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Synthesis of nanoparticles for controlling the solar heat gain through window

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Abstract: The applications of passive cooling techniques are increasing now these days. Further, the application of glass based windows and walls in the multistory buildings and complexes are also a new trend adopted by the building planners. These glasses increase the heat load of the room. For reducing the heat gain through glass windows/roofs different coatings have been analyzed in the present work. These coatings have been prepared by using different nanoparticles viz. magnesium oxide nanoparticle, zinc oxide nanoparticle, aluminium oxide nanoparticle. It has been found that zinc oxide based coating is best for reducing the heat gain. In this work a thermal indicator has also been proposed which changes the color with heat. The advantage of this copper sulphate based thermal indicator is that it can be reused. For regaining the color of the indicator from white to blue it can be treated with mineral water.

Keyword: Passive cooling technique, Nanoparticle, Glass, thermocol and Thermal indicator.

I. INTRODUCTION

Passive cooling techniques in buildings have proven to be most effective and can greatly impart in decreasing the cooling load of buildings. Passive cooling has also proven to provide excellent thermal comfort with very low energy consumption. The term lean signifies that the system is energy efficient so that only the amount of electricity needed to run fans and circulation pumps is required to maintain comfortable indoor temperature year-round. Passive cooling techniques can be classified in three main categories are solar and heat protection techniques, heat modulation techniques and heat dissipation techniques[1].

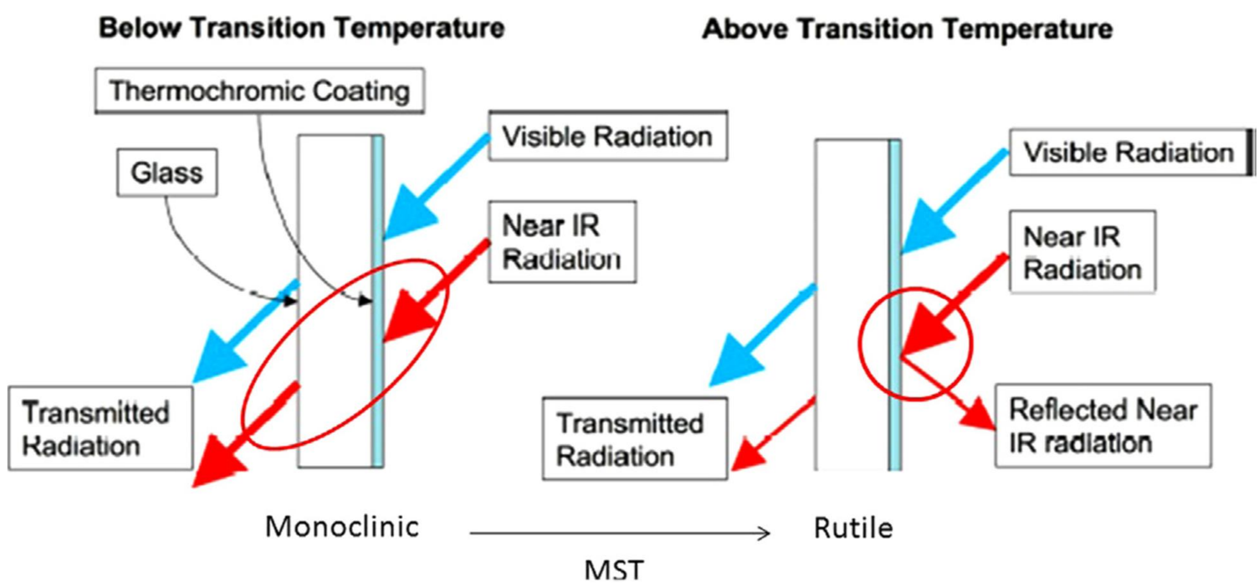

Fig. 1 Schematic representation of thermochromic materials applied as an intelligent windows coating

Smart windows defined as the type of windows that partially block the unwanted solar radiation, can help building to maintain higher energy performance levels. The energy performance can be improved by increasing heat gain in cold weather and decreasing it in hot weather by adopting windows radiative and thermal properties dynamically. Adding controllable absorbing layer on the

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surface of the glass can change the optical properties of the glass by controlling the incident solar heat flux. Therefore, smart windows lead to reduced HVAC energy consumption and size and electric demand of the building[2].
Thermochromism is the property of substances to change color due to a change in temperature[3].
Nanoparticles are particles of size between 1 and 100 nanometers. Scientific research on nanoparticles is acute as they have many potential applications in medicine, physics, optics and electronics. The term "nanoparticle" it usually refers to inorganic materials. Nanoparticles can demonstrate size-related properties importantly different from those of fine particles[4][5][6].

