2. Literature review

Research on semiconductor nanoparticles has become eminent interdisciplinary locale of science. Semiconductor nanoparticles are generally speculated to be particles with diameters in the range of 1 to 20 nm and have attracted an immense interest over the last decade. This could be due to the potentiality for numerous applications with two fundamental factors, first is the large surface-to-volume ratio and second approach is advantage of the surface-plasmon resonance from metal nanostructures to semiconductors (Jung et al., 2011; Pickett and Brien, 1998). The diverse electronic and optical properties of these semiconductors strongly depend upon the small size in nanometer size regime. It has been presented that the properties of these materials transform depending on the size of nanoparticles. Small sized nanoparticles have hybrid properties which are incompletely understood today, creating a challenge for theoreticians as well (Mingo et al., 2009; Chubilleau et al., 2011). Metal chalcogenide nanoparticles, as semiconductor materials have received increasing attention, due to many innovative chemical and physical properties discovered or assumed for this class of materials. At present various metal chalcogenide nanoparticles are being synthesized and used in numerous applications such as infrared photovoltaics (Sargent, 2005) optical switches (Barros et al., 2006), photo-detectors (Feit et al., 1991), optical detectors (McDonald et al., 2005), laser devices (Wise, 2000; Springholzet al., 2000), thermoelectrics (Fardy et al., 2007; Heremans et al., 2005), solar cells (Lakshmikvmar, 1994), super ionic material (Korzhuev, 1993), electrical conductive material (Dhasade, 2012), thermoelectric cooling materials (Chivers, 1996; Ritter and Pichai, 1995) and optical filters (Jiang et al., 2010) etc. (Figure 2.1).

Over the past years, a multitude of different synthesis studies has been focused on the metal chalcogenide nanomaterials, starting from the most relevant metal chalcogenides such as CuO (Pike et al., 2006), Cu_2O (Kuo and Huang, 2008), ZnO (Liu et al., 2012), Cu_2S, Co_2S (Khaorapapong et al., 2011), ZnS (Cetinkaya et al., 2011), CdS (Winter et al., 2005), PbS (Bakshi et al., 2007), CuSe (Bakshi et al., 2010), PbSe (Hostrerler et al., 2014), AgTe (Samal and T. Pradeep, 2009), BiTe (Matthew et al., 2009), CdTe (Pons et al., 2009), CuTe (Yang et al., 2013), Ga_2Te_3 (Kurosaki et al., 2008), GeTe (Yu et al., 2006), SnTe (Ning et al., 2010), SbTe
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(Christopher et al., 1994), PbTe (Li et al., 2009), ZnTe (Mohdet et al., 2012) etc. Out of these metal chalcogenides, metal tellurides represent a class of compounds that exhibits excellent properties and potential applications in electronic, optical, thermo electrical, catalysis, magnetic and biological fields. Numerous reports are accessible in the literature on synthesis techniques as well as potential applications of nano-sized semiconductor metal telluride nanoparticles (Ren et al., 2009; Murase et al., 2007; Zhang et al., 2009). Many of antecedent studies on telluride nanostructure were mainly focused on restrained synthesis of different morphologies, such as nanoparticles, nanoplates, nanorods, nanowires, nanoforks etc. We have focussed mainly on Lead telluride and Copper telluride nanoparticles.

Figure 2.1. Metal chalcogenide NPs and their applications.

2.1. Lead Telluride (PbTe): A brief review

Lead telluride is a narrow bandgap semiconductor (approximately 0.32 eV, at 300 K) and has been broadly studied and used in laser devices (Korzhuev, 1993; Dhasade, 2012), optical detectors (Lakshmikumar, 1994), and thermoelectrics (Chivers, 1996; Ritter and Pichai, 1995) etc. Low-dimensional PbTe semiconductors could more easily show the obvious quantum size effect on larger
scales because of the larger Bohr exciton radius (approximately 46 nm) in comparison to other semiconductor materials. Therefore, PbTe nanomaterials have attracted great scientific attention in recent years and have been synthesized by a variety of physical and chemical techniques (Figure 2.2).

Shi et al. (2012) reported reduced graphene oxide-lead tellurium (RGO-PbTe) composites via sonochemical method having high electro-conductivity and good biocompatibility, successfully used as a unique component for the synthesis of electrochemical biosensors. They developed an H_2O_2 sensor, which exhibited good linearity in the concentration ranges from 0.5 to 30 μM.

