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An Account of the Influence of TMDC Anodic Materials on Li/Na-ion Battery Capacity

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***Abstract*— The studies have revealed that there are a lot of scope designing high-energy capacity battery and it is also very challenging. The capacity of the battery depends on several factors like electrode materials, electrolyte, separator, etc., Electrode material plays a crucial role in battery capacity. It is observed that the battery capacity depends on the materials used in electrodes, and the synthesis process. To date, typically used batteries are Ni-Cd, Li-ion, and Na-ion batteries. Numerous studies have been conducted on the synthesis process of alkali metal ion (Li-ion, K-ion, and Na-ion) batteries to improve the electrochemical properties by developing scalable strategy structures. The electrochemical properties in metal-ion batteries are more dependent on anodic materials. This paper is an account of the battery capacities with good cycle life for different anodic materials mainly Transition metal dichalcogenides (TMDC) for both Li-ion and Na-ion batteries. The highlight is the Transition metal dichalcogenides (MX2, M = Mo, W, V, Ta, Ti, and X = S, Se, Te) synthesis process which enhances the specific storage capacity of the battery.**

***Index Terms*— Alkali metal-ion batteries (AMIBs), Transition metal dichalcogenides (TMDCs), Lithium-ion battery (LIB), Sodium-ion battery (SAB).**

I. INTRODUCTION

Rechargeable batteries are widely used as standard energy portable devices, also in supplying electricity to many electronic devices and electrical appliances[1]. Now, building high-performance low-cost rechargeable batteries is still a challenging task, and still is considerable scope for research and development of batteries for EVs and all other energy storage devices[2]. Fabrication and commercialization of high-performance rechargeable batteries made of Lithium are in present lead[3]. Further, substantial research must be carried out in the development of LIBs, but the cost of lithium (Li) is higher in comparison to sodium (Na) and potassium(K)[4]. Moreover, Na and K are more abundant than Li. Thus, the current trend in research is to replace Li with Na or K along with the cost-effectiveness[5]. The use of Na and K systems seems not that easy to maintain compared with state-of-the-art and high-energy LIBs[6-8]. SIBs and PIB have much lower energy density even though it has similar chemistry because of their high abundance in nature[9]. On the other hand, in the development of batteries as energy storage systems in large-scale will basically require a morenumber of materials [10].Hence, we need to concentrate on the battery capacity, cycle-life and safety[11].

After many years of research, researchers have concluded that choosing a good anode have major influence on electrochemical properties of material in alkali metal (Li/ Na/ K) batteries (AMIBs)[12]. Properties of

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electrochemistry in AMIBs lies in anodes when compared to cathode materials.In most of the batteries Graphite is used as anodes in Li and Na ion batteries and most of the research is going on to replace Graphite[13]. Graphite is replaced by metal oxides and metal hydroxides and these metal oxides/hydroxides are bought to the nano or micro sized by bottom-up or top-down methods to increase the intercalation and de-intercalation process, for this we need to investigate the method of approach[14]. Research had proved that battery performance and electrochemical performance is dependent on intercalation and deintercalation processes, the method of approach (preparation method) is more important, and amount of research is required on chemistry of the electrode materials[14-17].

Recent research have shown that alloy-type materials and conversion-type anode materialsshowsgood initial capacities but they lack in cycling life and rapid volume change [18].On tryingfew non-graphitic carbon such as titanium-based, carbide-based, and organic-basedcompounds as anode to check the capacity of the batteries[19].On focusing the development of the battery anodic materials, a good replacement for oxides, alloys, and sulphides is chalcogenides group due to its crystal structure, robust probabilities in catalysis, and mechanical properties[20].Hence for battery performance chalcogenides group (S, Se, T)is one of the options for the high capacity AMIBs[21]. Chalcogenides can be used in three categories with transition metals in batteries namely transition-metal-chalcogenides (TMCs), transition-metal-dichalcogenides (TMDCs), and transition-metal-tri-chalcogenides (TMTCs). The 2D TMC anode materials are having large interlayer spacing and fast charge transfer capacity, it is used as anode materials in AMIBs [22].But the main disadvantageis low conductivity, volume change and poor charge-discharge cycles[23].