TABLE 1
PROPERTIES OF CHEMICAL WHICH USED

Property	Aluminium nitrate	Zinc nitrate	Copper nitrate	Urea
Formula	$Al(NO_3)_3$	$Zn(NO_3)_2$	$Cu(NO_3)_2$	CH_4N_2O
Molar mass	212.996g/mol	189.36g/mol	187.56 g/mol	60.06g/mol
Melting point	72.8^0C	110^0C	114.5^0C	133^0C
Density	$1.72g/cm^3$	$2.06g/cm^3$	$3.05g/cm^3$	$1.32g/cm^3$

II. EXPERIMENTAL SET UP AND METHODOLOGY

The testing zone consists of ten cubical shape structure made up of glass and polystyrene (Thermocol). Objects/Equipments used in the present work are glass, polystyrene (thermocol), thermocouple, water bowl, adhesive (gum), thermochromic indicator (copper sulphate), nanoparticles (copper-aluminate, zinc oxide and aluminium oxide) and weigh machine. In the figure 2 the glasses are coated with the mixture/paste of zinc oxide nanoparticle and adhesive.

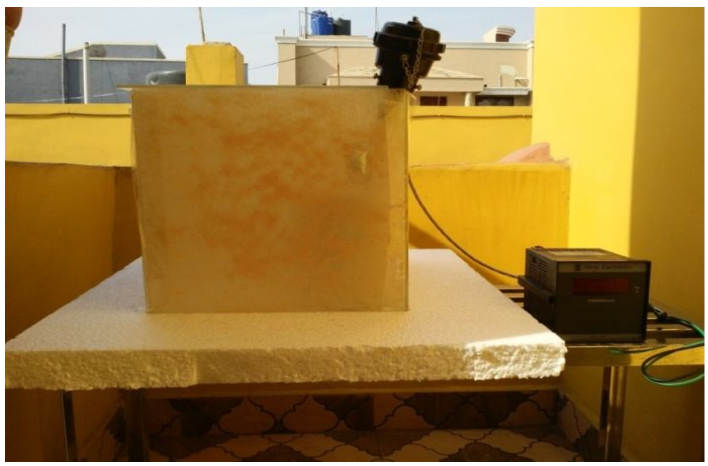

Fig. 2 Experimental Setup

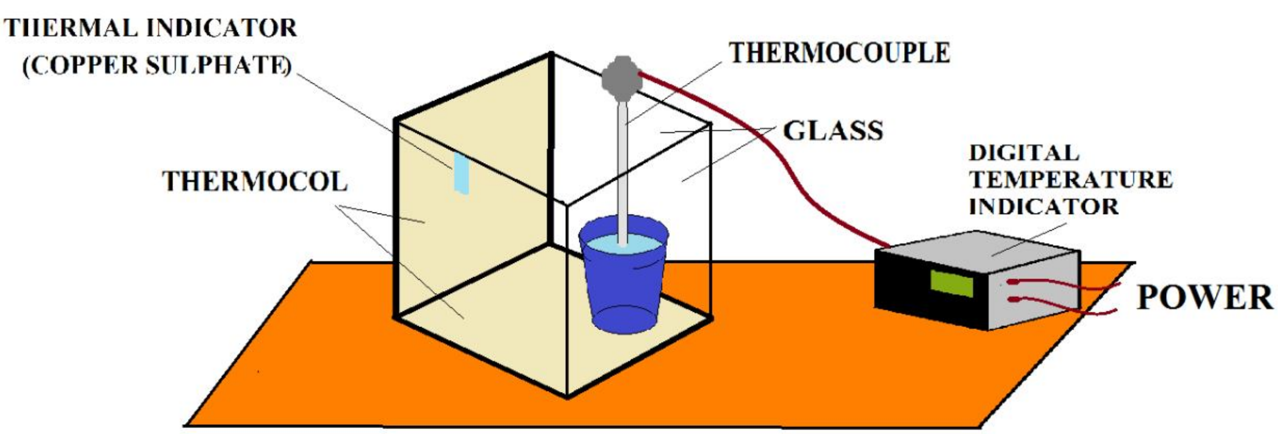

Fig. 3 Schematic diagram

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Ten different cubical structures of size 0.2×0.2×0.2 m^3 have been made for performing the experiments. These cubes are having four faces of glass and other two faces are of polystyrene (thermocol). All cubical structures are made in similar manner as described above. Three cubical structures are coated with aluminium oxide nanoparticles using 5gm, 10gm and 15 gm with the help of adhesive on the glass faces. Three cubical structures are coated with copper-aluminate nanoparticles