Lee et al. (2011) prepared PbTe nanowires by a vapour transport method and observed the enhanced thermoelectric properties with diverse sized nanowires at room temperature, compared with those in case of bulk lead telluride. Enhanced thermoelectric figure of merit ZT data may in part be attributed to the size effect of nanowires, but cannot fully exclude the parameters that also affect thermoelectric efficiency. Similarly enhancement in thermoelectric power shown by Paul and Banerji (2011) for single crystal PbTe grains with size in the range 25-350 nm by hot-press method, and because of higher power factor and reduced thermal conductivity these nanoparticles demonstrate a potential for thermoelectric applications.

Lead Telluride dentritic structures were prepared via electrochemical deposition, size spanning in between 100-500 nm with star like and trigonal shapes. DSC analysis were performed to study the thermal properties and higher transmittance of the PbTe structures in 500-4000 nm region, and the band gap energy calculated to be about 0.272 eV (Li et al., 2008). Paul et al., 2010 reported PbTe-Ag nanocomposites with average size 20 nm and they further established nanocomposites to be the key components to control the energy dependency of scattering of the carriers, i.e., energy filtering of the carriers having outstanding enhancement of Seebeck coefficient and electrical conductivity, which results in higher power factor of nanocomposite samples.

In case of capping of lead telluride, anisotropic growth of nanocubes to nanosheets with various stabilizing agents such as cetyltrimethylammonium bromide (CTAB), polyvinyl pyrrolidine (PVP), sodium dodecylbenzene sulphate (SDBS) have been reported hydrothermally which are industrially important for thermoelectric energy conversion and infrared devices. Size of nanosheets ranges 20-80 nm thickness and
0.2-5 μm length and the measured value of Seebeck coefficient is 120 μVK⁻¹ at 650 K (Zhu et al., 2010).

3-D flower-like crystal of PbTe with size about 3μm was successfully synthesized by Chen and his co-workers under hydrothermal conditions using hydrazine as reductant at different reaction time. When the reaction time was less than 1h, the shape was flower like with short pods, with increase in the reaction time, the morphology changed from short pods to relatively long pods. Further increasing the reaction time to 24h led to an increased length of a portion of flower-like crystal eight-pod. The temperature dependence properties of flower-like crystals of PbTe have been evaluated with an average thermoelectric power of 120 S cm⁻¹ and electrical conductivity of 220 μV/K at 740 K (Zhou et al., 2012).

Dong and co-workers synthesized core-shell Sb doped PbTe/Ag₂Te composite nanocubes composed of crystalline inner cube as a core with edge lengths of 20-50 nm and an amorphous outer shell with thicknesses of 3-6 nm by rapid one-step microwave assisted solvo-thermal method without using any complexing agent or surfactants (Dong et al., 2012). In another case Li and workers also synthesized Ag and Sb co-doped PbTe, pure PbTe nanopowder hydrothermally and these synthesized nanopowders were heated in vacuum for 5h at 1173-1223 K. The transport properties of the bulk samples were measured from room temperature to 773 K. Both nanopowder and bulk samples have significant effects on doping with Ag and Sb and the thermoelectric properties of PbTe were greatly improved after co-doping of Ag and Sb (Li et al., 2009).

Grabecki and co-workers patterned PbTe nanostructures by means of electron beam lithography and wet chemical etching. They described narrow gap paraelectric semiconductor, characterized by the huge static dielectric constant $\varepsilon>1000$ at pumping helium temperatures. Magneto size effects, ballistic motion of the carriers on nanostructures were revealed by performing magnetoresistance measurements. The most relevant perception is the conductances of narrow constrictions demonstrate a particular zero field quantization in $2e^2/h$ units. The conductance measurements in a nonlinear regime allowed for an estimation of the energy spacing between one-dimensional sub bands (Grabecki et al., 2005; Grabecki et al., 2009). Lead telluride micro needles were prepared by a simple aqueous chemical technique at low temperature without any additional surfactants. These face-cantered cubic lead telluride micro needles are in the range of 90-130
nm in diameter and length up to 2 μm. Lead telluride micro needles show large blue shift (1.26 eV) in comparison to those of bulk counterpart (0.32 eV) due to quantum confinement and electrical resistivity (Kungumadevi and Sathyamoorthy, 2013). They also synthesized PbTe nanodisks solvo-thermally in a short span of time with high yield using PVP as surfactant and studied structural, optical and electrical properties. Electrical analysis reveals that the electrical conductivity of the PbTe can be enhanced by the formation of nanodisks. Optical absorption and PL results explain a large blue-shift which implies that the prepared PbTe nanodisks show strong quantum confinement effect (Kungumadevi and Sathyamoorthy, 2013).