From past 30 years designing a new 2D layered materials are in lead due to large interlayer spacing, In2D layered transition metal trichalcogenides (TMTCs) the bandgap of monolayer is predicted of about 1 eV. TiS_3, $TiSe_3$, ZrS_3, $ZrSe_3$, HfS_3, $HfSe_3$, etc., are the examples for transition metal trichalcogenides (TMTCs)[24]. TMTCs has similar chemistry but has more different and outstanding properties compared to other 2D-materials. The TMTCs have more applications in detectors due to its semiconducting properties. To reduce the semiconducting properties carbon should be added along with the TMTCs. Which is not that suitable for designing a battery[23]. Discoveries should be made to improve physical and chemical property for the battery applications. Considering these things both transition-metal chalcogenides (TMCs) and transition metal trichalcogenides (TMTCs) are not suitable for designing the battery anodic material[24].

Transition Metaldichalcogenides:

The studies have revealed that structure of the anode material also plays a [25]vital role in chemistry of the electrode. In crystal structure and characterisation in metals, TMDCs are classified by layered and non-layered structures. Layered TMDCs are more interesting for batteries due to its graphene-like structure[26, 27]. 2D layered structure materials gave a successful outcome in multidisciplinary applications and electronic properties. Transition metal dichalcogenides (TMDCs) is one among the 2D structure and it has the attractive attention on batteries scientists with good physical and chemical properties[28, 29]. TMDC is written by the formula of MX_2 here M = Ta, Ti, W, Mo, Ta, and X =S, Se,Te[23, 28]. The covalent bondin the M-X interactions and form X-M-X layers, and Vander-Waals interaction act in between two adjacent MX_2 layers to form a bulk material[28].

Transition metal chalcogenides interlayer spacing:-The main parameters for MX_2 in LIBs and SIBs electrodes are interlayer spacing, if the interlayer spacing is large, there will be high electron participation which makes electrode more attractive.TMDCs have more interlayer spacing when compared to graphite and transition metal oxides (TMO), it is tabulated in [table.1].TMDC's Interlayer spacing can be varied by choosing the suitable physical and chemical methods of preparation. Interlayer spacing for graphite is 0.335nm, whereas few transition metal oxides have more interlayer spacing for example MgO nanosheets have interlayer spacing of 0.5nm [30]. Therefore, many researchers have used MgO nanosheets as the battery anodic materials since more intercalation mechanism takes place, which improves battery capacity. But CuO and ZnO has less interlayer spacing when compared to Graphite and MgO. For LIBs using ZnO nanowire as anodic material and obtained capacity of 978 $mAhg^{-1}$ it is thrice greater than the capacity of graphite [31], but there is an enormous change in volume upto 220% [32] and it also limits the cycle life of the batteries. The Dongheun at al., constructed a battery using 3D hierarchical ZnO nanostructure (nanowire and nanosheets) which was synthesized by using hydrothermal growth exhibits more than that of ZnO. The ZnO NWs and NSs exhibits a discharge capacity of 1760 mA h g^{-1} and 1752 mA h g^{-1} respectively and after 100 cycles capacity reduces to 440 mA h g^{-1}. This is one of the main disadvantage of this batteries[33].

The CuO nanowire of diameter 20nm-60nm with up to several μm in length has an interlayer spacing of 0.275nm. and ZnO nanowire of diameter 40nm-100nm has an interlayer spacing of 0.281nm which is less than the graphene and very much less than MgO[34]. When CuO nanowires used in LIBs it exhibits high specific capacity and good cycle stability of 687 $mAhg^{-1}$at 0.2C up to 120 cycles[35]. And when same CuO

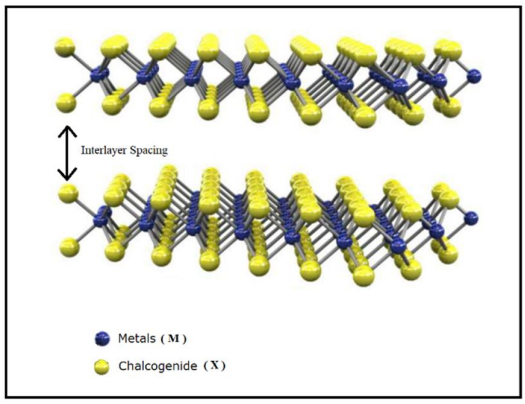

Figure 1:Interlayer spacing of Transition metal chalcogenides (TMDCs)