using 5gm, 10gm and 15gm with the help of adhesive on the glass faces. Three cubical structures are coated with zinc oxide nanoparticles using 5gm, 10gm and 15gm with the help of adhesive on the glass faces and one cubical structure is coated with only adhesive i.e. without nanoparticles on the glass faces. A bowl of water is kept inside all the cubical structure setup and thermocouple is placed to measure temperature of water. All the setup is kept in sunlight for 5-6 hrs.

A. Thermochromic indicator

The property of thermochromic indicator is that they can change the color with change in temperature. For testing the behavior of thermochromic material, 5gms copper sulphate powder has been measured and stricked on the wall of the cubical structure.

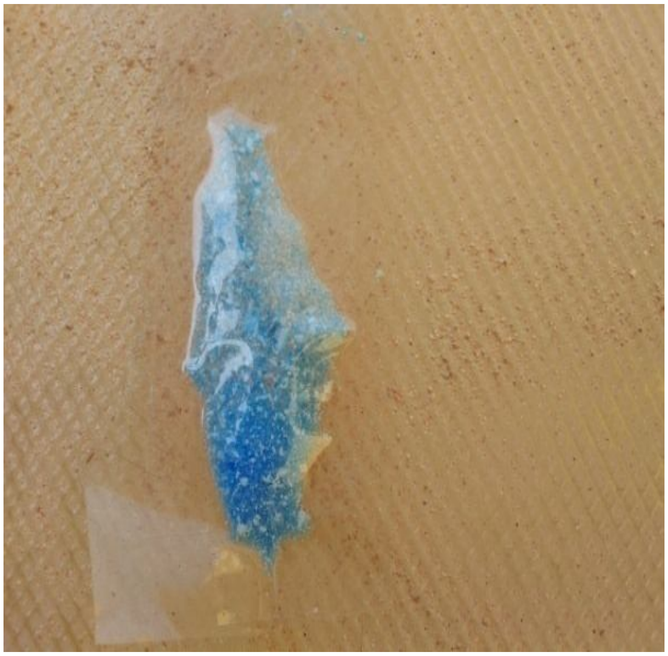

Fig. 4 Color of copper sulphate before

Fig. 5 Color of copper sulphate after

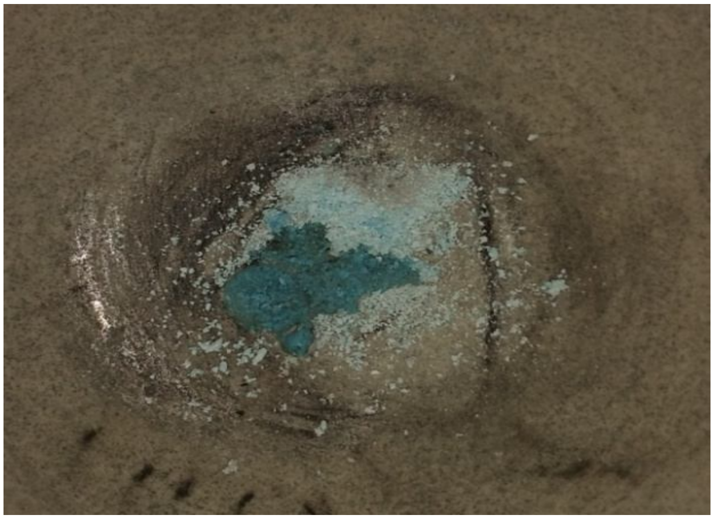

Fig. 6 Copper sulphate after putting drops of mineral water

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There are different types of thermal indicators but copper sulphate is used in the present work as a thermal indicator. As shown in figure 5 that after completion of experiment the color of copper sulphate has been changed. From the analysis of figure 6 it is evident that addition of few drops of mineral water into copper sulphate restores to its original color. The benefit of using copper sulphate as thermal indicator is that it can be used again and again.

