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Development of New Sorption Materials for Refrigeration Purpose

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Abstract: ***Solid sorption refrigeration systems are environmental friendly as they run on low grade energy sources. Considering the long term benefits of the solid sorption refrigeration system, many theoretical and experimental studies are being carried out through the world. In this point of view we developed the new sorption materials for refrigeration and find the thermo physical properties and applied the solid sorption refrigeration system, for find out the absorption capacity of the pure sorbent and newly developed materials.Upon the basis of the refrigerant sorbent pair we selected the ammonia chloride sorption refrigeration system for applying the new sorption materials, by doing this experiment BaCl2 is used as sorbent material. We developed the new materials by adding the additives to the sorbent. We selected the additive as the high thermal conductivity material Expanded Natural Graphite. Finally we developed the new sorption materials and tested the thermo physical properties of the pure BaCl2 and mixed sorbent of the BaCl2-ENG and decent comparison obtained between the materials. And also find out the ammonia absorption capacity of the pure BaCl2 and mixed sorbent of the BaCl2-ENG and obtain the comparison for those of the two materials. Thermal properties such as thermal conductivity, specific heat and thermal diffusivity are measured. Thermal conductivity decreases with increase in fiber content. Specific heat of samples increases with increase in temperature. Thermal diffusivity decreases with increase in temperature. Which signifies the fibers will be resist to flow of heat acts as insulating.***
Keywords: Sorbent, solid refrigeration, BaCl2-ENG, Sorption Refrigeration System.

I. INTRODUCTION

Sorption is a physical and chemical process in this process one substance became absorbed by another substance. The sorption process is divided into two types, absorption and adsorption

1) *Absorption:* In this process one substance completely changes to another of different state is called absorption (e.g. liquids being absorbed by a solid or gases being absorbed by a liquid). During the absorption the total molecules are entirely dissolved to the absorbent to form a solution. This is a strong solution, once dissolved the molecules into the absorbent cannot be separate easily of those.
2) *Adsorption:* It is the physical contact or bonding of ions on the surface of another phase (e.g., reagents adsorbed to a solid catalyst surface); Compared to the absorption this is a week process, in this process the molecules are held loosely on the surface of the adsorbent, and it can be separated easily removed One main difference between the absorption and adsorption is the absorption involves the whole volume of the material and adsorption is a surface based process. In the absorption process the gas molecules completely absorbed by liquid, the process occurs completely within the whole of the absorbent. In the adsorption process the liquid molecules absorb the solid in the surface of the solid only, so this is a surface to surface process only.

Now a days the need of refrigeration technology is increasing anonymously, by this cause people are looking the alternate refrigeration technologies. In the place of vapor refrigeration system the solid sorption refrigeration system appeared it's named as the green refrigeration technology. Sorption refrigeration system is integrated with combined cooling, heating and power generation sources (CCHP).These are called CCHP systems now a day's in industrial sector this CCHP systems are used enormously. Sorption technology is more environmentally friendly in terms of refrigerant and demand of energy. The demand and supply base the energy determine the waste development around the world and every particle of human activity. To satisfying the world demand and to find out the sufficient supply of energy. The solid sorption refrigeration system was developed and which is driven by low grade energy. The solid sorption refrigeration systems are environment friendly systems they run on low grade energy resources such as waste heat and solar energy etc. The best example of high grade energy is electrical energy, because it is very easy to convert electrical energy into thermal energy by the use of electrical heater. At the same time it is not possible to convert thermal energy into electrical energy completely. Where as in thermal power plants only 30% of thermal energy is to convert electrical energy, this type of energy is called the low grade energy forms this is the basically difference between those two types of energies. Compare to low grade energy resources; high grade energy resources are more expensive

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A. Advantages Of Solid Sorption Refrigeration System

1) Solid sorption system can be activated a heat source with a temperature as low as 50^0C. So it has a wide operating temperature range.
2) Solid sorption systems have less corrosion issues for the adsorbent−refrigerant Working pairs as incorporated to high temperature
3) crystallization issue in the solid sorption system is less
4) Where as in serious vibration occurring time the solid sorption systems are more suitable. Ex. fishing boats and locomotives solid sorption system more suitable for these applications
5) The activated energy of the system is low grade thermal energy
6) Ozone layer depletion potential and global warming potential are zero

B. Types Of Sorbents Used In The Solid Sorption System

Types of sorbents used in the solid sorption system are

1) Physical sorbents
2) Chemical sorbents
3) Composite sorbents

Rao et al., (2012), studied on the solid sorption refrigeration system; in this system they used the $SrCl_2$and NH_3 as working pair. NH_3 as the refrigerant $SrCl_2$ as the absorbent the whole analysis is based upon the heat and mass transfer aspects. They obtained the results in terms of the coefficient of performance (COP) and specific cooling power (SCP). Finally they find out by optimizing the bed and by controlling the operating parameters to obtain high COP and SCP.

