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SILICA AEROGEL NANOPARTICLES AS HEAT SHIELD AND FLAME RETARDANTS

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ABSTRACT
Silica aerogel nanoparticles have been synthesized from rice husk and beach sand via sol – gel technique as a green route. Flames from fire or heat waves have destroyed both lives and properties worldwide. Heat shield and flame-retardants (FRs) are synthetic materials used to prevent or slow the spread of heat and flame from fire. Hence, this group of materials is required in homes, school, transport systems, offices and industrial sites as safety substances. Flame-retardants can be use directly or as additives unto combustible items to slow ignition and prevent fire. Common categories of flame-retardants include chlorinated flame-retardants (CFRs), brominated flame-retardants (BFRs), phosphorus flame-retardants (PFRs), nitrogen flame-retardants (NFRs), Inorganic, and mineral compounds flame-retardants. In this work, we successfully characterized the silica nanoparticles grown in terms of the thermal energy transport through them with the use of a hotdisk thermal constants analyzer. The particle size and shapes' distribution were verified using a transmission electron microscope. The aerogels' ignition capabilities were tested by directly spraying them unto a flame as well embedding them in a combustive material before setting the material on flame. The results confirmed the low thermal transport via the aerogels and their non-combustive nature making their usage as heat shields and flame-retardants.

KEYWORDS*:* Silica aerogel, nanoparticle material, heat shield, flame retardant, thermal conductivity.

INTRODUCTION
Emerging environmentally friendly materials with high temperature thermal tolerance, high fire resistance and cost efficiency as insulation materials are in high demands for homes, schools, markets, worshipping centers, aerospace, land vehicles, navigational ships, military or security formations and the list is endless.

The frequent looses from fire disasters arising from man- made or natural cause calls for alternative material that is readily, cheaply and easy to carry about to augment the existing synthetic substances being used as thermal barriers or insulators and flame retardants.

Fire fighters require special fabric while on the field to quench any fire. There have severally reports of fire out breaks in airports, seaports, industrial estates, military base and institutions of learning.

Miskiewicz et'al., (2022) reported in their paper that aerogel is increasingly becoming the most attractive materials for protection against high temperature due to their light weight nature and low thermal radiation transmission. And that traditional clothing protecting against extreme temperature and heat is usually made of thick, multilayer material systems whose efficiency increases with increasing thickness, however, the use of aerogel provides adequate safety against heat and flame without excessive increase in their thickness and hence the mass. Their experiment on coating mixture based on silica aerogel led to a decline in thermal conductivity.

Traditionally, sand and water are used to put off any fire outbreak. These two notable natural materials are bulky and heavy to transport from where they exist to the areas of need. Hence, the needs for lighter materials like silica aerogels.

Herein, we present another sustainable and eco – friendly synthetic material from biological (rice husk) and as well from geological (beach sand) origins – nanosilica aerogel via the sol – gel technique.

Sol – gel technology is very popular and novel materials processing technique consisting of a system transition from liquid sol to solid state in the gel form (Miskiewicz et'al., 2022). The technology involves solution formation, gelling, aging, drying and thickening (Chen et'al., 2017).

CHARACTERISTICS OF SILICA AEROGEL

Silica aerogel is a choice material for use in almost every known human endeavor. It has exhibited fantastic and extreme unique properties that are enabling its uses in modern technology. Some of these properties include small particle size, from 2nm – 400mm (Dorcheh et'al.,2013,Gurav et'al.,2010,Thapliyal et'al.,2014), approximate mean pore diameter of 20nm(Nadiir et'al.,2013) and made up of 80% - 99.8% air (Greszta et'al.,2019). The density is extremely low of 120 – 150 kg/m^3 , low thermal conductivity of 0.004 – 0.018$Wm^{-1}K^{-1}$ (Venkataraman et'al.,2015, Shaid et'al.,2014, Jin et'al.,2013). The surface area lies between 500 – 1000m^2/g (Gurav et'al.,2010;Greszta et'al.,2019 and Jin et'al.,2013).

Silica aerogel is an inorganic, non – inflammable and a heat shielding material with a continuous operating temperature range from -273^oC to 650^oC and a high melting point of 1400^oC (Nadiir et'al.,2013). They further reported that the silica aerogel is an excellent firewall compared to the existing non-combustible organic fire - proof coatings that cause toxic fumes when burning.

The use of Aspen Aerogels as thermal barrier with an exposition to a flame of temperature of 1100^{o}C for quarter an hour but a record of about 150^{o}C at the opposite of the aerogel tile illustrates this material as not only a thermal insulator but a fire retardant (Nadiir et'al., 2013).

The space industry as a transport outfit is not spare of dense air, ice, water and liquefied air accumulation within the insulation materials in an aircraft. The overall effect of this disturbing and occurring phenomenon is the lack of the attainment of an optimum performance of a spaceship by increasing the thermal energy transmission via the insulation substance, thereby increasing the lift – off weight and risk to damaging debris. Hence, a solution to this problem (Fesmire J.E 2006) is the use of silica aerogel as a heat shield in the liquid –hydrogen (LH_2) tanks and liquid-oxygen (LO_2) cryogenic systems feed lines.