Structural, optical and electrical properties of nanocrystalline PbTe thin films were studied by Wang et al. (2008) at room temperature through thermal evaporation. The PbTe thin films shows p-type dc electrical conductivity at temperature higher than 200 K at different surfaces (glass slide surface and a 400 nm SiO₂ coated Si substrate). Both PbTe thin films show similar surface features and both have grain sizes in the range of 50-100 nm and surface roughness of 14-16 nm. At reduced temperature the electrical conductivity exhibit weaker temperature dependence due to tunnelling transport. The optical band gap energy is determined to be 0.386 eV using a direct transition model. Lead telluride nanorods and microcubes have been synthesized by the composite-hydroxide-mediated approach using hydrazine and NaBH₄ as reducing agents respectively at 200 °C for 24 hours. The nanorods with diameter of 40-70 nm and lengths of 300-500 nm have been synthesized using hydrazine as reducing agent. The prepared nanorods has very high Seebeck coefficient (679.8 μV/K) at room temperature, which is much higher than that of the bulk material and on similar conditions Seebeck coefficient of microcubes is only 195.5 μV/K (Wan et al., 2009). Tai and co-workers also synthesized pearl-necklace-shaped PbTe nanowires with Seebeck coefficient values of about 307 μV/K, by a hydrothermal process using tellurium nanowires as template. In the first step tellurium nanowires with diameter of 3-20 μm were prepared using hydrazine and polyvinyl pyrrolidine (PVP) as reducing and stabilizing agent respectively. The pearl necklace-shaped PbTe nanowires were synthesized hydrothermally using the tellurium nanowires as template at 373 K for 12 hours (Tai et al., 2008). Rough PbTe polycrystalline thermoelectric nanorods were synthesized via a simple reducing chemical route even without and with surfactant (EDTA only for
comparison) using NaBH$_4$ as reducing agent at 100 °C for 48 hours. Nanorods without surfactant are with smooth surface and have length ranging from 0.3 to 2 μm and a diameter of 50-200 nm and the nanorods synthesized in the presence of EDTA show a larger diameter and rougher surface. Both rough surfaces and polycrystalline nanostructures can reduce the thermal conductivity and increase the Seebeck coefficient, and hence may lead to improved thermoelectric performance (Chen et al., 2009).

Zhu et al., (2010) synthesized nanosheets from nanoparticles with alkaline hydrothermal method. The reaction parameters such as time, temperature NaOH concentration, reductant (N$_2$H$_4$.3H$_2$O and NaBH$_4$) and type of surfactants (PVP, CTAB and SDBS) have been systematically changed to prepare the nanosheets. Different morphologies of lead telluride nanostructures such as nanoparticles, nanocubes and nanosheets have been reported and all the parameters play important roles in the growth of PbTe nanocrystals. PVP, NaOH & N$_2$H$_4$.3H$_2$O are essential for the formation of PbTe nanosheets and these nanosheets are of 20-80 nm in thickness and 0.2-5 μm in plane sizes. In an another case PbTe and PbSe nanocrystals were synthesized with alkaline hydrothermal method using hydrazine as reducing agent without incorporating any capping agents. Spherical particles of PbSe (23 nm) and PbTe (18 nm) have been obtained at 100 °C for 18 hours and at 160 °C for 18 hours respectively and also PbTe nanorods have been (length up to 200 nm and width 15 nm) obtained at the same temperature for 72 hours (Wang et al., 2001). PbTe nanorods and nanowires were prepared hydrothermally using hydrazine as reductant and CTAB serve as a selective etchant. Nanorods have diameter of 50-150 nm, length 2-5 μm, while nanowires possess diameters of 30-100 nm and lengths greater than 10 μm. Lead telluride nanowires were prepared when the amount of CTAB was decreased (Zhang et al., 2005). In another case Carbon-coated PbTe nanowires were prepared for thermoelectric applications using CTAB as capping agent, ascorbic acid as a reducing agent and carbonization source, hydrothermally in four steps. The first step include telluride nanowires formation and then carbon sheaths were formed on the surface of telluride nanowires, third step comprises of diffusion of lead ions into the carbon sheaths and their reaction with telluride nanowires, while in the fourth step formation of Carbon-coated PbTe nanowires with diameter of 35-45 nm occur (Yong et al., 2011).
Two-step hydrothermal synthesis method has been developed to prepare uniform single-crystalline PbTe nanowires with enhanced Seebeck coefficient. In the first step tellurium nanowires were prepared using polyvinyl pyrrolidine (PVP) as capping agent and hydrazine hydrate as reductant at 453 K for 24 h. The second step involves the addition of lead precursor into above solution in an autoclave maintained at 373 K for 12 h. The thermoelectric measurements indicate a high Seebeck coefficient of about 628 μV/K and about 137% exceeding that of bulk PbTe (Tai et al., 2008).