Iloeje (1998) presented the highlights of solid absorber solar refrigerator design and existing parameters of the system. In this system$CaCl_2$ as absorbent stabilized with $CaSO_4$ design of an existing solid absorption solar refrigerator, using $CaCl_2$ stabilized it $CaSO_4$ as the absorbent. And they discussed the performances of the system also. The performances are also discussed. He identified the sources of poor performances of the system; they are high thermal and pressure inertia off the system, highest loss coefficient, and low absorbent thermal conductivity. By considering this parameters he designed new model refrigerator improved the performances of the system.

Rao et al., 2012 carried out solid sorption refrigeration system analyses with and without internal heat recovery. In this system employing ammonia as the refrigerant.

They used different combinations of salts, namely $MgCl_2/CaCl_2$, $CaCl_2/SrCl_2$ and $CaCl_2/CaCl_2$ and are studied for systems with internal recovery. The system chosen is the one that can produce ice at -10degree centigrade using a waste heat source available at 613K.They studied the four combinations of salts they concluded that $CaCl_2/CaCl_2$ cycle yields the highest coefficient of performance and specific cooling output per kilogram of the salt. They obtained the results in significant entropy generation is based upon the Cooling/heating of the generator/absorber. And they also find out IHR improves the performance of the system significantly.

Pierre et al., (2007) developed the solar thermo chemical prototype it can produce low temperature and tested during summer and autonym. They used the two simple solar flat plate collectors these are producing low grade heat and it cools 560L cold box down to -25^0C.

They select two cascade thermo chemical systems $BaCl_2$ as the reacting agent with ammonia. They operates the system two types of modes one is decomposition mode at high pressure in day time, another one is the cold production mode at low pressure in night time. They are proved experimentally the solar irradiation and outside are the major parameters influencing the process efficiency. And they showed the system performance during sunniest months, the rough solar coefficient of performance of the system as 0.031 over test period.

II. SELECTION OF SYSTEM AND MATERILS

Compared with other working fluid pairs ammonia-chloride system offers certain advantages Such as

1) High Heats Of Reaction And Fast Reaction kinetics
2) Higher Operating Temperature Range
3) Possibility of Energy Storage is high
4) Freedom from Crystallization

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So we selected the ammonia chloride refrigeration system.

A. Advantages of Ammonia Chloride System

1) By different refrigeration applications and wide operating conditions ammonia and chlorine soluble with each other

2) The major advantage of the ammonia-chloride solution is that water has strong affinity for ammonia.

3) Except copper and its alloys, the ammonia-chloride solution is highly stable and works well with many materials.

4) This system is used for domestic and commercial applications when the temperature is above 32^0F.

B. Selection of Refrigerant-Sorbent Pair

1) Refrigerant: Refrigerant is a substance usually a fluid used in heat pumps and refrigeration cycles. In this experiment I used ammonia as refrigerant because it has number of benefits.

2) Ammonia: Ammonia is a natural refrigerant, it is a combination of nitrogen and hydrogen with a chemical formula is NH_3.it has a color less gas and having a pungent smell. Ammonia has a one designation it is extremely soluble in water, and it is used as a water solution. And is used for many commercial cleaning purposes.