III. RESULTS AND DISCUSSIONS

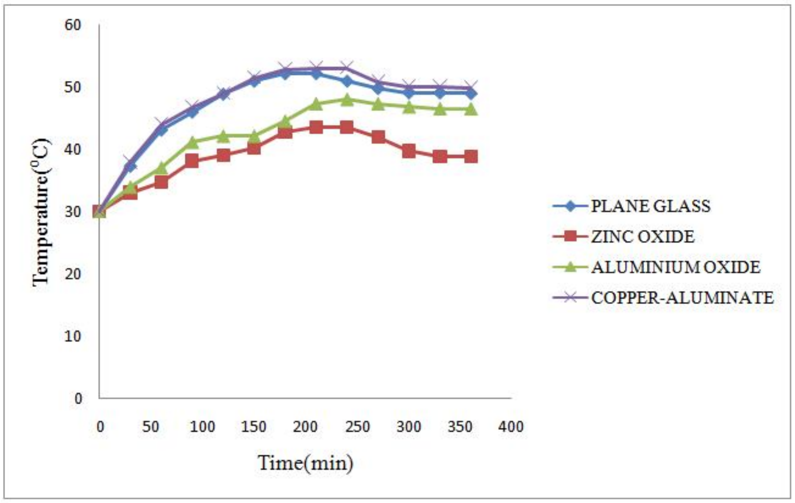

Fig.7 Comparison between time and temperature for 5gm nanoparticles

In the present work different types of nanoparticles have been prepared and applied over the test zone. The comparisons of solar heat gain in different conditions have been studied.
When 5gm nanoparticles are mixed with adhesive and coated on the glass faces-

1) *Plane glass:* Maximum temperature: 52.2^{0}C and minimum temperature: 30^{0}C.
2) *Zinc oxide nanoparticle:* Maximum temperature: 43.5^{0}C and minimum temperature: 30^{0}C.
3) *Aluminium oxide nanoparticle:* Maximum temperature: 48^{0}C and minimum temperature: 30^{0}C.
4) *Copper-aluminate nanoparticle:* Maximum temperature: 53^{0}C and minimum temperature: 30^{0}C.

From the analysis of figure 7 it is clear that zinc oxide nanoparticles are reducing solar heat gain and it is better for reducing solar heat gain than the other nanoparticles which have been used in the present work.

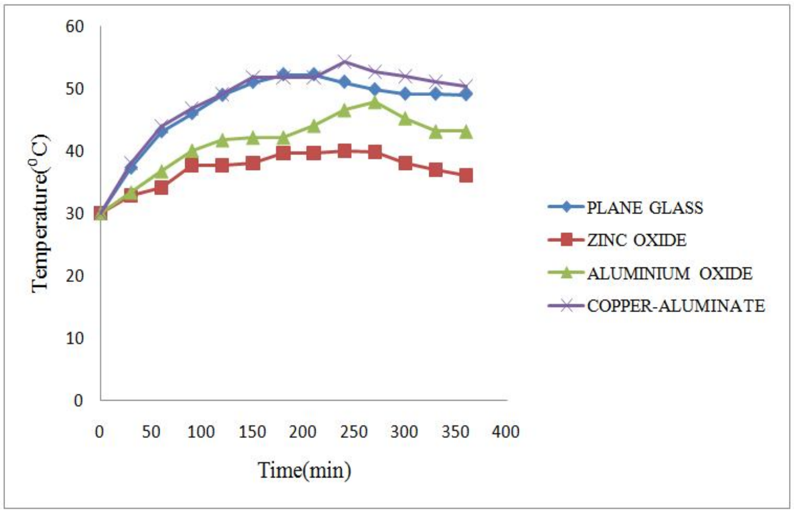

Fig. 8 Comparison between time and temperature for 10 gm nanoparticles

When 10gm nanoparticles are mixed with adhesive and coated on the glass faces-

1) *Plane glass:* Maximum temperature: 52.2^{0}C and minimum temperature: 30^{0}C.
2) *Zinc oxide nanoparticle:* Maximum temperature: 40^{0}C and minimum temperature: 30^{0}C.
3) *Aluminium oxide nanoparticle:* Maximum temperature: 47.8^{0}C and minimum temperature: 30^{0}C.
4) *Copper-aluminate nanoparticle:* Maximum temperature: 54.3^{0}C and minimum temperature: 30^{0}C.