A simple chemical bath method is used to synthesize PbTe nanoparticles and thin films at room temperature and ambient pressure. The average size of the nanoparticles was 25 nm while the electrical conductivity and Seebeck coefficient of the film are ~0.017 S cm⁻¹ and ~ 147 μV/K respectively (Wang et al., 2009). Poudel and co-workers, (2006) studied the shape evolution of lead telluride nanostructures hydrothermally under different synthesis conditions like temperature, concentrations of diverse reactants and time. Polyethylene Glycol (PEG) was used as surfactant and hydrazine as reducing agents. At 100 °C, formation of nanoboxes with face-opening in all six faces was formed, when temperature was increased to 125 °C, nanobox faces open to form semi-microflowers. Further increase in temperature to 160 °C results in microflowers and this morphology doesn’t change on increment to 185 °C and so on. However, when a lower temperature was used nanocubes with size 10-50 nm were formed. To improve thermoelectric properties, heterogeneous nanocomposites of p-type bismuth antimony telluride with lead telluride nano inclusions have been synthesized by incipient wetness impregnation approach using oleate as capping group and hydrazine as reductant at 150 °C. PbTe nanoparticles with an average particle size of 14 nm having cubic morphology were synthesized and bismuth antimony telluride with nominal composition Bi₀.₄Sb₁.₆Te₃ was employed as matrix material for making nanocomposites. The Seebeck coefficients and electrical resistivity of nanocomposites decrease with increasing PbTe nanoparticle concentration. The lattice thermal conductivity decreases with the addition of PbTe nanoparticles but the total thermal conductivity increases due to increased electronic thermal conductivity (Ganguly et al., 2011).
2.2. Copper Telluride (Cu_{12-x}Te): A brief review

The tellurides of transition metals are an important class of compounds that exhibit wide range of physical and chemical properties (Figure 2.3). Among them, copper telluride has different crystal structures depending upon the value of x (1<x<2). These may be used in solar cells (Lakshmikumar, 1994), super ionic materials (Korzhuev, 1993), electrical conductive materials (Dhasade et al., 2012), thermoelectric cooling materials (Chivers, 1996; Ritter and Pichai, 1995) and optical filters (Jiang et al., 2010) etc. Specially, nanocrystalline form of copper telluride exhibit diverse interesting and useful characteristic properties, which are very much different from its bulk counterpart due to after-effect of quantum confinement. Owing to the existence of a few possible crystalline compounds such as stoichiometric CuTe, Cu_{4}Te_{3}, Cu_{7}Te_{5}, Cu_{8}Te_{4}, Cu_{2}Te and non-stoichiometric Cu_{2-x}Te, it’s difficult to gain the pure products with a single phase (Pashinkin and Pavlova, 2005).

