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Investigation of Silica Aerogels Effect on Paint Characteristics

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Abstract

New methods of energy saving are being researched by many scientists. An important research area in these studies are insulating paints. Silica aerogels are one of nanostructured insulating materials with low thermal conductivity, high surface area and low density. The main aim of this project is to study on alternative paint insulator by producing silica aerogel. In this research, Na_2SiO_3 and H_2SO_4 solution were used for synthesis of aerogels by using the sol-gel method. Acetonitrile and methanol:hexane solution was used for solvent exchange and surface modification. The effects of the process parameters such as the reaction temperature (35-55ºC), the solution amount (150-180ml), the aging temperature (70-90ºC) and the drying temperature (50-70ºC) were studied. Depends on the reaction parameters, three different kinds of aerogels were synthesized (aerogel1(A1), aerogel2(A2) and aerogel3(A3)). After that production progress, silica aerogels were added to two different kinds of paints (water and solvent-based). Aerogel amounts (%1-%3) and aerojel types were chosen as experiment factors. Properties of these samples, such as viscosity, hydrophobicity and adhesivity were measured. The viscosity measurements showed that the viscosity increase with the increasing amount of aerogel in both types of paint. When compared, the hydrophobic properties, best results were obtained in the using of A2 for water-based paint and using of A1 for the solvent-based paint. For the adhesivity, it can be said that it has an improving effect for all aerogel and paint types . In conclusion, the result of experiments demonstrated that silica aerogels have a positive effect on paint characteristics.

Key words

Aerogel, Insulation materials for paints, Energy saving

1. INTRODUCTION

Aerogels are nanoporous materials usually synthesized from silica, with a high porosity, high specific surface area area (500–1200m^2.g^{-1}), high porosity (80–99.8%), low density (~0.003–0.5g.cm^{-3}), low thermal conductivity (0.005–0.1W/mK), low refractive index (~1.05) [1]. First aerogel was produced by S. Kistler in 1930's. He defined the aerogels as a material which is produced by replacing the solvents in the gel by air without substantially altering the network structure or the volume of the gel body [2]. Aerogels can be synthesized from various raw materials such as Tetramethylorthosilicate (TMOS), Tetraethylortosilicate (TEOS) and sodium silicate. There are lots of production methods to produce aerogels. Co-precursor method, derivatization method and sol-gel can be given as examples. In these several kinds of methods, sol-gel method is the best appropriate method in laboratory conditions. The applications of the method in large scale production increased in recent years [3].

The unique properties of aerogels make them great canditates for many applications. In recent years so much attention has been given to silica aerogels in several technological applications. Chemistry, aerospace, electronics, energy, agriculture and insulation can be given as an examples of the some applications areas [4].

In the present work, the role of different process conditions, such as reaction temperature, the solution amount, the aging temperature and the drying temperature was analyzed. Sol-gel method was chosen for the aerogel production. After the aerogel production has been done, these samples were used as paint additives. In this research, two kinds of paint were chosen; solvent and water based paints. Finally, for the investigation of the aerogels effect on paints, some paint analyses were done.

2. MATERIALS AND METHODS

2.1 Synthesis of aerogels

Sol-gel polymerization is the commonly employed method for the preparation of the aerogels. In this study, Na_2SiO_3 and H_2SO_4 solution were used for synthesis of aerogels by using the sol-gel method. Three different kinds of aerogels were obtained in the end of the polymerization. Sodium silicate solution amounts were determined as 150 ml,180 ml and 160 ml and also the other reaction parameters such as the drying temperature (70 ºC ,70 ºC and 50 ºC), the aging temperature (70 ºC, 90 ºC and 90 ºC), the reaction temperature (45 ºC, 55 ºC and 35 ºC) were worked on. The mixing rate was 240 rpm for every mixture. Depends on these reaction parameters, three different kinds of aerogels were synthesized (aerogel 1, aerogel 2 and aerogel 3, respectively). In the end of the reaction, the gelation was obtained which is shown in figure 1. After gelation, samples were sent to the oven to aging step at different temperatures for 3 hours. The aging step is shown in figure 2. The aging step to remove the Na+ ions from the samples, they were washed with distilled water for 24 h. Distilled water was changed at every 6 h of the day. The washing step is shown in figure 3. Acetonitrile was used for solvent exchange and methanol:hexane solution (molar ratio 1:1) was used for surface modification. Finally, the samples were dried at different temperatures for 24 h. The drying step is shown in figure 4.

