹, respectively [59]. Due to the advantage of surface area, the rate proficiency with steady strength of P @ CMK-3 accomplished for the quantity of red phosphorous [60].

6.1.2 Black phosphorous

Black is maximum thermodynamically stable and layered structure among all three allotropes of phosphorous. It contains a similar structure like graphite. The interlayer space can be extended up to 4.18 Å in the case of black P to host Na ion [61]. By van der Waals forces, the layers are held together. Black P contains higher electrical conductivity than red P. All these things show that black P may be a good anode substantial for Na ion batteries. The solution process comprises of two phases: the intercalation development monitored by alloy kind results. Both intercalation and alloy type reaction is escorted by an alteration of the laminar structure [62]. There is no alteration in the black P crystal structure with no P-P bond breakage. The amorphous phase will be formed by the cleavage of the P-P bond. So, it is important in the diffusion of the sodium ion to not segment change from the covered construction to the amorphous phase.

Phosphorous/graphene with inserted construction. The black phosphorous/multi carbon nanotubes make mix constituents. This hybrid material shows the particular capability of 2400 mAh/g at solidity 0.06 A/g [63]. Black phosphorous/multi-walled carbon nanotubes complexes are synthesized by extraordinary energy sphere with specific capacity of 1600 mAh/g after 110 rotations at 1.2 A/g density, and changeable capability was found 1010 mAh/g at 4 A/g density [64]. The application of carbon materials is here as automated strength with electrical artery. Various procedures for carbon incorporated composites provide information for black P such as anode for Na ion batteries. Black P like anode materials with Na ion batteries, should report the matter for high value, few layers phosphorene, large area, with a minor number of defects [65]. The most commonly used methods are automatic exfoliation and liquid segment peeling. The scotch tape technique was reported for a few layers’ phosphorene, but the chemical residue is unavoidable in the scotch tape method. A long time ultrasonic exfoliated procedure is required for liquid-phase exfoliation in organic diluters. It is needed to discover an actual manner for the research of huge area phosphorene.
7. **Conversion based material**

7.1 **Metal oxides**

Due to polyelectronic reactivity, metal oxides contain high reversible capacity. The reaction mechanism is divided into dual types: M is here a non-electrochemical dynamic component such as Fe, Co, Ni, and Cu. M is also active electrochemical components such as Sn and Sb. Metal constituent after the reaction with sodium oxide gives metal oxide. Hypothetically, metal oxide with transformation reactions has more particular capability than practical value due to poor conductivity, and it contains maximum volume expansion. The coulombic capacity is below 75% [66]. It can be accredited to the dilapidation of electrolytes, and it forms the compact electrolyte interphase level. To improve an electrochemical routine, nano crystallized, and nanostructured electrode material is the general pathway to restrict the volume change. Sn based oxides among various metallic oxides attract consideration due to maximum reversible capability, low cost, and abundance, and it is based on conversion reactions. In the alloying process, large volume change occurs in SnO$_2$, which is Sn to Na$_{15}$Sn$_4$ and accumulation of Sn Particles during the method of cycling. Several modifications in SnO$_2$ have been introducing to solve this issue with the use of new morphology and the introduction of carbon materials. Carbon cloth and graphene draped SnO$_2$ has been arranged to improve the electrochemical recital. These materials show the particular reversible capability of 500 mAh/g at 0.14 A/g with 440 mAh/g at 0.05 A/g, respectively [67-70]. The comparison between pristine SnO$_2$, a complex of SnO$_2$ and carbon resources, particularly graphene, have exposed the electrochemical performance. It could be accredited the graphene qualities of electrical behavior, biochemical constancy with the maximum particular external zone. It was studied that the SnO$_2$/N-doped graphene complex shows better performance than SnO$_2$/bare graphene compounds. The investigation shows that the presence of electroactive site caused by N-doping is the chief motive. It increases the particular alterable capability from the increase in electron transmission proficiency. The amorphous SnO$_2$ showed more electrochemical implementation compared to crystal-like SnO$_2$ because of the change in volume from an amorphous state to crystalline oxide. To analysis the effect of SnO$_2$ crystalline on its electrochemical implementation, the experiments were designed. The alterable capacity was observed 370 mAh/g at the existing solidity of 55 mA/g over 110 rotations, but SnO$_2$ crystal-like provides one-third of the capacity. It is supplied by amorphous SnO$_2$ under equal circumstances [71, 72].

Due to the enhanced sodium ion distribution constant and the durable contact among amorphous SnO$_2$ with graphene, the electrochemical implementation of amorphous SnO$_2$
usually profited from the fundamental isotropic properties. Small amorphous SnO₂ particles give well release for volume strains [73].

7.2 Metal sulfides

These metallic sulfides are separated into two classes of configurations: coated and no coated structures. Most metallic sulfides like SnS₂, MoS₂, WS₂, and TiS₂ contain a characteristic layered structure. The atoms are firmly engaged with covalent bond where films were associated by frail van der Waals bonds. Through the process of adsorption, intercalation, and interruption without the damage of structure, some polar molecules can enter between the layers [74-79]. These kinds of materials display greater electrochemical implementation. A layered structure MoS₂ used as an anode for Na ion batteries. MoS₂ undergo two steps reactions: sodium ion intercalation in which two-phase effect exists from the trigonal to octahedral prismatic. During the process of intercalation, sodium ion 1.4 per formula was intercalated in MoS₂ [80-82].