Copper telluride nanocrystals have been successfully synthesized hydrothermally by Wan and co-workers through strong alkaline aqueous environment using hydrazine hydrate as reducing agent. Characteristically, the KOH concentration effectively adjusts the morphology of the product at low concentration (<1 mol/L).
formation of nanoplates occurs and high concentration (>6 mol/L) facilitates the
growth of nanowires. Furthermore the DSC and electrical conductivity
investigations demonstrate that phase transformation of copper telluride nanowires
occur at 322, 353 and 477 °C and these nanowires exhibit metal electrical
conductivity (Wan et al., 2011). Homogeneous Cu$_7$Te$_4$ nanoparticles with an
average size of 15 nm have been prepared solvothermally at 160 °C for 10 hours
using ethylene diamine as solvent in the absence of a capping agent. (Liet et al.,
1999). Cu$_7$Te$_4$ nanosheets have also been prepared solvothermally using acetone
and cyclohexanone as solvents. Change in reaction temperature and types of
organic solvents have crucial effects on the morphology of the Cu$_7$Te$_4$
nanostructures. Studies revealed that the surface morphology at higher temperature
(220 °C) resulted in fewer regular crystals, while a low temperature (140 °C)
produces large lump containing small particles. Cu$_7$Te$_4$ sheets like particles were
formed with similar procedure, except that cyclohexanone was used as the reacting
solvent. For the formation of pure Cu$_7$Te$_4$ phase selection of suitable solvents are
essential (Wang et al., 2011). Different morphologies such as nanowire, nanorods,
nanobelts, nanosheets and hierarchical dendrites of copper and silver telluride were
obtained with hydrothermal method grown on corresponding metal substrate
through reaction between metal foils and tellurium powder wherein CTAB as
capping agent and hydrazine hydrate as reducing agent have been used. In
deionized water, the resulting film is composed of irregular particles and hexagonal
plates. When an aqueous cetyltrimethylammonium bromide (CTAB) solution was
used as the reaction media, rod like structures were obtained; these nanorods are
cumulatives of nanosheets and the resulting nanostructure was about 50 nm in size.
When an aqueous hydrazine solution was used as the reaction media, the resulting
copper telluride grew into nanowires of more than ten micrometers in length with
diameters in the range 50-300 nm. In a mixed CTAB and aqueous hydrazine
solution, copper telluride nanorods were formed with a diameter in the range 80-
400 nm and lengths of several micrometer. In case of silver telluride irregular
particles were grown on the silver substrate in deionised water. The introduction of
CTAB into the system resulted in the formation of nanobelts with a width of about
80 to 200 nm and a length of about a few micrometers. In an aqueous hydrazine
solution, mostly nanowires and minor nanosheets were obtained (Zhang et al.,
2006).
Dong et al. (2012) synthesized Cu_{(2-x)}Te nanowires with rapid microwave assisted solvothermal method using telluride nanotubes as self-sacrificial template involving the use of polyvinylpyrrolidone (PVP) and ethylene glycol (EG) at 200 °C for 10 minutes. The prepared Te nanotubes were directly used as a template for the synthesis of Cu_{(2-x)}Te nanowires.