The MgO has more interlayer spacing compared to CuO and ZnO, hence we can expect more battery capacity. In MgO battery the initial capacity and initial coulombic efficiency is more when compared to other transition metal oxides, the first cycle delithiation is 3033 $mAhg^{-1}$with higher initial Coulombic efficiency of 84.3%which has 10 times more capacity than any other batteries, but it has poor cycle life [37]. When we compare the capacity MgO is better than any other batteries as discussed in this paper, but the cycle life plays a vigorous role in rechargeable batteries. When we compare these TMOs with different TMDCs, MoS_2 nanoflowers with a interlayer of 0.615 nm shows a high capacity of 814.2 mA h g^{-1} after 50 cycles at 100 mA g^{-1}. It gets as high as 652.2 mA h g^{-1} and 547.3 mA h g^{-1} at current densities of 1 A g^{-1} and 2 A g^{-1} at 25 ℃[38]. If we compare the $MoSe_2$ with hybrid phase - 2H $MoSe_2$ nanostructures with 0.646 nm interlayer spacing provides 843 mA h g^{-1} at 100 mA g^{-1} with 99% coulombic efficiency after 100 cycles [39]. For WS_2 carbon nanotubes in LIBs the reversible capacity is 688.3 mA h g^{-1} after 1000 cycles at 1 A g^{-1}[25, 40]. The interlayer of TiS_2 is 0.569 nm and the specific capacity of the SIB has an capacity of 165.9 mA h g^{-1} at 1 C and 132.1 mA h g^{-1} at 20C over 500 cycles.[41] and in LIBs the initial specific capacity was found to be 450 $mAhg^{-1}$ with 80% retention in capacity after 50 cycles.

Even though WSe_2 has large interlayer spacing of 0.651 nm it has high reversible capacity of 530 mA h g^{-1} with stable cycling life.[42, 43]. VS_2 anodic battery has high performance with 859 mA h g^{-1} at 2000 mA g^{-1} with 98% coulombic efficiency and stable cycle life [44]. TiS_2 battery gives 528 mA h g^{-1} with high capability and cycling life [45] and MoS_2 nanosheets prepared by fabricating electrodes using chemical lithiation and exfoliation method in LIBs and then compared with bulk MoS_2. It was noticed that the capacity of Bulk-MoS_2 decreases from 800 mA h g^{-1} to 226 mA h g^{-1} after just 50 cycles. In the other hand restacked MoS_2 showed better capacity of 750 mA h g^{-1} after 50 cycles, even when the interlayer spacing is lower.[46]. The SnS_2 anode battery shows an outstanding performance even if the interlayer spacing is smaller than the other TMDCs this provides the viable research` on the synthesis process and electrochemistry of the batteries. [23, 47].

*Various Transition metal Chalcogenides:-*The different transition metal is incorporated with dichalcogenides like TiS_2, $TiSe_2$, MoS_2, $MoSe_2$, $MoTe_2$, VS_2, VSe_2, VTe_2, WS_2, WSe_2, ZrS_2, CrS_2, NbS_2 and HfS_2, etc., elements with different combination of transition metals and three chalcogenides group predominantly crystalizes,theelements which are highlighted in periodic tablein fig.2 which indicated the combination of chalcogenides to form transition metal dichalcogenides (TMDCs).