WS₂ is a developing anode solid for Na ion batteries. It shows the alterable capability to 330 mAh/g on the concentration of 201 mA/g over 190 cycles. The diameter of the WS₂ nanowire is around 22 nm and can perform the long cycle life in the potential window between 0.6 to 4V. It is the lasting cycle life and firm routine for WS₂ in morphology modification. Particular non-layered metal sulfide was established to have motivating sodiation/desodiation qualities like FeS₂, Sb₂S₃, NiS₂, and Co₉S₈ [83-86].

This has been stiff to adjust the interlayer detachment of non-layered sulfides. It is limited by the essential kinds of stuff in comparison of coated metallic sulfides. Non-coated metallic sulfides display poorer rotation lifecycle activity. To improve the cycle performance of sulfides, modified electrolyte composition like NaSO₃CF₃ was added for solvent into the ether electrolyte. Conspicuously, it has been observed that below voltage 0.8V, FeS₂ would undergo from a high capacity degeneration and low cycling implementation. Well, cycling performance and advanced energy density would be above 0.8 V [87-90].

8. Graphene

Graphene-like carbonaceous material appeared as another energy storing substantial with possessions like small mass, chemically inactive, etc. Graphene contains big sp² attached microscopic carbon monolayer with numerous benefits such as exceptional optical, electrical, motorized, etc. qualities. It also contains favorable features of the huge external zone and conductivity for adsorption of ion [91-93]. It has been studied to make a complex electrode with graphene constituents for energy storing devices. In some papers,
graphene has been described as anode for Na ion batteries. The oxide of Graphene (RGO) was discovered the first time like anode with a maximum capability of 140 mAh/g at 40 mA/g over 1000 cycles. The rate proficiency was also obtained, 95 mAh/g at a great amount of 1010 mA/g [94].

3D anode from nitrogen-doped graphene was discovered as high-performance Na ion battery. The nitrogen doped graphene shows the particular excessive capability of 2900 mAh/g paralleled to decrease graphene and simple nitrogen-based graphene towards a capability of beyond 2100 mAh/g at 0.2C [95]. The implementation of the nitrogen-doped graphene was observed at the 3D mesoporous structure. It consists of a huge external zone and distended matrix arrangement among sheets of the graphene. It has been defected by N-doping. It simplified a dispersion of Na ions and increased the storing of Na ions. It also minimizes the consequence of bulk expansions throughout the charge/discharge process. So, this was established that N-doping displays an encouraging result on carbon-based constituents. Recent work has been employed on graphene composite as anode for SIBs [96-102].

Metal oxides such as Fe₂O₃ can be uniformly attached on to graphene nanosheet (Fe₂O₃ @GNS). The capacity of Fe₂O₃ @GNS was observed 410 mAh/g over 220 cycles. The graphene functioned here as a conductive improver without any added reagents [103].

**Conclusion and challenges**

The utility of carbon-based materials undergoes enormous development among the variable SIB anode materials. Recently several studies have been dedicated to searching for a different carbon electrode, and review for these signs of progress have been concise in this review. It was observed that important developments had been done in making of carbon materials. Solid carbon is the furthermore extensively used carbon basis as sodium ion battery anodes and showed the electrochemical performance of SIBs. Various nanostructure materials have been evaluated. The composition of alloy constituents along with carbon, is graphene. It has been discussed & summarized. This complex shows well electrochemical implementation than pristine, consistent element and complexes. Constructed towards development was accomplished by the cathode constituents, carbon-based constituents with metal sulfides and cathode constituents were discussed in brief.

There are various challenges in the growth of SIBs for practical application. Firstly, the promising challenge is the additives into the electrolyte of sodium ion battery [104]. It was described that additives might progress the Na storing implementation of carbon-related constituents with complexes. Occasionally, additives with low coulombic efficiency could encourage the expansion of the SEI layer. Research should focus on the
aim of why they encourage sheet creation. The additive was added in the electrolyte, selecting a suitable additive is another task. So, the extra investigation should be carried out. Another task is that if additive was not added in the electrolyte how to accomplish sodium ion battery anodes with Na storing implementation.

The second challenge is the rateability of hard carbon should more enhance [105]. Numerous statements for stiff carbon are established. The rateability is very small related to carbonize based carbon. Furthermost methods have been used to improve the rateability of solid carbon; it is the calculation of additives. To some extent, the process can recover the rate ability.

With all these factors, carbon will donate to further growth of sodium ion battery as different generations of the battery. Extraordinary improvement in SIBs should be considered so that the lithium-ion battery can be substituted.

The third challenge is the rate capability of another carbon-based electrode, and it embraces important challenges. Carbon materials in nanostructure need to be produced more. Recently, there are a lot of developments regarding the synthesis and manufacturing of carbon substantial nanostructure but still need to develop further.

Moreover, the process accepted in manufacturing the complexes of carbon-related constituents with alloy ingredients requires further development. The reports regarding the collaborating of dynamic carbon with further constituents increase quickly.

Sodium ion battery cathode constituents have fascinated great consideration in the last few years, but newly they were less measured. This is because of the little capability and modest rate capabilities of cathode materials. Such a problem can be concentrated by carbon crust on the external of cathode materials or graphene. The coated layers of carbonaceous were discovered to assist as a conductive system path for cathode constituents in sodium ion battery. There are still a lot of research areas requiring advancement. Much attention is required on carbon related materials in terminologies of storing capability improvement.

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