From the analysis of figure 8 it is clear that zinc oxide nanoparticles are reducing solar heat gain and it is better for reducing solar heat gain than the other nanoparticles which have been used in the present work.

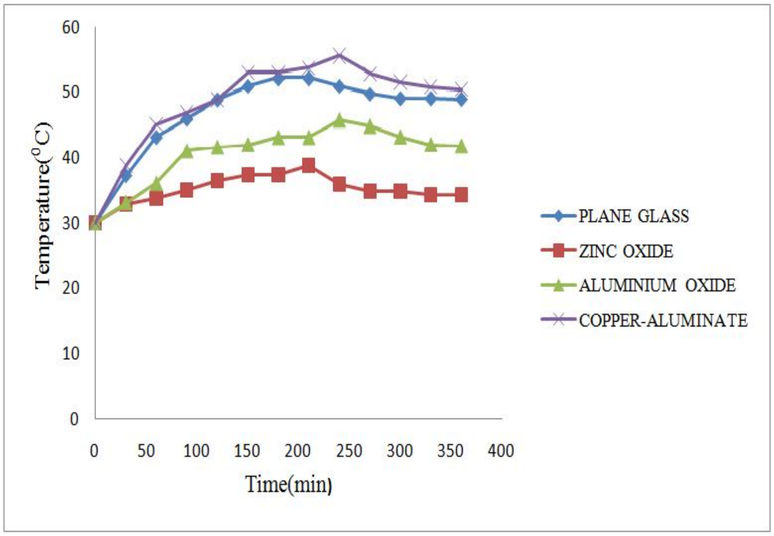

Fig. 9 Comparison between time and temperature for 15gm nanoparticles

When 15gm nanoparticles are mixed with adhesive and coated on the glass faces-

1) *Plane glass:* Maximum temperature: 52.2^{0}C and minimum temperature: 30^{0}C.
2) *Zinc oxide nanoparticle:* Maximum temperature: 38.8^{0}C and minimum temperature: 30^{0}C.
3) *Aluminium oxide nanoparticle:* Maximum temperature: 45.7^{0}C and minimum temperature: 30^{0}C.
4) *Copper-aluminate nanoparticle:* Maximum temperature: 55.6^{0}C and minimum temperature: 30^{0}C.

From the analysis of figure 9 it is clear that zinc oxide nanoparticles are reducing solar heat gain and it is better for reducing solar heat gain than the other nanoparticles which have been used in the present work.

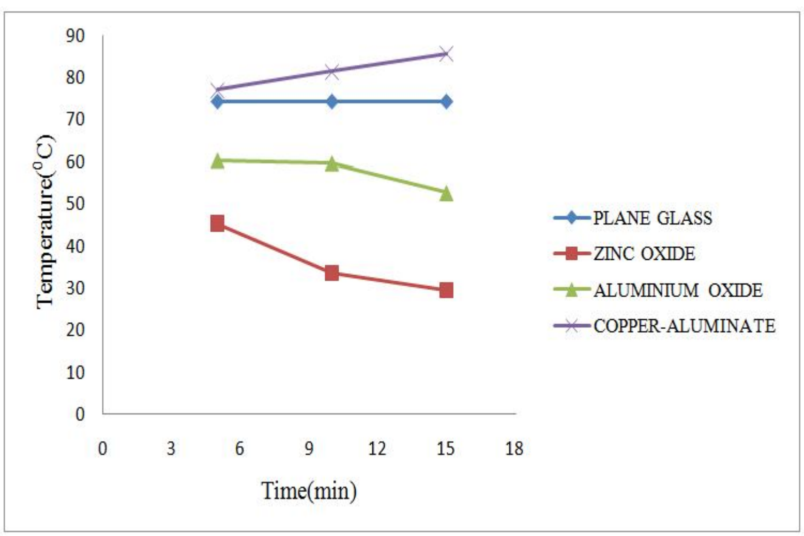

Fig. 10 Comparison between solar heat gains in different test zones of different nanoparticles

From the analysis of figure 10 it is clear that when all the nanoparticles are applied on the ratio of 5gm, 10gm and 15gm then it is found that the zinc oxide nanoparticles are better for reducing solar heat gain than the other nanoparticles which have been used in the present work.