There are about 40 different layered TMDC compounds are present. The transition metals and three chalcogen elements that predominantly crystalize in those layered structure. Elements which are highlighted in the periodic table. Ni, Co, Rh, and Co indicates that only some of the dichalcogenides form layered structures [Fig.2.]. Capacitance depends on the TMDC material, which will be discussed more in detail later. In solid-state LIBs, powered TiS_2 is used as the anode and exhibits a capacity retention of 226 mA h g^{-1} after 1000cycles with a current density of 0.5 A g^{-1}. TiS_2 has higher performance than other solid-state LLIBs. This is because other solid-state LIBs have poor cycle and rate performance due to poor interfacial contact . For MoS_2 nanoflowers

from nanosheets with capacity of 824.3 mA h g^{-1} at 103 mA g^{-1} up to 50 cycles. And gets 653.2 mA h g^{-1} and 548.3 mA h g^{-1} at 27°C[38]. When the same VS_2 is used in SIBs, it has a specific capacity of 520 mA h g^{-1} at 1 A g^{-1} in 100 cycles. Highly crystalline VS2 nanosheets as LIB anodes has reversible capacity of 854 mA h g^{-1} at 509 mA $g^{-1}$with high efficiency of 98%.With better cycling stability and good rate capability. [24].

TABLE I: INTERLAYER SPACING OFVARIOUS TMDS, TMO,ANDGRAPHITE.

Interlayer spacing							
TMDCs			TMO			Graphite	
Type	Spacing	Specific Capacity	Type	Spacing	Specific Capacity	Spacing	Specific Capacity
MoS_2	0.615 nm	814.2mAhg^{-1}	CuO	0.275nm	687 mAhg^{-1}	0.335nm	496.4mAhg^{-1}
$MoSe_2$	0.646 nm	843 mAhg^{-1}	ZnO	0.281nm	978 mAhg^{-1}		
WS_2	0.618 nm	688.3 mAhg^{-1}	MgO	0.5nm	3033 mAhg^{-1}		
WSe_2	0.652 nm	530 mAhg^{-1}					
TiS_2	0.569 nm	450 mAhg^{-1}					
VS_2	0.572nm	859 mAhg^{-1}					
SnS_2	0.588 nm	862 mAhg^{-1}					
TaS_2	0.602 nm	528.2 mAhg^{-1}					

The core/ branch structure provides a large, exposed surface area for VS_2 nanosheets, providing additional room for volume expansion. On the other hand, CNTs surrounded by VS_2 nanosheets not only provide a continuous and fast conduction path for charge carriers through the electrode, but also improve the mechanical stability of the electrode material [49][44]. If this is the capacity of LIBs, even the flower structured VS_2 nanosheets provide comparable capacity and periodic performance. With a high reversible capacity of about 600 mA h g^{-1} at 0.1 A g^{-1} and excellent cycle stability of 83% and 87% of the initial capacity, the flower-like VS_2 retains at 2 and 5 A g^{-1} after 700 cycles. In addition, the VS_2 anode exhibits a high initial coulombic efficiency of 94% when approaching 100% in subsequent cycles [50, 51].

A cost-effective and scalable industrial approach to high-quality tungsten disulphide (WS_2) that provides a capacity of 581 mA h g^{-1} at 0.1 C in approximately 100 cycles for LIBs [52]. With SIBs, a remarkable capacitance of 605.3 mA h g^{-1} is obtained at 100 mA g^{-1}, but an irreversible conversion reaction is seen at a potential of 0.01 to 2.5V, and WS_2 nanowires shows a potential window of 0.5 to 3V[53]. The ZrS_2 electrode shows significantly higher initial discharge and charge capacities at 477.5 mA h g^{-1} over a wide voltage range of 0.1 to 3V and 0.3 to 3 V [54].