Figure 1. The gelation was occured after the polymerization step.

Figure 2. The aging step at different temperatures for 3 hours.

Figure 3. The washing step was done for removing sodium ions.

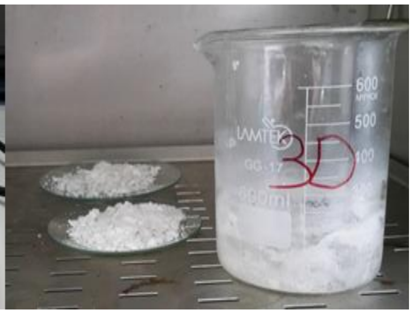

Figure 4. The drying process at different temperatures for 24 h.

2.2 The preparation of the paint samples

After the production progress, silica aerogels were added to two different kinds of paints; water and solvent based. Aerogel amounts (%1, %2 ve %3) and aerojel types were chosen as experiment factors. For these two different kinds of paints, paint amounts were determined as 75 g and due to these ratio 0.75 g, 1.5 g and 2.25 g aerogels were used respectively. As the preparation of the samples Design Expert 7 optimization program was used.

3.RESULTS AND DISCUSSION

After the addition of the aerogels to paints, firstly viscosity measurements were done. Then the hydrophobicity of the samples were investigated and for the each sample, water flowing velocities on the surfaces were measured. For the investigation of the adhesivity, cross-cut tests were applied.

3.1 Viscosity measurements

Viscosity is the resistance of a liquid material with homogeneous structure to flow. Liquids with lower viscosity under the same conditions flow faster than those with higher viscosity.

3.1.1 The analysing of the viscosity graphics for water based paint

The viscosity graphics were created by using Design Expert 7 optimization program. The effect of aerogel types and aerogel amounts on viscosity are shown in Figure 5 and Figure 6.

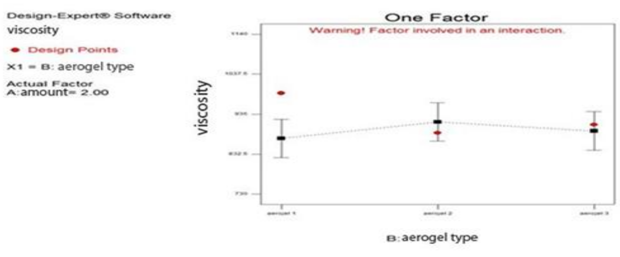

Figure 5.Viscosity vs. aerogel types graphic for the water based paint

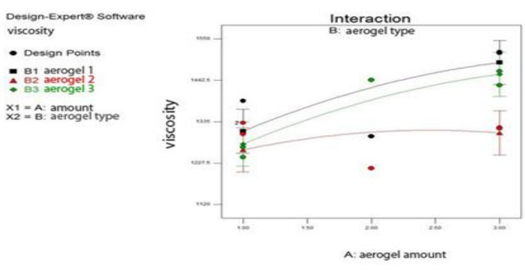

Figure 6. Viscosity vs. aerogel amounts graphic for the water based

These graphics demonsrated that the highest viscosity were reached by using aerogel type 2 and the least viscosity were reached by using aerogel type 1. For all the types, it was observed that the viscosity increases with the increasing amount of the aerogel.

3.1.2 The analysing of the viscosity graphics for solvent-based paint

The effect of aerogel types and aerogel amounts on viscosity for the solvent based paint are shown in Figure 7 and Figure 8.

