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NANOPARTICLES (NPS) LEVERAGE IN LITHIUM-ION BATTERIES PERFORMANCE

Raid Salih Jawad^{1,*}, Miqdam T Chaichan² and Jaafer A Kadhem²

¹Energy and Renewable Energies Center, University of Technology, Baghdad, Iraq.

²Biomedical Department, University of Technology, Baghdad, Iraq.

Email: dr99990@yahoo.in

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Abstract

The effects of nanomaterials on lithium-ion batteries are studied in this paper, by refer what the scientists do by these NS materials which used directly in the anode and cathode of these rechargeable cells, and it is clear that these materials developed and increased the efficiency of charging, (energy storage) and conversion as well as the life of this batteries.

Keywords: Nanostructured materials, Lithium-Ion Batteries, energy storage.

I. Introduction

Rechargeable including lithium-ion battery technology began almost at the beginning of 1990s. They are intended power for portable electronic devices such as mobile, watches, laptops secure [1], currently these types of rechargeable is growing because use of in energy storage of smart systems & in the sources of renewable energy [2], the ions of lithium will moving from positive electrode to negative electrode during discharging, & reversed during charging, the electric currents will moves during outer circuit like diodes, graphite which are the primary material for rechargeable batteries (Figure.1).

II. Nanoparticles NPs Technology role in Li-ion Batteries

Nanoscience is the science of time, which adopted it hopes for the researchers in terms of development and secure the requirements of the population also it enters in all disciplines and fields, one of these fields Li-ion rechargeable batteries.

III. Effect of NPs in Anode

The anode of these batteries was the Lithium metal, but because of its reactive to the air and water and low melting point, it's replaced with other stable materials like carbon [3] which used as a "slurry" covered layer, also its found

that essential change in volume in these alloys during intercalation / de intercalation leads to loss of electrical contact and specific capacity during cyclic loading also highly attention attracted because of using oxide materials like, SnO₂ and PbO as anodes for Li-ion batteries [3] the anodes of these batteries is made from graphite in which one unit (six carbon atoms for graphite) can store one or less lithium ion, which lead to a limited theoretical capacity of 372 mAh/g also to circumvent the low power density of graphite.

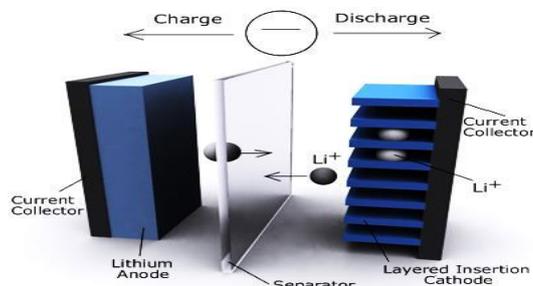


Fig. 1 Lithium-ion battery diagram

Theoretically, one atom from each lithium and tin can react and form Li_{4.4}Sn alloy, the Tin anodes capacity reaching of 993 mAh/g which are three times higher than graphite that's why attracted much attention. However, insertion/ extraction large amount of Li into/from Sn lead to large change in volume (about 300%), which make squelch the tiny particles and loss of contact with current collector, which minimize the electrochemical performance [4]. Rechargeable batteries are catchy power-storage devices having low power density because of the high polarization at high charge-discharge levels, this polarization are occurred by slow spread of Li in the active material and increases in the impedance of the electrolyte because of the increases in charging-discharging percentage [5].

Ye et al. [1] generated a novel method for elaboration Si NPs interjection in graphene sheets, this method include two processes (a self-assembly technique and a thermal process).The presences of non-covalent linkages deny the assemblage of Si NPs and ataraxic that Si NPs are uniformly inserted into graphene layers. The mesoporous structure of the Si/G composite permit for the free extension and constriction of Si NPs during lithiation and delithiation without mechanical limitation or tension being mandatory. At 200 mA g⁻¹, the Si/G electrodes transmit a capacity of 803 mAh g⁻¹ in 100 cycles and <0.25% capacity lessening per cycle before 150 cycles. The anode still signs a reversible capacity of 748 mAhg⁻¹ in the 40th cycle at a rate of 1600mA g⁻¹ see figure.2.