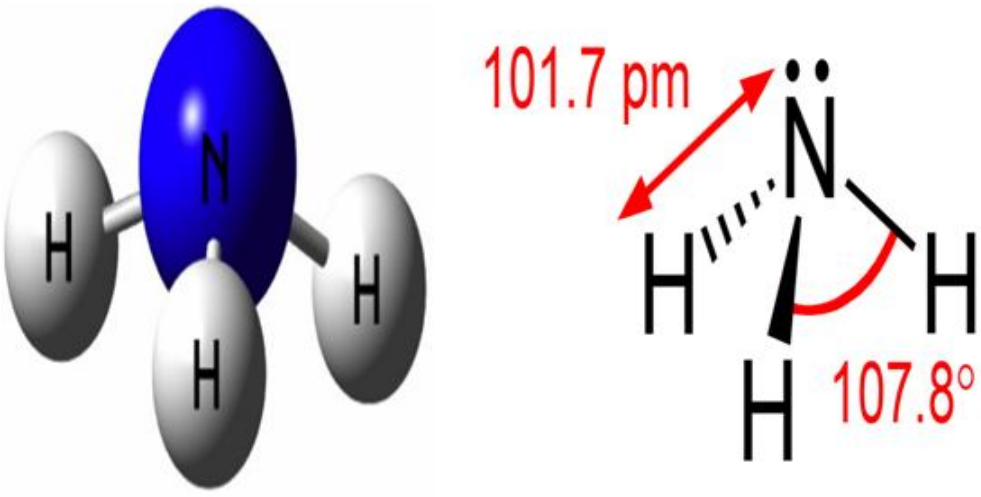


Fig: 1. Structure of ammonia

The fig: 1. shows the structure of ammonia it has a combination of three hydrogen molecules and one nitrogen molecules the three hydrogen molecules, one is the 101.7 microns per molecule and another two molecules have angle between them is the 107.8^0 .

3) Sorbent: Sorbent is a material used in the refrigeration systems or cycles for absorb or desorb the liquids or gases. a substance which has the property of collecting molecules of another substance by sorption. It has a large internal surface area and good conductivity. Now we used barium chloride as a sorbent upon our availability.

4) Barium chloride: Barium chloride is an inorganic compound with a chemical formula of $Bacl_2$. Compare to the all barium compounds barium chloride is the one of the most common water soluble salt. The colorization of flame is yellow-green. And it has a toxic nature. This is the availability of two forms hydrous and anhydrous barium chloride. Here we used the anhydrous barium chloride salt because it is most suitable in heat treatment.



Fig: 2. Anhydrous $BaCl_2$

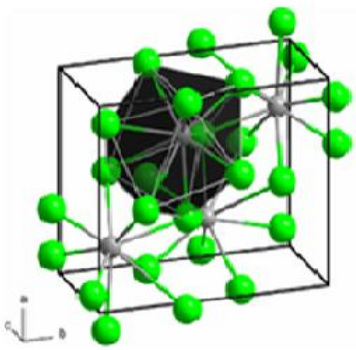


Fig: 3. Crystalline structure $BaCl_2$

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C. Expanded Natural Graphite

During alternate cooling and heating of the salt (sorbent) beds in the cyclic nature of the operations some additional losses occur during this time. For getting the require output amount of salt content in the sorbent has to be removed, heat and mass transfer characteristics has to be improved considerably. By adding the high thermal conductivity inert material to the sorbent like expanded natural graphite and vermiculite considerably increase the rate of heat transfer. And getting more absorption rate, so that's why we selected the expanded natural graphite as the additive.

Expanded natural graphite is made by immersing the natural flake graphite in a bath of chromic acid, then concentrated sulfuric acid, which forces the crystal lattice planes apart thus, expanding the graphite



Fig: .4. Natural graphite before expansion

III.SORBENT PREPARATION

The supporting base, graphite filled engine valve set up is fixed between the top and bottom plates of the universal testing machine. Beside the top and bottom plates load indicator is placed to know how much load applied on the piece. Below the load indicator the load set up and top and bottom plate's setup valves are placed. In the graphite sample preparation process first we applied a load of 15KN and tested the material broken, and after that we decrease the load to 12KN repeated the same result, finally we applied the 10KN this gave better result; graphite sample was prepared by applying the different weights of powders. Graphite samples were prepared.

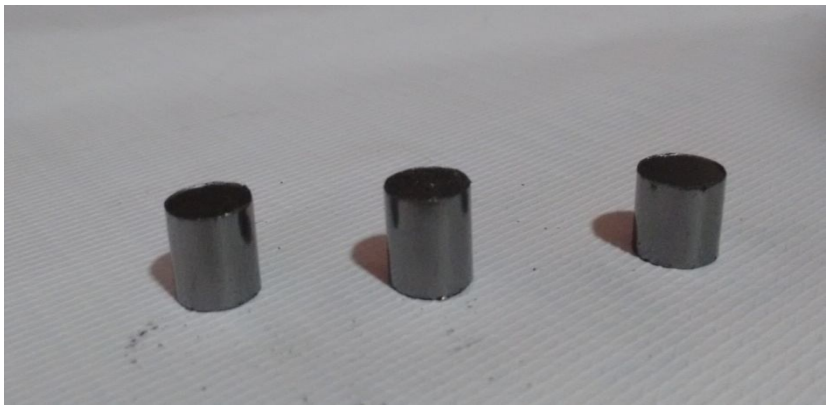


Fig 5. prepared graphite samples

A. Preparation Of Sorbent By Adding Expanded Natural Graphite As Additive

We prepared the composite sorbents of $BaCl_2$ and expanded natural graphite upon the different weight combinations, with water combination. The apparatus used for the preparation of the composite sorbent were HOT AIR OVEN and, PORCELAIN CRUCIBLE.