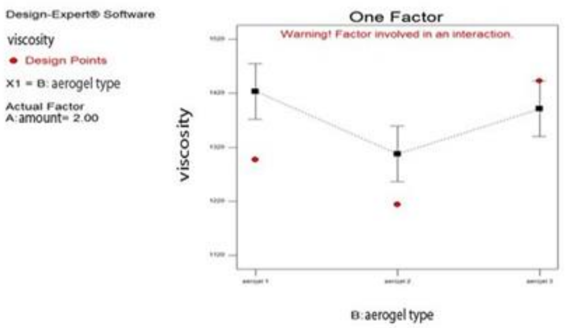

Figure 7. Viscosity vs. aerogel types graphic for the solvent based paint

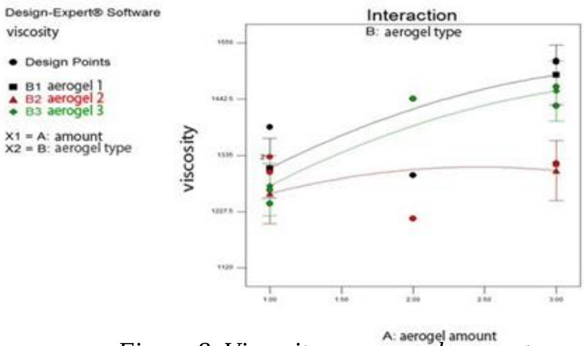

Figure 8. Viscosity vs. aerogel amounts graphic for solvent based paint

The graphics showed that the maximum viscosity were achieved by using aerogel type 1 and the minimum viscosity were achieved by using aerogel type 2. For all the types, it can be said that the viscosity increase with the increasing amount of the aerogel. When compared the behaviour of the solvent and water based paints, it can be seen that there is a similitiary in terms of the increasing viscosity with increasing amount of the aerogels.

3.2 Hydrophobicity measurements

Contact angle is a measure of static hydrophobicity. When a pipette injects a liquid into a solid, the liquid will form some contact angle. Contact angle is higher than 90° for hydrophobic surfaces. In this present work, flow appearances and flow velocities of the samples were compared with control samples which includes no aerogels. The results of some samples are given below:

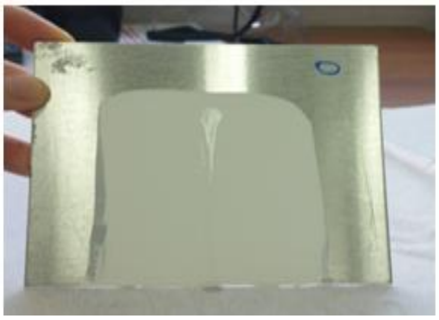

Figure 9. Control sample of water based paint

Figure 10. Flow appearance of control sample for water based paint

Figure 11. Sample with aerogel as a paint additive for water based paint

Figure 12. Flow appearance of sample with aerogel as a paint additive for water based paint

Figure 13. Control sample of solvent based paint

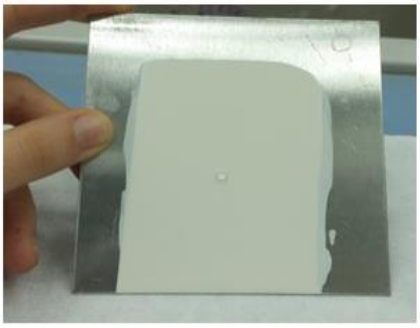

Figure 14. Flow appearance of control sample for solvent based paint

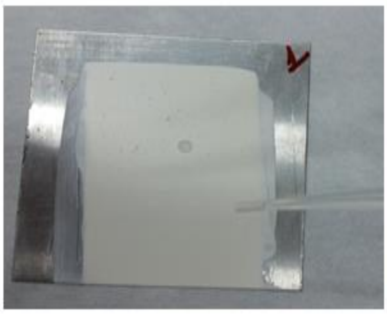

Fıgure 15. Sample with aerogel as a paint additive for solvent based paint

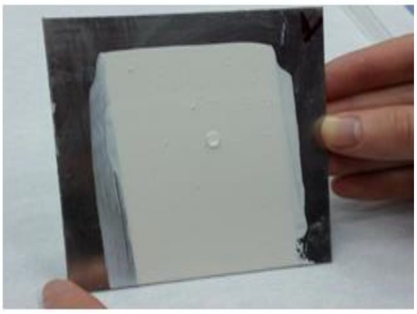

Figure 16. Flow appearance of sample with aerogel as a paint additive for water based paint

3.2.1 The analysing of the hydrophobicity graphics for water based paint

The effect of aerogel types and aerogel amounts on hydrophobicity for the water based paint are shown in Figure 17 and Figure 18.