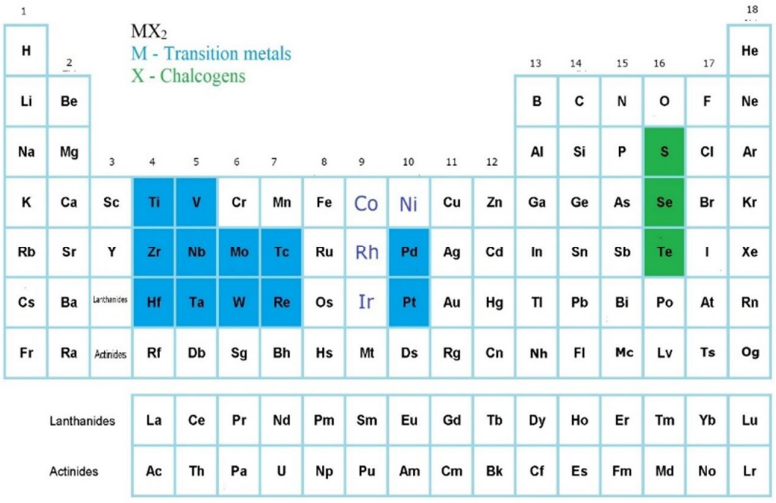

Figure2: Structure OfMonolayered TMDCs

The chemically exfoliated NbS_2 nanosheets as SIB anode offers a high reversible specific capacity of 205 mA h g^{-1} at 100 mA g^{-1} and exhibits high performance rate and good cycling stability[55]. TiS_2 nanosheets are synthesized by shear mixing method and shows excellent cycle performance of 386 mA h g^{-1} after 200 cycles at 0.2 A g^{-1}[56][29]. The Bulk TiS_2 acts on the intercalation mechanism as the anode of the LIBs. It has a theoretical capacity of 260 mA h g^{-1} with a voltage window of 1.14 to 2.09V. By comparing, the monolayer TiS_2 acts on the adsorption mechanism, providing a theoretical capacity of 780 mA h g^{-1} at 0.18 to 1.43V[57].
$TiSe_2$-graphite based anode in SIBs shows the reversible capacity of 81.8 mA h g^{-1} at the current density of 100 mA g^{-1} for over 200 cycles[58]. $TiSe_2$ is also used in Zn-based batteries as anode which gives the capacity of 128 mA h g^{-1} and has retention after 300 cycles[59], and it is used an cathode in LIBs, PIBs, and SIBs [60]. $MoTe_2$ as the anode of LIBs shows a remarkable specific volume of 432 mA h g^{-1} and maintain a specific volume of 291 mA h g^{-1}at 1.0 A g^{-1}after 260 cycles[61, 62].
As discussed abovein [table.1], even if the interlayer spacing is more in few TMDCs the capacity of the battery is less, this concludes that along with interlayer spacing synthesis of the TMDCs materials should also be included in improving the battery electrochemistry for the high-capacity batteries.This paper has the brief discussionon the metal disulphates to check and compare whether the synthesis depends on the battery performance. And is tabulated in [table.2] on the variation of the synthesis along with the capacity and cycle life.

TABLE II: COMPARISON OF TRANSITION METAL (MO, V & W) DICHALCOGENIDES WITHDIFFERENT SYNTHESIS MECHANISM WITH CAPACITY AND CYCLES LIFE.

M-S_2	**LIBs**			**SIBs**		
	TMDC materials	**Capacity In mA h g^{-1}**	**Cycle life**	**TMDC materials**	**Capacity In mA h g^{-1}**	**Cycle life**
MoS_2	MoS_2 nanoflowers in Containing nanosheets	814.2 At 100 mA g^{-1}	50 cycles[38]	MoS_2 nanofibers	370 at 2 A g^{-1}	200 cycles [63]
	MoS_2 on carbonnanosheet	709 At 2 A g^{-1}	520 cycles[64]	MoS_2 nanobelt	520 at 1 A g^{-1}	100 cycles [65]
	MoS_2 inPowder exfoliation form	1400 At 1 A g^{-1}	100 cycles[66]	MoS_2 nanosheets Vertical alignment	434 at 1000 mA g^{-1}	100 cycles [67]
	MoS_2 nanosheet on carbon nanotubes	950 At 2 A g^{-1}	500 cycles[68]	MoS_2 Graphene Microspheres	573 at 0.2 A g^{-1}	600 cycles [69]
	MoS_2 nanosheets by Hydrothermal Process	1009.2 at 500 mA g^{-1}	500 cycles[70]	MoS_2 – vertically oriented in graphene	484.9 at 0.2 A g^{-1}	1500 cycles [71]
	MoS_2 flakes embedded in carbon fibers	1000 at 1000 mA g^{-1}	100 cycles[72]	MoS_2 - QuantumDotIncorporated in $Li_4Ti_5O_{12}$ Nanosheets	313 at 0.25 C	200 cycles [73]
	MoS_2 sheets on amorphous graphene	912 at 0.1 A g^{-1}	100 cycles[74]			
	MoS_2nanoplates Graphene likeHydrothermal process	700 at 0.1 A g^{-1}	60 cycles[75]			
	MoS_2 sheets on CNT by Solvothermal process	1000 at 0.05 A g^{-1}	45 cycles[76]			
	VS_2 Graphene Nanocomposites	180.1 at 200 mA g^{-1}	200 cycles [77]	VS_2 – nanosheets coated with $Na_2Ti_2O_5$ nanowire	203	100 cycles [78]