IV. CONCLUSION

Passive cooling methods should be used because it is low cost exercise and it does not cause harm to the environment. Here various nanoparticles are used for the passive cooling and after comparing the results it can be suggested that zinc oxide based nanoparticles are work suitable for maintain comfort temperature during sunny days for human being.

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V. APPENDIX

TABLE 2

TEMPERATURE READING WHEN 5GM NANOPARTICLES ARE MIXED WITH ADHESIVE

TIME	PLANE GLASS	ZINC OXIDE	ALUMINIUM OXIDE	COPPER-ALUMINATE
0min	30^0C	30^0C	30^0C	30^0C
30min	37.3^0C	33^0C	33.9^0C	37.9^0C
60min	43.1^0C	34.7^0C	37^0C	44^0C
90min	46^0C	38.1^0C	41.1^0C	46.8^0C
120min	48.9^0C	39^0C	42.1^0C	48.9^0C
150min	51^0C	40.2^0C	42.1^0C	51.5^0C
180min	52.2^0C	42.7^0C	44.5^0C	52.9^0C
210min	52.2^0C	43.5^0C	47.3^0C	53^0C
240min	51^0C	43.5^0C	48^0C	53^0C
270min	49.8^0C	41.9^0C	47.3^0C	50.8^0C
300min	49.1^0C	39.7^0C	46.8^0C	50.1^0C
330min	49.1^0C	38.8^0C	46.5^0C	50^0C
360min	49^0C	38.8^0C	46.5^0C	49.8^0C