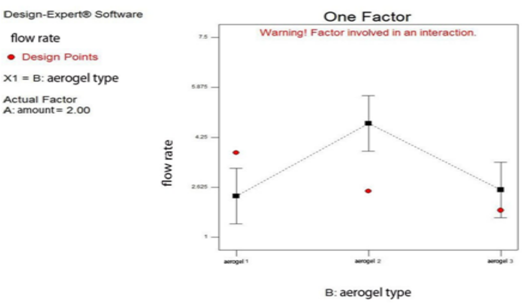

Figure 17. Aerogel type vs flow rate graphic for the water based paint

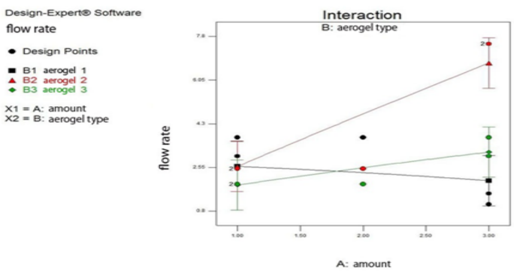

Figure 18. Aerogel amount vs. flow rate graphic for the water based

The graphics demonstrated that the maximum hydrophobicity were achieved by using aerogel type 2 and the minimum hydrophobicity were achieved by using aerogel type 1. For aerogel 2 and aerogel 3, hydrophobicity increased with the increasing amount of aerogel. On the other hand, for the aerogel 1, hydrophobicity decreased with the increasing amount of the aerogel.

3.2.2 The analysing of the hydrophobicity graphics for solvent based paint

The effect of aerogel types and aerogel amounts on hydrophobicity for the solvent based paint are shown in Figure 19 and Figure 20.

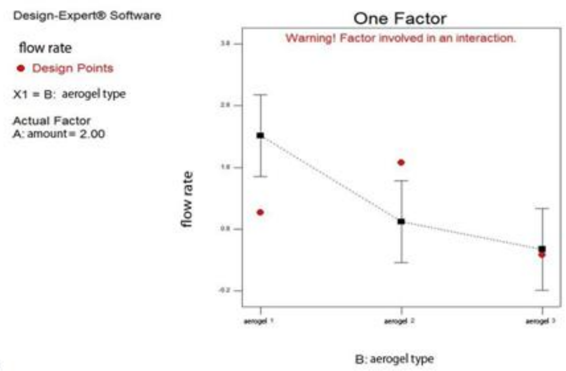

Figure 19. Aerogel type vs. flow rate graphic for the solvent based paint

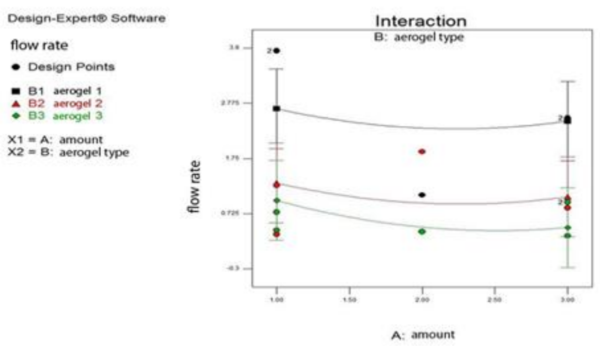

Figure 20. Aerogel amount vs. flow rate graphic for the solvent based paint

The graphics showed that for the solvent based paint, the best results were obtained by using of aerogel type 1. Minimum hydrophobicity was observed in case of using aerogel type 3. For all aerogel types it can be said that hydrophobicity decrease with the increasing amount of aerogels.