The silica aerogel from the experiments conducted by Fesmire et'al (2008) is able to prevent liquid nitrogen (LN_2) from being stored within the inter tank of a space shuttle as silica aerogel bulk adds up to the insulation system.

The significance of the deployment of silica aerogel as a heat shield within a cryogenic insulation set up is in the assessment of the performance of the cryogenic insulation systems-the lift off and re-entry into the space environment by space shuttles if sudden changes in pressure and temperature occur. The temperature of a vehicle during a re – entry is above thousand degrees on the Celsius scale with the condition that the LH_2 and LO_2 being retained below -253^{o}C and – 183^{o}C respectively in order to remain in the liquid state (Nadiir et'al., 2013).

GROWTH OF NANOSILICA AEROGEL

The figure below is a flowchart showing the path and processes followed to synthesize the nanosilica aerogel from rice husk (RH) and beach sand (BS.)

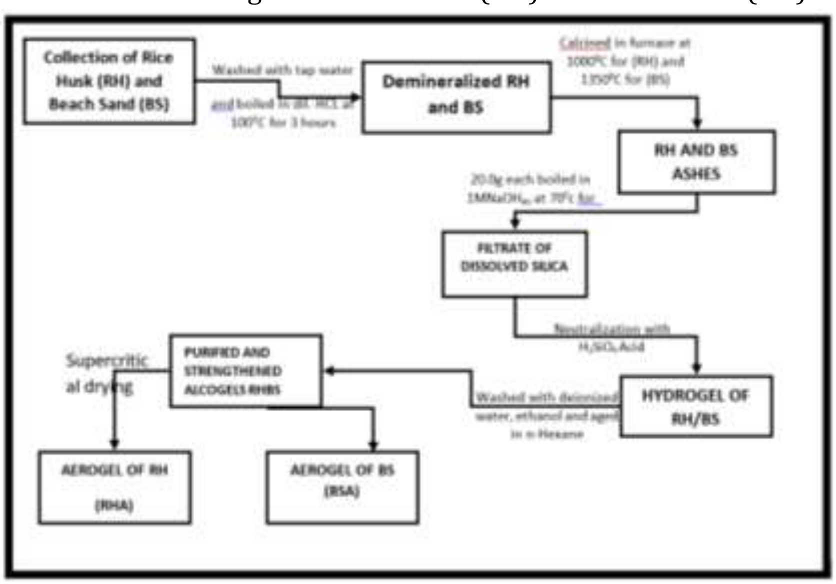

FIGURE 1: FLOW DIAGRAM OF SYNTHESIS OF SILICA NANOPARTICLE FROM RICE HUSK AND BEACH SAND

CHARACTERIZATIONS

The aerogels obtained were characterized in terms of thermal conductivity with the use of the Hot Disk Constants Thermal Analyzer and particle size with the use of a Transmission Electron Microscope (TEM).

The flame retardancy test of the synthesized silica nanoparticles was done by spraying the aerogel granules each from the rice husk and beach sand source unto a glowing flame. The second confirmatory test was the embedment of the separate aerogel in a piece of squeezed paper set on flame.

The third test of the flame retardancy was the mixing of the matchstick chemical with the separate aerogel in a pasted form but dried later before setting them on flame by striking the dried paste on a matchbox.

RESULTS AND DISCUSSION

TABLE 1: VARIATION OF THERMAL CONDUCTIVITY OF SILICA AEROGELS WITH TEMPERATURE RISE

TEMPERATURE ^{0}C (OR K)	THERMAL CONDUCTIVITY IN W/mK	
	RICE HUSK AEROGEL	**BEACH SAND AEROGEL**
50 (323)	0.196	0.188
100 (373)	0.187	0.183
I70 (443)	0.188	0.176
200 (473)	0.155	0.146
250 (523)	0.156	0.134
300 (573)	0.150	0.138