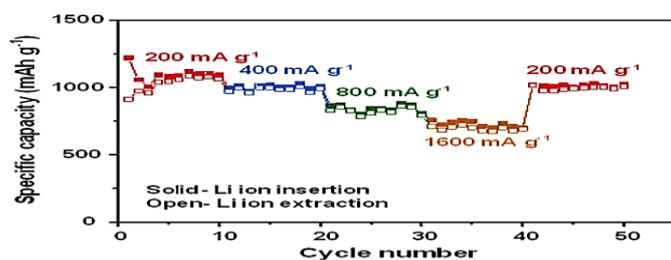


Fig. 2. Si NPs/G 3/1 composite rate ability.

(Zhang et al. [6] synthesized gel polymer electrolytes (GPE) in the form of membranes by trapping ((CH₂O) 2CO) and (CH₃C₂H₃O₂CO) in a composite of (poly (1, 1-difluoroethylene)) and N-ethylpyrrolidone (1-Methyl-2-pyrrolidone). Membranes with micro-pores synthesized by applying phase-transfer method, which means higher ionic conductivity. The suggest membrane is to be adjusted moreover to have higher capacity, stronger mechanical properties, also lower internal resistance.

NPs - polymer composites Membranes made by a doped polymer with (Au- NPs), these membrane contains tunable higher porosity and conductivity, and higher ion mobility which lead to improve the electrical conductivity. Membranes resistance checked by four-terminal sensing. The performance of rechargeable Li-ion batteries improved by advanced GPEs because it can be fabricated in different shapes and geometries, GPEs significantly superior than to solid - liquid electrolytes. The including of lithiation – delithiation kinetics of (positive electrode) anodes to the carbon-coated ZnFe₂O₄ NPs investigated by Martinez-Julian et al. [7] who confirmed that, is happen with other transmutation electrodes, the processes of lithiation of ZnFe₂O₄ NPs is a multi - step with the Participation of median Li-Zn-Fe-O (phase) or status as isotopes for making amorphous Li₂O, also they mentioned that the lithiation reactions shows a long delay which make limitation to the electrode charging, which not regarding to the diffusion mechanisms. Figure (2) shows main processes of the carbon coated ZnFe₂O₄-C nanoparticle. Delithiation sweep and make of ZnO and Fe₂O₃ mostly same.



Fig. 2 lithiation–delithiation main reactions, which occurs in zinc ferrite NPs (ZnxFe_{3-x}O₄).

As an anode, a novel Sn@C/ graphene nano material synthesized by Liang et al. [8]. The particular structures of the graphene ematrix can accommodate the volume change during the charge-discharge process of the cells and ma the lithium ion and electrolyte transit inside the electrodes, so that the Sn@C/ graphene nano-composite owning a large reversible ability excellent cycle execution (the capacity fixed(662m Ahg₋₁ at 100 mAg₋₁ after 100 cycles), this material delivers no wilt but increasing capacity even after the large current cycles) and high rate capability (417mAhg₋₁ at 1000 mAg₋₁), the meaning of that are high density of energy , more performance, and ultra-long life. Both of thermal process and self-assembly technique used by Ye et al. [1] to developed a novel method to

synthesized Si NPs intercalated in graphene sheets. The presence of noncovalent linkages prevents the aggregation of Si nanoparticles and insurance that Si NPs are uniformly inserted into graphene layers. The mesoporous structure of the Si/G composite allows for the free expansion and contraction of Si NPs during lithiation and delithiation without mechanical hindrance or tension being imposed. Comparison bare Si NPs and Si/RGO proved that this novel method improved cycling and rate performance. At 200mA g⁻¹ current density, capacity of Si/G electrodes delivered of 803 mAh g⁻¹ in 100 cycles and <0.25% capacity before 150 cycles decreasing per cycle. At a rate of 1600mA g⁻¹ the electrode still exhibited a reversible capacity of 748 mAh g⁻¹ in the 40th cycle.

Kanjwal et al. [9] synthesized a polymeric nanofibers TiO₂ containing solid NPs ZnO by isolation of colloidal solution consisting of titanium isopropoxide / poly(vinyl acetate) zinc NPs than at 600 °C calcination of the obtained electrospun nanofiber mats in air has been revealed to produce TiO₂ nanofibers include ZnO NPs, the nanostructure anode showed a high rate capacity of 1232 mAhg⁻¹.as an anode, Lee et al. [10] prepared SnO₂/ graphene nanocomposites from graphite oxide (GTO), and they conform that SnO₂/rGTO was superior to SnO₂/rGO for both reversible charge – discharge (C–D) cycle ability & capacity.