Barium chloride and graphite are mixed in the porcelain crucible to add the water based upon our requirement applied the stirring up to soluble the combination of graphite and barium chloride in to water. We added the chemical composition in the weight list 25gms of $Bacl_2$ and 5gms of graphite this is the one combination and 25gms of $Bacl_2$ and 10gms of graphite powder.

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Fig: 6. Mixture of sorbent with water



Fig: 7. Mixtures of $Bacl_2$ and graphite

This is the final sorbent powder prepared. We prepared like this type by changing the different weights of graphite and barium chloride. By handling of the sorbent powder we take few precautions, because the barium chloride has to release the harmful gases, we used face mask and hand gloves, after completing the work cleaned the hands with Dettol liquid hand wash. For doing of the heat treatment first time failure occurs. The crucible broken by applying the temperature of above 400^0C. Again remix the powders and repeat experiment by applying the temperature of 300^0C, in that time also little bit cracks occurs on the crucible, last time we applied the temperature of 250^0C, the perfect sorbent prepared, after that I continued the process by applying the same temperature.

IV. RESULTS AND DISVUSSIONS

A. Specific Heat

The figure below shows that comparison of the pure BaCl2 and mixed sorbent of the BaCl2 expanded natural graphite. So by adding the additives to the sorbent specific heat value is increasing very high rate. For the increase of the specific heat the average temperature of the molecules will increase and occurs collision to the molecules and impart energy to allow rotational and vibrational motion. The figure 8 sows the clearly the variation between the $BaCl_2$ and $BaCl_2$-ENG by adding the expanded natural graphite to the sorbent the specific heat value increased. By increasing the specific heat value the rate of heat transfer increase.

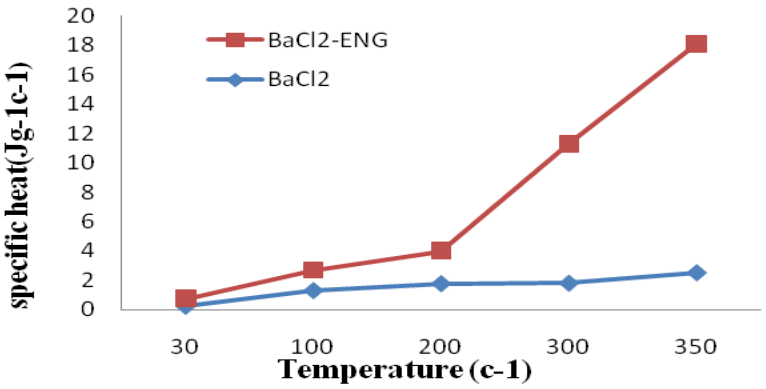


Fig: 8. Specific heat vs. temperature graph

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B. Thermal diffusivity test

Thermal diffusivity is defined as the thermal conductivity divided by the product of density and specific heat. It measures the rate of transfer heat of the material from cold side to the hot side. But here we don't know the thermal conductivity so we used the Laser Flash Apparatus (LFA) for find out the thermal diffusivity. By using the LFA apparatus we find out the thermal diffusivity value of the pure $BaCl_2$ and mixed sorbent of the $BaCl_2$-ENG. Obtain the comparison to those of the two sorbent that comparison is represented graphically in fig: 9.