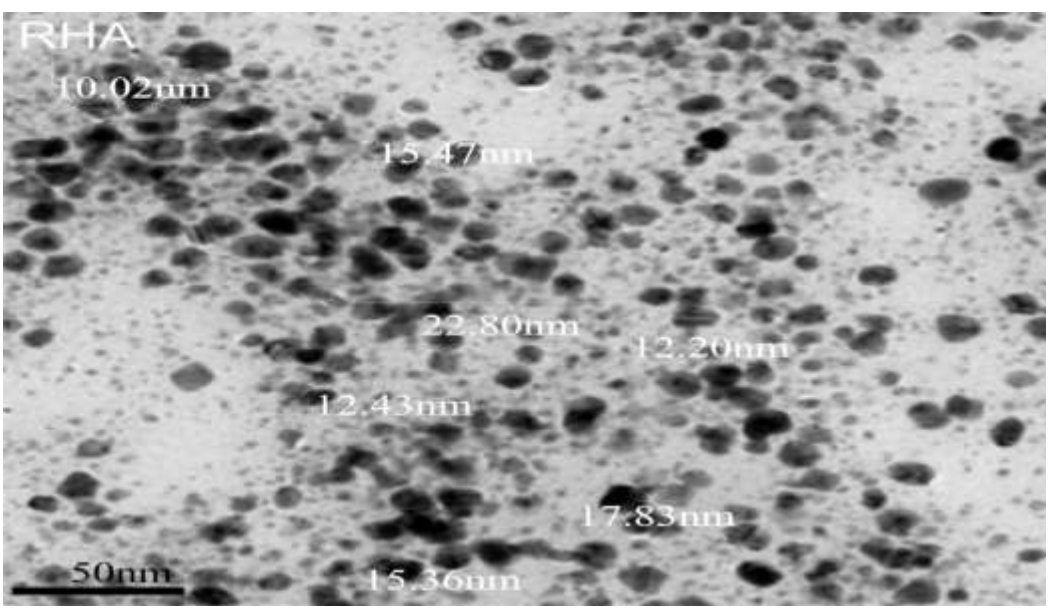

FIGURE 2: TEM IMAGE OF RICE HUSK SILICA AEROGEL NANOPARTICLE AT 50nm MAGNIFICATION

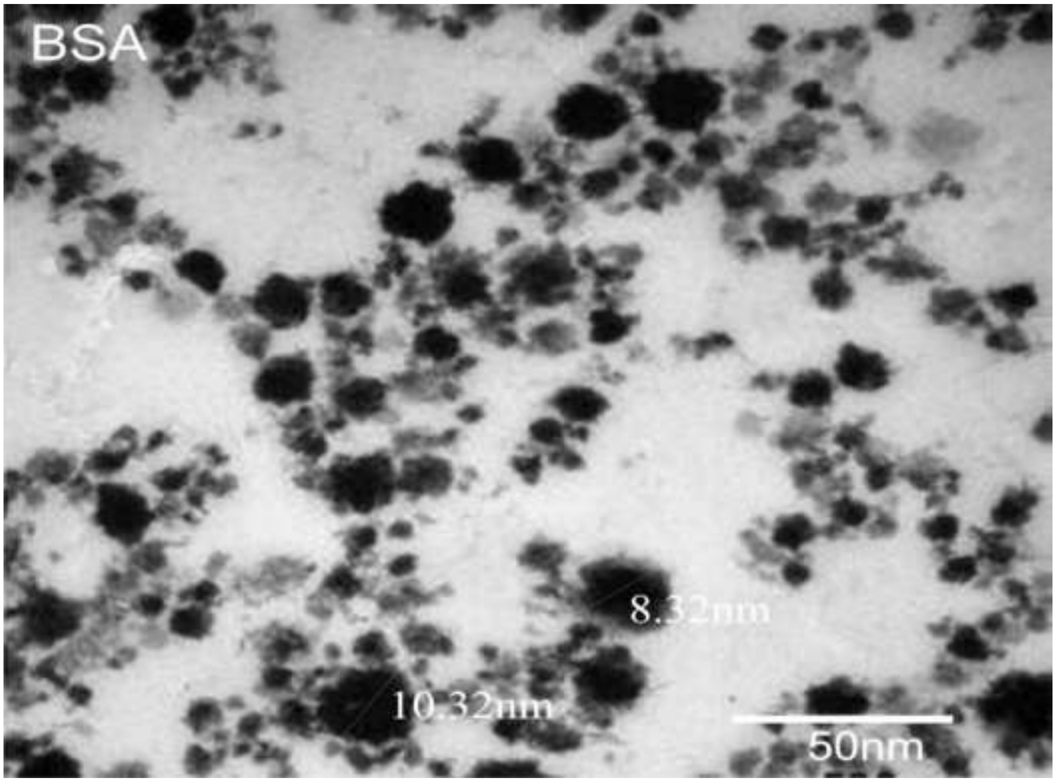

FIGURE 3: TEM IMAGE OF BEACH SAND SILICA AEROGEL NANOPARTICLE AT 50nm MAGNIFICATION

The thermal tolerance and stability is evident from the thermal conductivity test results. We recorded a low thermal conductivity values with rising temperature that eventually became stable at elevated temperature.

The average particle size of the rice husk and beach sand silica aerogel is 15.16nm and 9.33nm from figures 1and 2 respectively with polygonal shapes as obtained from the TEM analysis.

The flame resistive capacity of the aerogels was evident from all the confirmatory tests carried out. The quenching of the glowing flame when the aerogel was sprayed separately.

The second confirmation arises from the non – combustive behaviour of the embedded system of squeezed paper with the separate aerogel when ignited by a matchstick.

Lastly, is the inability of the mixture of the matchstick chemical and separate aerogel to ignite or support combustion upon scratching the stick on the rough surface of the matchbox.

CONCLUSION

The low thermal conductivity with rising temperature via the nanosilica aerogels shows the heat shielding or heat inhibitive capability of the synthetic aerogel from rice husk, beach sand respectively while their non-inflammability, and non-combustive features earn this novel material as a good flame-retardants or fire extinguisher.

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