TABLE 3
TEMPERATURE READING WHEN 10 GM NANOPARTICLES ARE MIXED WITH ADHESIVE

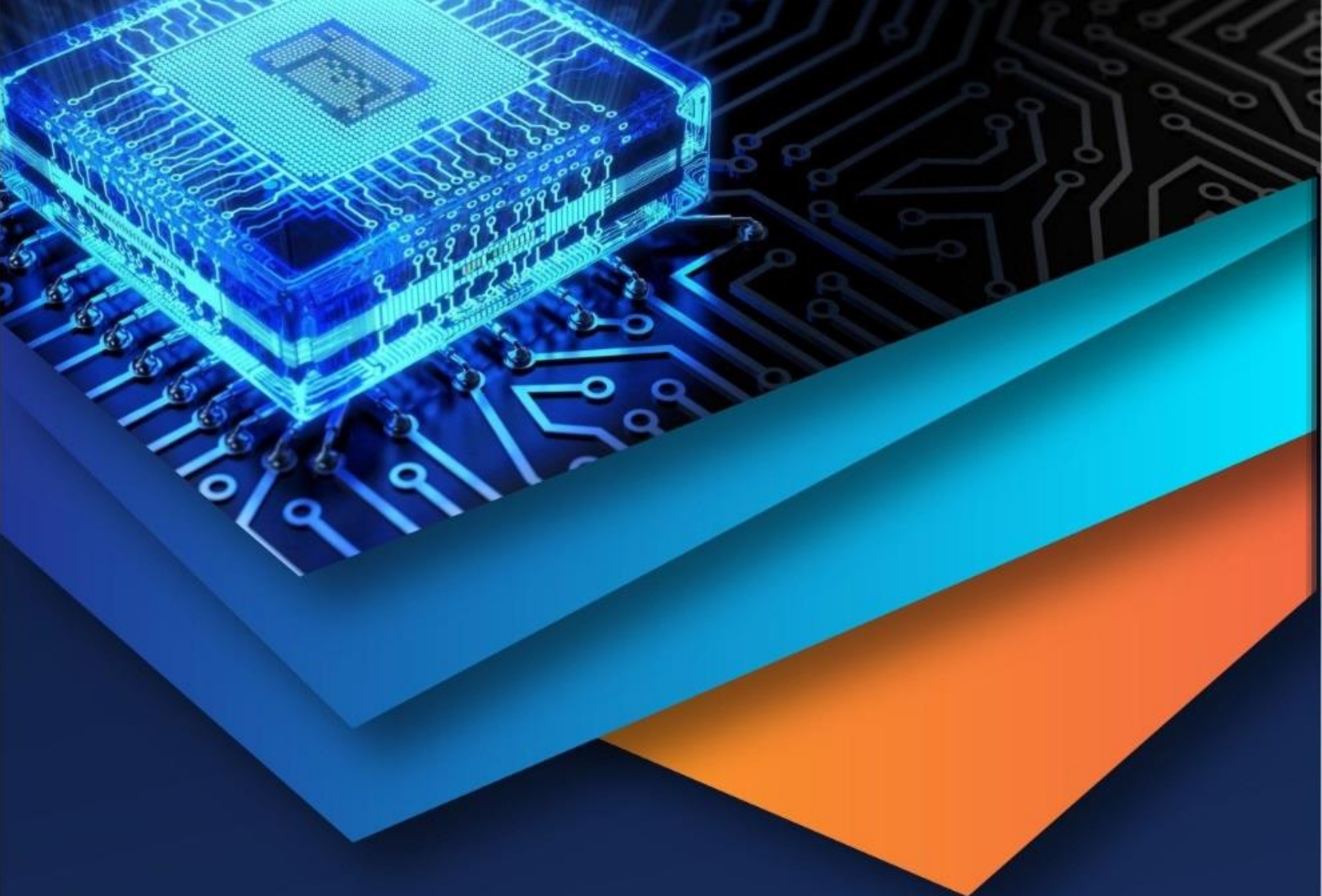
TIME	PLANE GLASS	ZINC OXIDE	ALUMINIUM OXIDE	COPPER-ALUMINATE
0min	30^0C	30^0C	30^0C	30^0C
30min	37.3^0C	32.9^0C	33.3^0C	38.1^0C
60min	43.1^0C	34.1^0C	36.7^0C	44^0C
90min	46^0C	37.7^0C	40^0C	46.8^0C
120min	48.9^0C	37.7^0C	41.7^0C	49.1^0C
150min	51^0C	38.1^0C	42.1^0C	51.8^0C
180min	52.2^0C	39.7^0C	42.1^0C	51.8^0C
210min	52.2^0C	39.7^0C	44^0C	51.8^0C
240min	51^0C	40^0C	46.5^0C	54.3^0C
270min	49.8^0C	39.9^0C	47.8^0C	52.7^0C
300min	49.1^0C	38.1^0C	45.2^0C	52^0C
330min	49.1^0C	37^0C	43.1^0C	51.1^0C
360min	49^0C	36.1^0C	43.1^0C	50.4^0C

TABLE 4
TEMPERATURE READING WHEN 15 GM NANOPARTICLES ARE MIXED WITH ADHESIVE

TIME	PLANE GLASS	ZINC OXIDE	ALUMINIUM OXIDE	COPPER-ALUMINATE
0min	30^0C	30^0C	30^0C	30^0C
30min	37.3^0C	32.9^0C	33.1^0C	38.8^0C
60min	43.1^0C	33.7^0C	36^0C	45.1^0C
90min	46^0C	35.1^0C	41^0C	46.9^0C
120min	48.9^0C	36.5^0C	41.6^0C	49^0C
150min	51^0C	37.3^0C	42^0C	53.1^0C
180min	52.2^0C	37.3^0C	43.1^0C	53.1^0C
210min	52.2^0C	38.8^0C	43.1^0C	53.8^0C
240min	51^0C	36^0C	45.7^0C	55.6^0C
270min	49.8^0C	34.9^0C	44.8^0C	52.9^0C
300min	49.1^0C	34.9^0C	43.2^0C	51.7^0C
330min	49.1^0C	34.3^0C	42^0C	50.9^0C
360min	49^0C	34.3^0C	41.8^0C	50.5^0C

TABLE 5
HEAT TRANSFER (IN WATTS) BY USING DIFFERENT NANOPARTICLES IN DIFFERENT AMOUNT

NANOPARTICLES	HEAT TRANSFER, Q (IN WATTS)		
	5gm	10gm	15gm
PLANE GLASS	74.30784	74.30784	74.30784
ZINC OXIDE	45.2496	33.472	29.45536
ALUMINIUM OXIDE	60.2496	59.58016	52.55104
COPPER- ALUMINATE	76.9856	81.33696	85.68832



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