Vs_2	VS_2 - nanosheets in CNTs	850 At 200 mAg^{-1}	[44]	micro-flower-VS_2 coated with VOOH	330 at 0.2 A g^{-1}	150 cycles [79]
	VS_2 – nanosheets in crystalline layer	532.2 at 50 mAg^{-1}	30 cycles[80]	Nano-flower of VS_2- nanosheets	600 at 0.1 A g^{-1}	700 cycles [26]
	VS_2 in TiO_2 -B heterogeneous nanowires	365.4 at 335 mAg^{-1}	500 cycles [81]	VS_2 – nanosheets (Stacked)	250 at 0.2 A g^{-1}	600 cycles [82]
WS_2	WS_2 nanotubes ongraphene	318.6 at 1 A g^{-1}	500 cycles [83]	WS_2 Nanowire	605.3 at 100 mA g^{-1}	>1400 cycles [53]
	WS_2 nanosheets	118	50 cycles[84]	WS_2 Layered	58.8 at 50 mA g^{-1}	50 cycles[85]
	WS_2 - nanosheets on hollow nitrogen doped carbon spheres	801.4 at 1 A g^{-1}	150 cycles[86]	WS_2 embedded S/N–C	381 at 0.1 A g^{-1}	1000 cycles [87]

The comparison from the table.2. gives us the result that, not just the interlayer spacing can give an account to good capacity of the batteries, even the different synthesis methods do plays a major role in battery capacity and cycle life. There is different type of synthesis used for the TMDCs.

Synthesis of TMDCs:-Literature reviews shows that both physical and chemical approaches have used so far. Effective for TMDC synthesis. This section gives an overview of some recent synthesis methods in 2D materials[88].

Exfoliation process:

The micromechanical exfoliation process was first used to produce single layer nanosheets. Uses scotch tape technology. In this methos, use cello-tape to pull a thin film and then repeat. Finally peel-off from the thin film, stamp on the SiO_2 substrate, and carefully remove the tape. A significant amount of work was done in the early stages of nanosheet manufacture[89-92].Lee reported on the separation of single-layer and multilayer MoS_2 films from luck crystals of 2H-MoS_2 uses a micromechanical exfoliation process widely used in the production of graphene rehearsal. In a typical process, a small piece of MoS_2 crystal mass was placed on the sticky side of the tape [25, 93, 94].This was followed by repeated folding and unfolding of the tape to produce vertically think flakes.The surface of the tape.The ribbon was then pressed onto a silicon substrate converted with a SiO_2 layer with a thickness of 285 to 300 nm.Afterlight rubbing, the type was peeled off the subtract, leaving behind atomically thin MoS_2 flakes.The size of the single layer ranging from 1 to 10μm, and even the single layer thick MoS_2 membrane was thick. Optical visibility of SiO_2/Si substrates [95-98].

Chemical approaches:-This is a type of process to exfoliate or intercalate 2D nanomaterials with help of surfactants. O'Neill and his team reported a significantly increased dispersion with the side nano panels size with increased flake size with increased flake size of MoS_2 by choosing the appropriate sonication time and using solvent. The typical procedure is as follows, the MoS_2 concentration experiment is performed by adding powder to 20ml of N-methyl-2-pyrrolidane (NMP) in a flat-bottomed beaker of capacity 100mL. These models sonicated continuously for 60mins using a horn acoustic transducer. The cup is connected to the chiller.[24, 99] The system allows cold water (5℃) to flow around the diffuser during sonication. Then they were centrifuge at 1500 rpm for 45 min. For concentration versus time sonication experiment, 100 mL NMP was added 10gm of MoS_2. The Sonic tip is pulsed for 8 seconds and 2 seconds to resist the damage and reduce solvent heatingand hence degradation. During sonication, 5 mL fractions were removes at several points and was centrifuged [100].

