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Synthesis of Silica Nanoparticles: A Review

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Abstract: The prefix "nano" in the term Nanoscience or Nanoparticle accounts one billionth or 10^{-9} units. Nanoparticles possess unique size and shape reliant chemical, physical, magnetic and optoelectronic traits varying from that of bulk material due to its large surface area to volume ratio. There are two different approach for the synthesis of nanoparticles: Top to bottom approach and bottom to top approach. Silica nanoparticles are optimistic agents in variety of areas like drug delivery, water purification, environmental bioremediation, disease diagnostic and therapeutic applications. In the present study chemical and biogenic synthesis of silica nanoparticles with variable precursors are discussed.
Keywords: Silica nanoparticles, Sol-gel method, Stober method, Biogenic synthesis

I. INTRODUCTION

Nanoscience has been recently recognized as interdisciplinary science and it encompasses intact acquaintance on elementary traits of nano-sized entities. The prefix "nano" in the term Nanoscience or Nanoparticle represents one billionth or 10^{-9} units [1]. Michael Faraday first provided an insight on scientific elucidation of nanoparticles properties in his famous paper "Experimental Relations of gold and other metals to light" [2]. The term nanotechnology was first depicted by Richard Feynman who is known as Father of nanotechnology in 1959 in his lecture "There's plenty of room at the Bottom" [3]. Nanoparticles possess unique size and shape reliant chemical, physical, magnetic and optoelectronic traits varying from that of bulk material due to its large surface area to volume ratio. As a result of these, nanoparticles possess variety of interesting applications like catalysts , electronic components, chemical sensor, pharmaceutical products and so on [4,5]. Silver nanoparticles are antibacterial, anti-cancer, anti-microbial, anti-fungal and anti-ageogenic agents. They are also utilized as drug delivery agents, air and water disinfectants, cell imagining and anti-stain textile agents [6-10]. Iron nanoparticles are anti-bacterial and anti-oxidant agents; they are also used as catalyst for environmental decontamination, dilapidation of ionic dyes and adsorbent for heavy metals [11, 12]. Gold nanoparticles functionalized with polyethylene glycol are as employed in drug and gene delivery agents [13]. Copper nanoparticles are used in gas sensors, catalytic process to reduce toxic azo dyes Congo red and methyl orange, high temperature superconductors and solar cells. Copper nanoparticles also possess anti-microbial, anti-oxidant, and anti-cancer traits [14-16]. Silica nanoparticles are promising agents in variety of areas like drug delivery, water purification, environmental bioremediation, disease diagnostic and therapeutic and so on [17,18].Different physical, chemical and biological methods employed for the fabrication of nanoparticles can be classified in mainly 2 approached: First is the Top to bottom approach which involves gradual controlled devastating of bulk substance into dwarf particles by size reduction. Second one is the Bottom to top approach in which self adhering of atoms to nuclei leads to formation of particles of variable sizes [19, 20].