Kim et al. [11] studied the oxidation of anode material by using (13.56 MHz) inductively coupled plasma, so that they synthesized Non-stoichiometric silicon oxide NPs, oxygen concentration must be less than 18 % . By using electro-spraying Valvo et al. [12] precipitate Sn (II) chloride by NaBH₄. The Sn-based powders tested as negative electrodes, they be shore that the existence of nanostructures has an importance influence on the behavior cycling of the materials, that maintained capacity about 300mAhg⁻¹ through 100 cycles from 0.050V- 1.20 V as in figure 3.

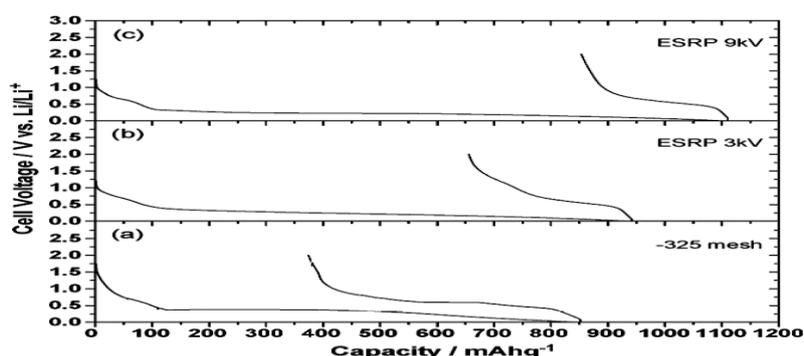


Fig.3 Voltage features for the first cycle of discharge–charge at 113mA g⁻¹

between 0.0 and 2.0 V. (a) Commercial powders,

(b) powders synthesized at 3 kV and (c) 9 kV.

Simple two-step method used by Zhu et al. [13] to fabricate RG-O platelet / Fe₂O₃ NPs composite as an anode material with high-performance. the composite are (1693 and 1227 mAh/g the 1st charge & discharge capacities),

respectively, at a current density of 100 mAh/g. a fine capacity retention after the 50th discharge with 1027 mAh/g, also ~ 800 mAh/g of discharge capacity even at 800 mA/g. The total specific capacity of the sum of pure NPs Fe₂O₃ and, RG-O is smaller than RG-O/Fe₂O₃ which means a positive synergistic effect of RG-O and Fe₂O₃ on the improvement of electrochemical performance.

Wang et al. [14] studied the structural developments of Sn NPs during lithiation/ delithiation cycling with in situ TEM, also reported that Sn NPs in the size range of 79–526 nm undergo a two-step lithiation, resulting in c-Li₂₂Sn₅ with a total volume expansion of about 258%. There is no breakage or cracking occurs after full lithiation of Sn NPs, in contrast with the lithiation-induced cracking in micron-sized Sn particles. In addition, lithiation/sodiation can lead to the fusion of small Sn NPs. Delithiation/ desodiation causes the crushing of the large Sn NPs, which can be attributed to the high de-alloying rate that leads to a large concentration gradient of lithium/sodium and thus a high stress/strain in the de-alloyed Sn region. Chen et al. [15] synthesis ultrafine S NPs with (10, and 20) nm diameter by the precipitation technique and throw a membrane, these S NPs coated by poly (3, 4-ethylenedioxythiophene) (PEDOT) to synthesis S/PEDOT core/shell NPs. These S NPs with ultra-small size increase the electrical conduction and sulfur utilization. The encapsulation PEDOT shell put a limits on each of (polysulfide's diffusion, mitigate self-discharging, the shuttle effect, and then enhances the cycling stability. The S/PEDOT core/shell NPs shows initial and stable discharge capacity of 1117 mAh g 21930 mAh g 21 after 50 cycles respectively, see figure 6.

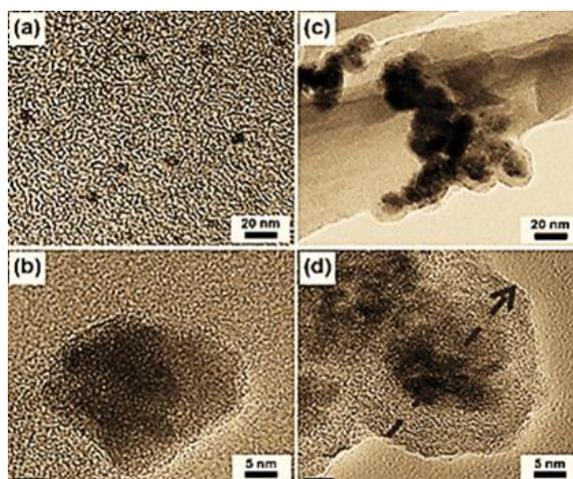


Figure .6 Structural characterizations of S NPs. (a) and (b) TEM images of pure S NPs. (c) and (d) TEM images of S/PEDOT core/shell NPs.

