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Review: Synthesis and Application of Nickel Sulphide Nanoparticle

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Abstract—*Due to consumption of fossil fuel, environment pollution, bio oil etc, we require clean and green sustainable energy[1]. Among the metal sulfides, nickel sulfide (NiS) has received attention due to their potentials in the field of semiconductor devices. In this paper we have discussed the different methods for synthesis of nickel sulphide and its application in energy systems. Various methods for synthesis of nickel sulfide are for e.g. co-precipitation, hydrothermal, ultrasonic method, solvo-thermal, microwave irradiation, pulse laser ablation, sol-gel etc. Nickel sulfide nanoparticle has multiple phases as well as stoichiometric compounds (NiS (α-NiS and β-NiS), NiS_2, Ni_3S_2, Ni_2S_3, Ni_3S_4, and Ni_9S_8)[2]. The most stable state of nickel sulphide is heazlewoodite (Ni_3S_2), polydymite (Ni_3S_4), millerite (NiS) and vaesite (NiS_2).Different phases of nickel sulphide can be utilised in different applications such as ; NiS_2 can be used for hydrogen production and in super capacitor. Ni_3S_2 for water splitting, NiS as counter electrode in Quantum dot dye sensitized solar cells[1].*

1. INTRODUCTION

Fossil Fuels are the major non renewable energy resources that are used in our world. Consumption of Fossil fuel cause serious environmental issue such as air pollution, water pollution and soil pollution etc Due to environmental issue we have required clean and green sustainable energy.[3]

Nickel sulphide is a functional material. Nickel sulphide is a highly crystalline inorganic compound. It has unique, morphology and high surface area. Due to these properties it can be used in energy systems[4]. Nickel Sulphide has many phases such as NiS,$Ni_{3+X}S_2$, Ni_3S_2, Ni_7S_6, Ni_7S_2, Ni_3S_4 NiS_2. The most stable state are NiS_2, α- NiS and β- NiS [5]. Different phases used in different application. NiS has two phase Rhombohedral and Hexagonal. NiS_2, α- NiS and β- NiS nanoparticles have excellent electrical, magnetic and optical properties, due to large surface area and quantum size effect[6], it can be used as a counter electrode in Dye Sensitized Solar Cell and Quantum Dot Dye Sensitized Solar Cell. The structure of Ni_3S_2 is hazelwoodite, it has two phase low temperature phase α- Ni_3S_2 and high temperature phase β- Ni_3S_2, its crystal structure is Fcc and it have high potent catalyst properties so it can be used for water splitting[1].The structure of Ni_3S_4 and NiS_2 are Polydymite and Vaesite both have high theoretical capacity, excellent rate performance and good conductivity due to these electrical properties of nickel sulphide used in supercapacitor and lithium ion batteries etc[7] Magnetic properties depends on the different phases of Nickel sulphide.

There are several method for the synthesis of Nickel sulphide such as Hydrothermal, Solvo-thermal, Co-precipitation, Sol-gel, Reflux and Microwave Irradiation method. The low temperature phase of nickel sulphide are NiS_2, β - NiS and β- Ni_3S_2 and high temperature phase of nickel sulphide are α- Ni_3S_2, α- NiS, and so on. Low temperature phases of nickel sulphide can be synthesized using reflux, solvothermal, hydrothermal and ball milling[6]. For the synthesis of single phase of nickel sulfide

2. CHEMICAL PRECURSORS FOR THE SYNTHESIS OF NICKEL SULFIDE:-

2.1 Nickel Source: - Nickel foam, Nickel acetate, Nickel chloride and Nickel nitrate

2.2Sulphur Source:- Thoiurea, thioaceteamide sodium sulfide and thioglyocial

2.3 Solvent :- De-ionized water, ethanol, ammonia, ethylene diamine and and hydrazine hydrate

Different methods for the synthesis of Nickel Sulphide:-

3. HYDROTHERMAL METHOD

Hydrothermal method is one pot synthesis method, Hydro means water and thermal means pressure. Hydrothermal method is combination of water and pressure this method depends on the solubility of minerals in hot water under high pressure and temperature. This method gives various shape and characteristics.

4. SOLVOTHERMAL METHOD

Growth of a single crystal in a non aqueous solution in an autoclave at high temperature and pressure. In this method, we control size, shape distribution and crystallinity of nanoparticles. The characteristics of nanoparticle can be varied by changing experimental parameters such as temperature, reaction time, surfactant type, precursor and solvent [8]

5. SOL-GEL

Sol-gel is used for the synthesis of metal alkoxide and metal chlorides. It involves hydrolysis and condensation of metal precursors. In sol –gel method either aqueous or non-aqueous, both can be used as medium[9].It is a conversion of monomers into colloidal solution (gel). After the formation of 3-D gel (Xerogel or Aerogel) is subjected to drying process and gets the final products. This method is used for the synthesis of composites monoliths, porous membrane thin film and so on. Purity of the is high this technique is not suitable for the manufacturing of electronic and photonic devices[10]

6. MICROEMUSLION METHOD

It is simply a mixture of oil, water and surfactant. Enough surfactant is required to create an interface between oil and water by decreasing the interfacial tension. Water-in-oil micro emulsions are also known as reverse micelles.[11]. Microemulsion method is a reversible method. they become unstable at low temperature and higher temperature, when the temperature become in the stability range microemslusion reform.[12]

7. MICROWAVE IRRADIATION METHOD

This method is used for the synthesis of inorganic nanoparticle [9], This is a good control of particle size, distribution of particle size is uniform and it also control the morphology, optical and electronic properties of the nanoparticle. This method has high reaction rate. Microwave wave assisted method is more efficient in term of the energy used, produce higher temperature homogeneneity. In this method less hazardous chemicals are used, distribution of particle size is uniform [9]

8. APPLICATIONS OF NICKEL SULFIDE

β-NiS has excellent optical and electronic properties[5]. It has high intrinsic electrical conductivity, theoretic capacitance[13], high thermal stability[14], large surface area and it shows the quantum size effect[6], so it can be used as a counter electrode in Solar Cell. The structure of Ni_3S_2 is hazelwoodite. It has high power density, rapid charging and discharging, long life, wide thermal operating range.[15] Due to its surface morphology, porous size distribution, good electrical conductivity due to these properties [16] it can be use in Supercapacitor and Lithium ion Battery. The structure of Ni_3S_4 and NiS_2 are Polydymite and Vaesite. Both have high potent catalysis properties so it can used for hydrogen Production.

9. CONCLUSION

In this paper we concluded that Microwave Irradiation method, Hydrothermal and solvothermal is the best method for the synthesis of nickel sulphide. NiS_2 and β- NiS both can be use as counter electrode Quantum Dot Dye Sensitizes solar cell as well as Dye Sensitized Solar cell. Ni_3S_2 has good electronic properties so it can be used in supercapacitor and lithium ion batteries. Ni_3S_4 has potent catalyst so it can be used for water splitting.

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