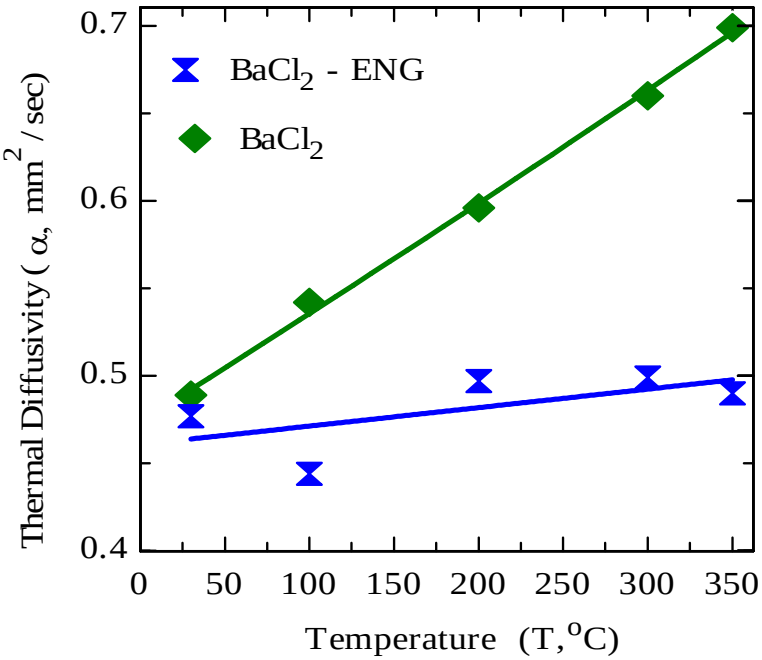


Fig: 9. Thermal diffusivity vs. temperature graph

C. Thermal conductivity test

The figure 10 Shows the thermal conductivity with varying temperature. In the above graph clearly observe that compare to the pure BaCl2, mixed sorbent of the $BaCl_2$-ENG getting higher value we concluded that by adding the additives to the sorbent considerably increase the rate of heat transfer for obtaining the higher rate of heat transfer more cooling effect will give the system to the room and can improve the life of the system also, and requirement of the pure sorbet to the preparation of the sorbent bed is also decrease.

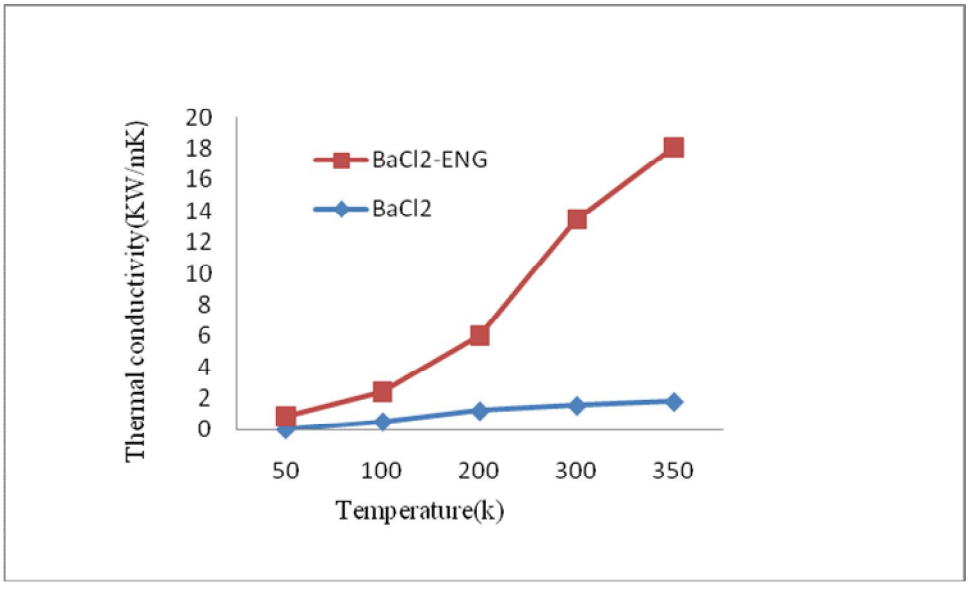


Fig: 10. Thermal conductivity vs. temperature graph

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V. CONCLUSION

Considering the long term benefits of the solid sorption refrigeration system we developed the new materials. That new materials developed by adding the additives to the sorbent. Here sorbent material is taken as the $BaCl_2$ and additive is the expanded natural graphite. Because expanded natural have high pore diameter, that high porous medium materials having a high thermal conductivity, due to that high thermal conductivity the rate of heat transfer is high. The analysis is based on to find the thermo physical properties and ammonia absorption capacity of the pure $BaCl_2$ and mixed sorbent of the $BaCl_2$-ENG.