ability owing to its NPs storage sites, Fe₃O₄, less than 5 nm, the benefit from graphene nanosheets are: - 1. Increase the performance of the composite by enhancing forming a flexible network 2. Rising the electrical conductivity, 3. Increase the Li storage sites. By the same way, they form composites for Li- ion anode Fe₃O₄ NPs which decorated onto MoS₂ nanosheets. due to high reversible capacity which provided by MoS₂ nanosheets and excellent

performance offered by Fe₃O₄ NPs, superior cyclic and rate performances are achieved by Fe₃O₄/MoS₂ anode during the subsequent electrochemical tests, at current densities of (2000, 10000 mA g⁻¹), respectively, delivering 1033 and 224 mAh g⁻¹. Flames spray pyrolysis used by Ng et al. [17] and successfully synthesized crystalline, spherical-like V₂O₅ NPs. With the increase of counterpart concentration and injection proportion, higher V₂O₅ crystal purity (reach to 98 wt %) and bigger particles with lower surface area (~32m²g⁻¹) were made, also they found that the V₂O₅ NPs appeared an amended cycling behavior (for discharging) with the increase of lower cut-off potential from (1.5V - 2.5 V) vs Li/Li⁺. Flame-made V₂O₅ NPs with the minimal specific superficies area and the highest purity present superior cyclability during the cycled between 2.5 and 4.0 V vs. Li/Li⁺. By using direct current (DC) arc-discharge method [18] fabricate Sn-carbon nanotube Nano capsules (Sn-CNT NCs). The Sn is filled partially into multi-walled CNTs, as anode materials ; Sn NPs provide: - 1.great storage capacity, 2. CNTs confine 3. Staffing the volume expansion of Sn, 4. Maintain the conductive network 5. Participate their own capacity. Hung [19] exhibited adding metal NPs to carbon effects that increased its capacity without minimizing the period life of the carbon as an electrode. The experimental cell having of C (Pd)/0.5M Li -50/50 (vol. %) EC and DMC/Li, where C (Pd) was graphitized carbon fibers containing Pd NPs, this amendment was not seen if the Pd NPs were replaced by aluminum, may be because during storage the Al NPs were oxidized in air. Lin et al. [20] synthesized Sn_{0.9}Cu_{0.1} NPs by a surfactant-assisted wet chemistry method as an anode material for rechargeable sodium ion batteries. The Sn_{0.9}Cu_{0.1}NPs based electrodes present a stabilized capacity of more than 420 mA h g⁻¹ at 0.2 C rate, detained 97% of their maximum bid capacity after 100 cycles of sodium enrollment/ deinsertion see Fig. 4. Their activity is much superior to electrodes made with either Sn NPs or Sn micro particles.

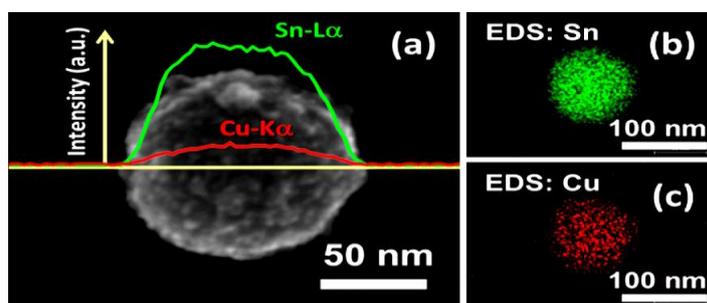


Fig. 4 a) SEM image of a solo Sn_{0.9}Cu_{0.1} particle with EDS line scan toward the particle; EDS mapping for element (b)

V. Effects of NPs in cathode

The frequent slurries for (negative electrode) cathodes are Mn, Co, and iron phosphate particles, LiMnO₂ and, LiCoO₂ are the common materials used as cathode coatings, nevertheless, LiFePO₄ particles according to the other materials has more safety, extend cycles, and operating life also less expensive , and high charge intake [21] the

cathode materials of Li-ion batteries used a lot of compounds and alloys like N-Sn, Cu-Sn, Ni-Sn, Sn- Zr-Ag , Si- Sn and Li-based alloys, but the theoretical gravimetric capacity of carbon is half than these materials, Ulvestad et al. [22] got of transformation of 3-dimensional strain by a single NPs, this means a promising high voltage cathode material, $\text{LiNi}_{0.5}\text{Mn}_{1.5}\text{O}_4$, under in situ conditions. The 3-dimensional strain under particle is independent of cell voltage after disconnection; this means that the particle didn't have the ability to redistribute lithium within its volume or to its neighbors.