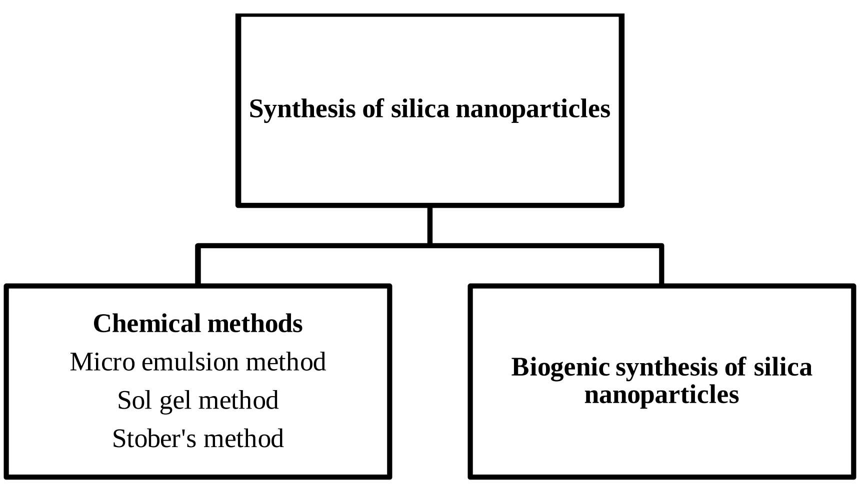

Figure 1: Synthesis of silica nanoaprticles

II. CHEMICAL SYNTHESIS OF SILICA NANOPARTICLES

A. *Micro Emulsion Method*

Microemulsions are uniform, macroscopically analogous and thermodynamically stable solutions comprising of three components: a polar phase, a non-polar phase and a surfactant. Reverse micelles can be understood as water in oil microemulsion in which polar head of surfactant molecule is attracted towards aqueous core and is oriented inwards whereas hydrocarbon chain is attracted towards non-polar core and oriented outwards. At specific ratio of aqueous phase and surfactant, these reverse micelles behave as identical nanosize reactors which allow precipitation of organic and inorganic substances . R.Nooney et. al. fabricated far-red fluorescent cyanine dye Cy5 and FR670 doped silica nanoparticles by microemulsion method for detection of C-reactive protein , a bio-marker for cardiovascular disease . This method allows effective coating of nanoparticles with different functional groups for range of applications. The major drawback of this process is its high cost and adversity in removal of functional groups in final product [21-24].

B. *Sol Gel Method*

Synthesis of nanosilica by sol-gel process mainly involves hydrolysis and condensation of metal alkoxides or inorganic salts such as tetraethylorthosilicate or sodium silicate respectively in the presence of mineral acid or base which acts as catalyst. Hydrolysis of alkoxides or inorganic salts leads to the formation of silanol groups and condensation in between them results in whole silica structure . Silica nanoparticles fabricated using tetraethyl orthosilicate, ethanol, water, ammonia and surfactants (Sorbitan monolaurate, sorbitain monopalmitate and sorbitain monostearate) by sol-gel upon incorporation in cementitious substance improved its morphology and mineralogy . R.S.Dubey et. al produced silica nanoparticles by sol-gel method using tetraethyl orthosilicate precursor and Polyvinylpyrrolidone surfactant . Sol-gel is simple and efficient technique to produce high purity Nanomaterials. But it involves use of organic solvents which may be toxic and has prolonged reaction time [25-28].

C. *Stober's Method*

The fundamental principle of Stober's process is hydrolysis and condensation polymerization of silica source in presence of ammonia catalyst and ethanol solvent. Surface modified Stober silica synthesized using tetraethylorthosilicate precursor, ammonia catalyst and hexamethyldisilazane surfactant resulted in improved dispersion of silica in hydrophobic environment . H. Rutledge et. al. fabricated germanium quantum dots embedded silica by Stober's method . Stober's method relatively simple and effectual process facilitating size regulation of nanoparticles . The major drawback of Stober's process is requirement of expensive raw material in synthesis process and risk of environmental hazard [29-32].

III.BIOGENIC SYNTHESIS OF SILICA NANOPARTICLES

Biogenic silica is exceptional substitute to synthetic silica due to its cost-effective synthesis, eco friendly preparations , density, composition and less toxicity . J. Athinarayanan et al. prepared biogenic nanosilica from acid pretreated rice husk as precursor. The author revealed that fabrication biogenic silica could be successfully employed in bone tissue engineering application . Biogenic silica prepared from 3 varieties of acid treated rice husk ash namely sticky rice husk, brown rice husk and red rice husk as precursor exhibited anti-bacterial activity against gram positive (*Escherichia coli*) and gram negative (*Staphylococcus aureus*) bacterial stains respectively . Kalboush, Zeinab, A.,et al. prepared biogenic silica from rice staw and rice husk and revealed its antifungal activity against *P. grisea* and *B. oryzae* . Extraction of silica nanoparticles from corn stalk by sol gel hydrothermal method using CTAB as template led to the formation of amorphous nanosilica. Silica nanoparticles are promising drug delivery candidates . Silica nanoparticles prepared from *Cynodon dactylon L.* by sol gel method led to the formation of spherical, monodispersed particles with size range 7-80 nm. These silica nanoparticles exhibited anti-microbial activity against bacterial stains *Bacillus subtilis*, *Staphylococcus aureus*, *Escherichia coli* and *Pseudomonas aeruginosa* [33-38].