Much work has been dined in the preparation of MoS_2 monolayers by micro-exfoliation for used in various next-generation nano-electric devices. Although the dispersion of microorganic solvents and chemical-free exfoliation produces the highest quality layered TMDCs, this method is limited by low productivity. On the other hand, chemical exfoliation has advantage has advantage of large-scale production. At the same time, it has a lot of disadvantages such as being very toxic and its contribution to highly exothermic reactions. It includes many methods such as reducing TMDSs by CVD, hydrothermal method, microwave method, etc.,[101-104].

Chemical vapor deposition (CVD):-CVD is widely used in the electronics industry based on thin layers as well as full exfoliation multilayer material. It seems that many interesting results have been obtained from CVD for

production layerd nanomaterials [105]. In addition, CVD has become an important method to obtain high quality MX_2 films. Few researchers are working on an alternative to large-scale fullerene-type inorganic nanostructure MoS_2 and nanoflowers by CVD technique. Zhan and their team reported the synthesis of MoS_2 in atomic layers directly on SiO_2 substrate by an evolved CVD, Large-scale synthesis of atomic layer semiconductors directly on the dielectric layer opens many possibilities for easy device fabrication, extending the important range of useful single-layer or several-layer materials with special properties, such as graphene and hexagonal boron nitride. Many other works have also reported on CVD and CVD like exfoliated graphene.[106, 107].

Hydrothermal method:-Much works has been done on the hydrothermal methods. Liu and his team had tried a process of coral-like Mn-NC composite materials through two-step reaction. First, the PVP capped $(NH_4)_2Mn_2(So_4)_2$ process was synthesized through hydrothermal method. Ni-PVP used as doped-N. In this, 0.015 mol $MnSo_4$ H_2O an accurate $(NH_4)2S_4O$ and PVP was dissolved in distilled H_2O to form homogenous solution under continuous stirring. The solution then transferred to Teflon autoclave and kept in oven at 120 ℃ for 10-12 hours. Then it is centrifuged and washed with deionized water and ethanol, and dried at 80 ℃. For suitable tines, precursors were sintered in N_2 at different temperature. Wang and his mates reported in improving the lithium storage performance of hierarchical hollow MoS_2 nanoparticles assembled from nano panes by hydrothermal method in which 0.865gm of molybdenum trioxide power, 0.515 gm of sodium fluoride and 1.930 gm potassium thiocyanate was added to the mixture of 30mL distilled water and 10mL ethanol. After being stirred for 10mins, the solution is then transferred to a 50 mL Teflon-autoclave and kept in oven and maintained at 200 ℃ for 16 hours. The black precipitation is obtained and washed with dilute acid and then in ethanol many times. Finally, the product is dried under vacuum at 60℃. To evaluate the performance of these hollow nanoparticleshierarchically in LIB, solids MoS_2 nanoparticles were prepared by a similar process, using glycerine for the solvent mixture rather than ethanol. Other parameters of the test remains the same.[99, 108]

CONCLUSION

Thus, conclusion can be drawn based on the studies of researchers that the synthesis process of TMDC materials are eligible to be employed for the high-capacity batteries. Even though MoS_2 based batteries provide good stability, the energy density is sensitive to high intercalation potential. The expansion of TMDCs layers results in the increase in interlayer spacing which further enhances capability and stability rate. Along with the interlayer spacing the synthesis of the TMDCs materials plays an important role in electrochemistry of the battery. Therefore, TMDCs have a lot of advantages and scope in diverse morphologies and relative ease of exfoliation.

ABBREVIATION

AMIBs – Alkali metal-ion batteries
TMOs - Transition metal oxides
TMCs – Transition metal chalcogenides
TMDCs – Transition metal dichalcogenides
TMTCs – Transition metal trichalcogenides
LIB – Lithium-ion battery
SAB – Sodium-ion battery
PAB – Potassium-ion battery
NS- Nanosheets
NW – Nanowires

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