Yuan et al. [23] utilize a precipitation polymerization to prepare a sequence of polyvinylimidazolium-based NPs as binders in cathodes. according to the commercial standard poly-(vinylidene fluoride), This “little change” of a polymer in otherwise un change devices provide a higher specific capacity and long-date electrochemical Sturdiness at least for 1000 charge–discharge cycles. Metastable amorphous Cr–V–O NPs synthesized by Sheng et al. [24] and evaluated as cathode material. The enhanced electrochemical rendering result from the good diffusion aqueduct for Li^+ , creating from the particular metastable amorphous state with a proven amount of chemical constraint, there results mentioned that metastable amorphous Cr–V–O is a hopeful material for Li storage. Also by a novel method Schuster et al. [25] prepared a spherical OMC NPs of 300 nm in diameter, which can scattered in water by sonification to produce a stable colloidal suspensions. By silica precursor solution PMMA spheres with opal structure was casted, to make silica inverse opal, which used as template for a triconstituent precursor solution containing resol as the carbon precursor, tetraethylortho silicate (TEOS) as the silica precursor, and the block copolymer Pluronic F127 as a structure- directing agent. Orvananos et al. [26] test a half cell consisting of two particles. The interactions kinetics between NPs is studied particles undergo interparticle and intraparticle phase separation, and they found that both interactions phases are similar. In both cases, sequential transformation occurs at low and high current. From Table .1 we can imagine the concluded data about each researcher.

Table 1. Conclusion data.

Ref.	Type of electrode	Material	Type of method
ye	anode	Si NPs/graphene sheets	Self-assembly technique and a thermal process.
torabi	anode	PbO NPs	Electrochemical evaluation
Xu	anode	Nano-Sn/ composites	aerosol spray pyrolysis technique
zhang	anode	Au NPs	Advanced gel polymer electrolytes (GPEs).
Liang	anode	a novel (Sn@C/graphene)	Hydrothermal synthesis and subsequent annealing.
Orvananos	cathode	LiFePO_4 NPs	React through interparticle phase

				separation, intraparticle phase separation, or a combination of both
A. kanjwal	anode	ZnO-doped nanofibers	TiO ₂	Electrospinning
Lee	anode	Graphite oxide and SnO ₂ NPs	(GTO),	Hummer's method
Kim	anode	silicon oxide		Inductively coupled plasma
Valvo	cathode	Sn NPs		Electro-spraying
Zhu	anode	oxide/Fe ₂ O ₃		Homogeneous precipitation and subsequent reduction of the G-O with hydrazine under microwave irradiation
wang	cathode	lithium transition metal oxides, vanadiumoxides, manganese oxides, lithium phosphates		Review
Chen	cathode	S NPs		Membrane assisted precipitation technique
Xue	anode	Fe ₃ O ₄ Nanoparticles/2D Nanosheet Composites		Facile hydrothermal method
Ng	cathode	V ₂ O ₅ NPs		One-step and scalable flame spray pyrolysis (FSP) process
Liu	anode	Sn-Carbon Nanotube		Direct current (DC) arc-discharge method
Hung	anode	C(Pd NPs)		-
Ulvestad	cathode	LiNi _{0.5} Mn _{1.5} O ₄		Sol-gel method
Yuan	cathode	polyvinylimidazolium		precipitation polymerization
Sheng	cathode	Cr-V-O NPs		facile co-precipitation reaction followed by annealing treatment
Schuster	cathode	ordered mesoporous carbon (OMC) NPs		two-step casting process

Conclusions

This paper summarized the battery-material technology being developed by adding nanoparticles, and it seems clearly that nanoparticles increased the efficiency of the lithium - ion batteries and opened a broad areas for the researchers to research and hopes of the possibility to develop this type of battery by increasing the efficiency, reduce the weight, and increase the life time .

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