IV. CONCLUSIONS

Nanoparticles are fundamental building blocks of nanoscience and nanotechnology with dimensions ranging from 1-100 nm. Differnt chemical and biogenic methods of synthesis of silica nanoparticles are utillized to fabricate nan-silica. Chemical mehtods for synthesis of silica nanoparticles mainly include sol-gel synthesis, micro-emulsion techniques and stober's method. Biogenic synthesis is advantageous due to its low cost, simplicity of process and eco-friendly characterstic. Silica nanoparticles are promising agents in variety of areas like drug delivery, water purification, environmental bioremediation, disease diagnostic and therapeutic and so on . Different agro-waste derived precursors such as corn stalk, rice husk, *Cynodon dactylon L* . Hence , biogenic synthesis of silica nanoparticles is an optimistic approach to fabricate improved and cost-effective nanosilica.

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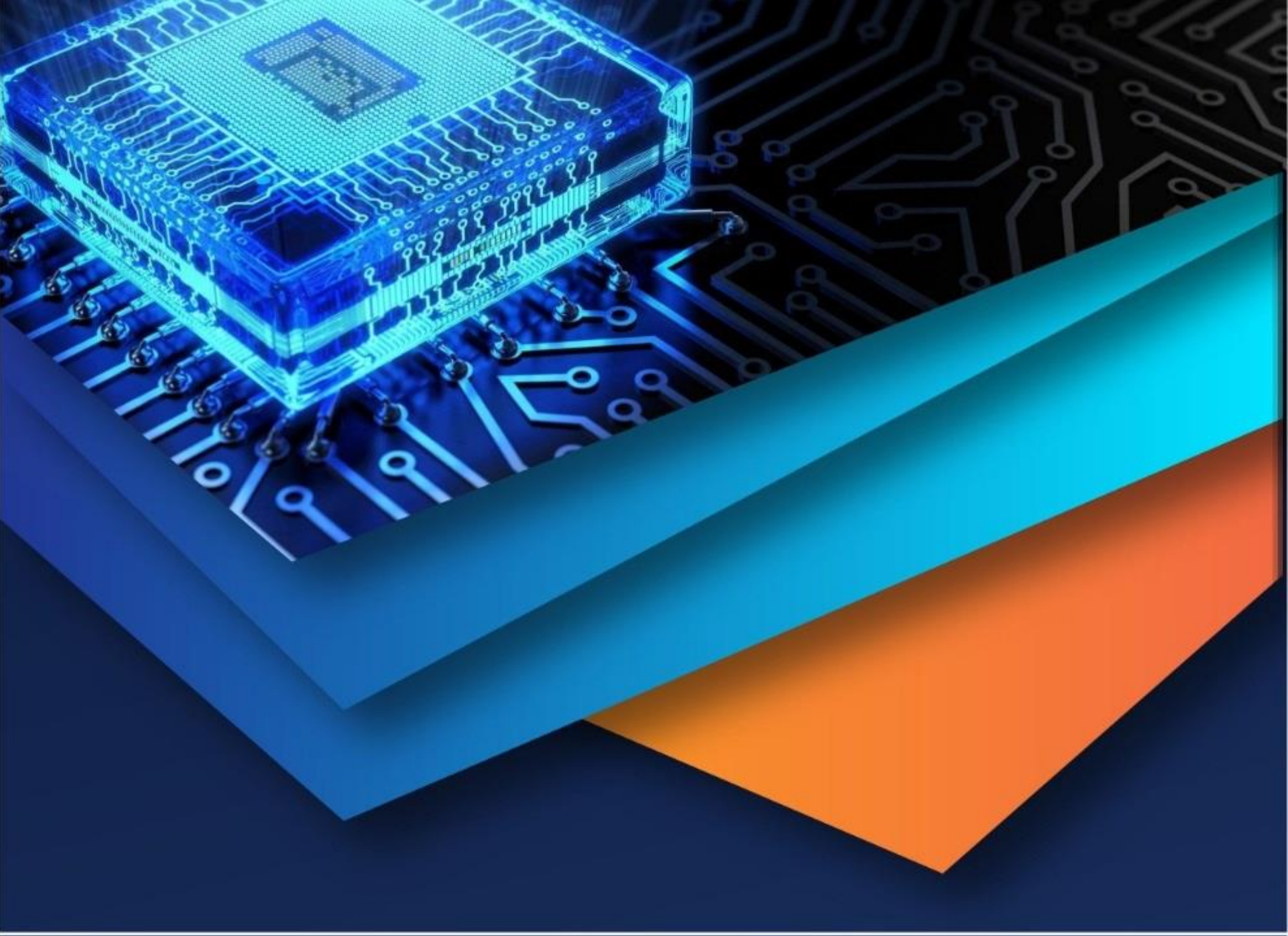

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