The morphology and size of the samples were investigated by SEM, EDS TEM and SAED. The diameter of single crystalline nanowires ranges from 100-200 nm and lengths of several micrometers, while the electrical conductivity of the nanowires have been measured as 5.99-7.19 x10^{3} \text{Ω}^{-1}\text{m}^{-1} at temperatures 300 to 450 K. Copper telluride nanoparticles were prepared by Kumar and Singh with a wet chemical method by refluxing under stirring at 70 °C for 9 hours. The UV-Visible spectra indicate that the direct and indirect band gaps of the Cu_{2}Te nanoparticles were 2.04 and 3.05 eV respectively. XRD, TEM and HRTEM analysis revealed that the diameters of the particles are in the range of 25-30 nm (Kumar and Singh, 2009). Rough surfaced Cu_{7}Te_{4} nanowires were prepared solvothermally with a typical length of few micrometer using dipropylamine (DPrA) as coordinating solvent at 180 °C for 20 hours and thereafter studied the influence of various reaction parameters such as effect of reaction temperature, the role of concentration of OH^{-} ions and influence of solvents (DPrA and SDAs). SEM revealed long 1D nanobelts with multilayer structures and rough surfaces (Wang et al., 2012).
Aforesaid discussion enlists various semiconductor metal chalcogenides with conventional surfactant because surfactant-assisted synthesis of semiconductor nanoparticles has attracted much attention due to its soft-template effect, reproducibility and aqueous phase reaction and petite is identified about the hydrophobicity on the shape controlled aspects. Gemini surfactants are the efficient capping agents and due to higher hydrophobicity and morphology control, these are considered to be better shape directing agents over the conventional surfactants. Bakshi et al. (2007) prepared PbS nanocrystals and microcrystals stabilized by Gemini surfactants (12-0-12, 10-2-10, 12-2-12 and 14-2-14). Results from TEM studies reveals that various PbS structures including star-shaped, cubic, tree-shaped, hexagonal, spheres, plate-like nanoparticles were obtained by changing the concentrations of various Gemini surfactants. Bakshi et al. (2010) also synthesized PbSe and CuSe nanoparticles with Gemini surfactant (12-2-12, 12-0-12 and 16-2-16) as stabilizing agents and aqueous hydrazine as reducing agent at 85 °C temperature. Shapes of PbSe and CuSe nanocrystals are cubic, hexagonal and nanoplates respectively at different concentrations of Gemini surfactants.
Singh et al. (2009) successfully synthesized PbS nano and micro-crystals using dimeric surfactants (12-6-12, 12-8-12, 12-10-12 and 12-12-12) as capping agents at 80 °C for 48 hours. Nano and microcrystals with different shapes (star-shaped, cubic and octahedron) have been observed. Chen et al. (2010) synthesized CuS nanocrystals using 12-3-12, a Gemini surfactant by adjusting the concentration of reactants, molar ratio of surfactant in solution and incubation time. The resultant CuS nanostructures can be selectively controlled to be nanorods, tube like and star sheet-like structures with various dimensions as divulged by TEM studies. Sun et al. (2009) synthesized polymer/carbon nanotubes (CNTs) nanocomposites, improved with Gemini surfactants, 6,6-(butane-1,4-diylbis(oxy)) bis(3-nonylbenzenesulfonic acid) to attain homogeneous and stable dispersion of multi-walled carbon nanotubes (MWNTs). Optical microscopy and TEM studies explain that the dispersion and stabilization of MWNTs in toluene is greatly improved by Gemini surfactants. Synthesis of 2D metal nanoparticles/graphene nanocomposites including gold nanoparticles (GNPs), platinum nanoparticles (PtNPs) and palladium nanoparticles (PdNPs) have been carried out using cetyltrimethylammonium bromide (CTAB) and cationic gemini surfactant (bis(cetyltrimethylammonium) butane dibromide). The morphology of resultant nanocomposites was investigated by means of TEM at different magnifications and for all metal nanoparticles/graphene nanocomposites and it was observed that in case of Gemini surfactant nanoparticles are uniformly distributed as compared to CTAB, in which nanoparticles show a strict aggregation (Song et al., 2012). Colloidal gold nanoparticles, nanoclusters and nanowires are prepared by (Bakshi et al. 2007) in aqueous phase under ambient conditions with Gemini surfactants (from 12-2-12 to 12-6-12 and from 10-2-10 to 14-2-14) in the presence of cyclodextrin, which has strong ability to complex with surfactant tail. UV-Visible and TEM studies shows that Gemini surfactants, due to their stronger hydrophobic interactions bring nanoparticles in nanoclusters or nanowires arrangement and hence acts as better templates as compared to conventional.

As presented in the introduction and literature review, metal chalcogenide nanoparticles have attracted much attention in past few years due to change in their optical properties in accordance with their small size and applications such as infrared photovoltaics, optical switches, photodetectors, optical detectors, laser devices, thermoelectrics, solar cells, super ionic material, electrical conductive
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material, thermoelectric cooling materials and optical filters etc. these properties and applications paves the way to the present study having a focus on a systematic and encyclopaedic work to synthesize and characterize semiconductor nanoparticles by using a series of Gemini surfactants. In all the cases, the aim was to achieve the size controlled synthesis by adjusting the surfactant concentration and hydrophobicity. All reactions have been carried out in aqueous phase keeping in mind the environmental concern and to achieve their better applications. The effect of hydrophobicity has been thoroughly evaluated on the synthesis of these nanomaterials. The results have been generalized on the basis of surfactant hydrophobicity, which is considered to be the driving force for the interfacial adsorption of surfactant molecules.

By implementing these factors on the various reactions, the following objectives were achieved.

**Objectives:**

1. Synthesis of Gemini surfactants through the methods in the literature available.
2. Preparation of semiconductor nanoparticles (Metal chalcogenides such as PbTe, Cu_{(2-x)}Te etc.) by using the synthesized Gemini surfactants.
3. To testify the effect of hydrophobicity of various Gemini surfactants on semiconductor nanostructure.
4. Spectroscopic and morphological characterization by various techniques such as UV-Vis-near IR spectrophotometer, FTIR, RAMAN, PL, XRD, SEM, TEM and EDAX.
5. Exploration of structural, optical and electrical properties of aforesaid semiconductor nanoparticles for their countless innovative applications in the contemporary semiconductor industry.