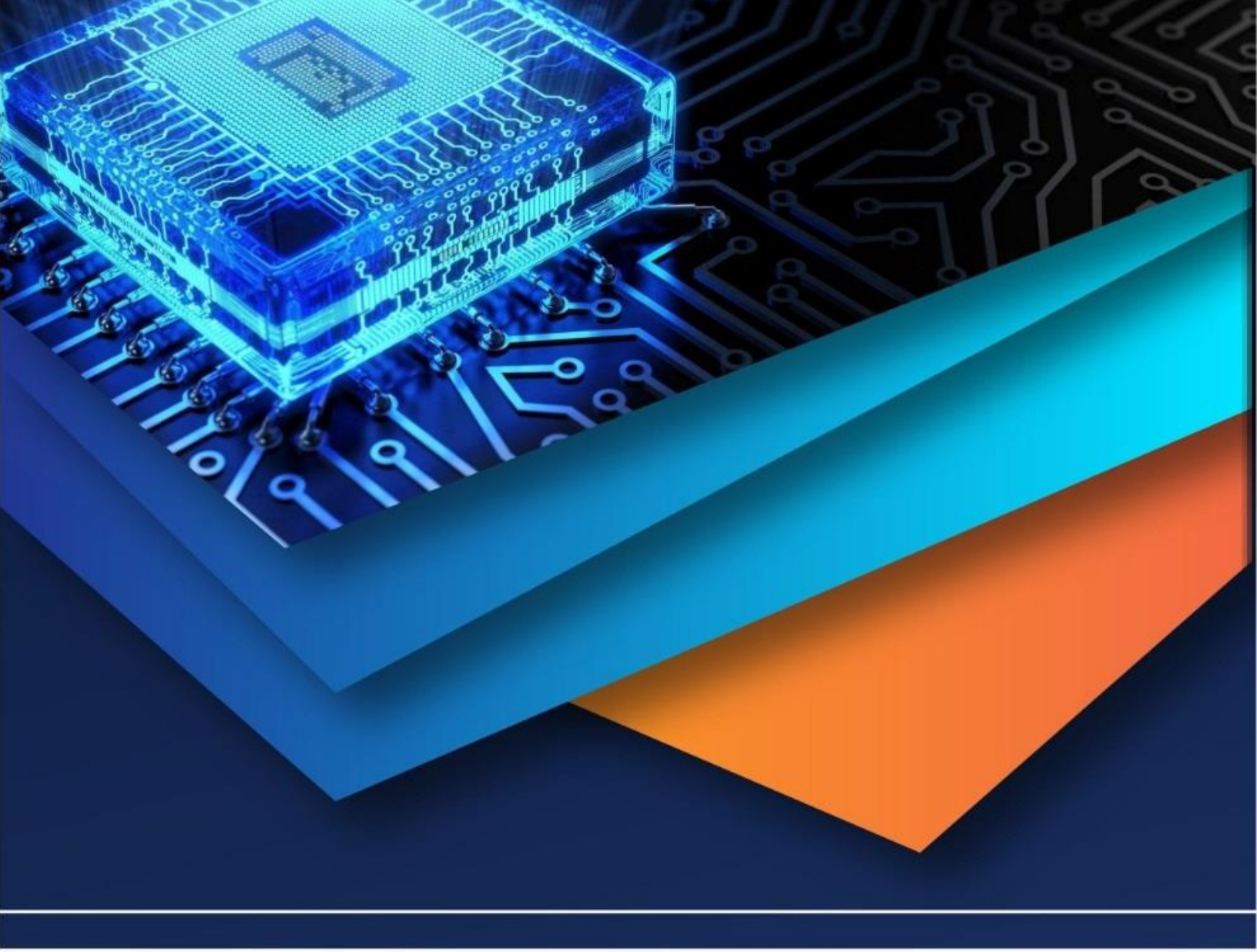
We find out the thermo physical properties such as thermal conductivity, thermal diffusivity, specific heat, coefficient of linear expansion, of pure $BaCl_2$ and $BaCl_2$-ENG. A decent comparison obtained between the with and without adding the $BaCl_2$.in the comparison we concluded that, the specific heat of the sample increased by increasing the temperature of by adding of the ENG to the $BaCl_2$. Compare thermal diffusivity of the pure $BaCl_2$ the, mixed sorbent of the $BaCl_2$-ENG value decreased, the decrease the thermal diffusivity means temperature rises. Another property also finds out thermal conductivity, its value increased by adding the ENG in to $BaCl_2$, thus the rate of heat transfer increased.

So finally we concluded that by adding the high porous medium materials to the sorbent can improve the rate of heat transfer and can also improve the life time of the system and required amount of pure sorbent is also decrease the adding of the additives to the sorbent bed.

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