3.3 Adhesivity Measurements

For the investigation of the adhesivity, cross-cut tests were applied. This test is a method for measuring the resistance of paints and coatings to separation from surfaces when a right angle cross pattern is cut into the coating, penetrating through to the surface.

Figure 21. Water based paint without aerogel as a paint additive

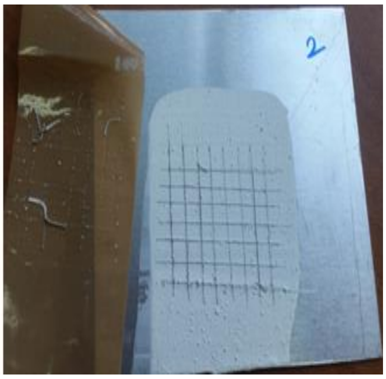

Figure 22. Water based paint with aerogel as a paint additive

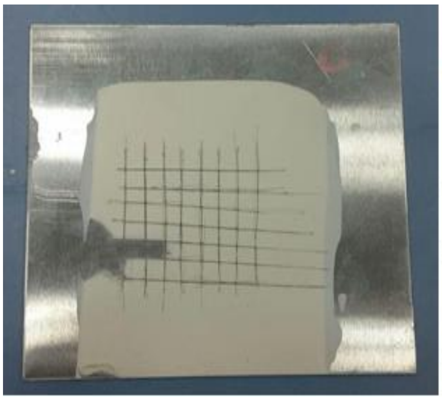
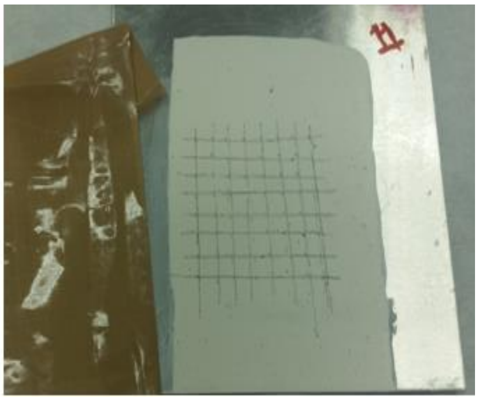

Figure 23. Solvent based paint without aerogel as a paint additive

Figure 24. Solvent based paint with aerogel as a paint additive

3.3.1 The analysing of the adhesivity graphics for water based paint

The effect of aerogel types and aerogel amounts on adhesivity for the water based paint are shown in Figure 25 and Figure 26.

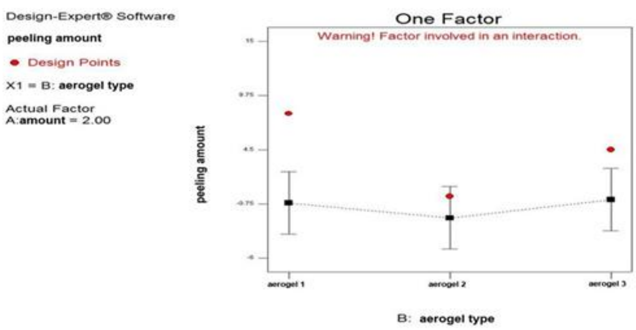

Figure 25. Aerogel type vs. peeling amount graphic for the water based paint

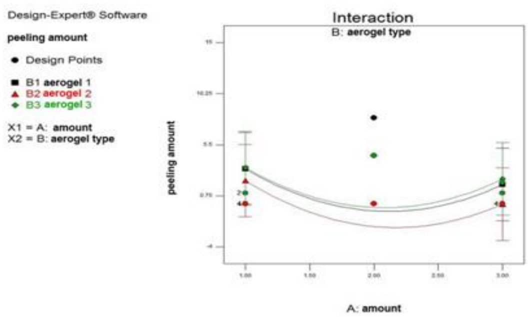

Figure 26. Aerogel amount vs. peeling amount graphic for the water based paint

The graphics showed that the maximum adhesivity was obtained in case of using aerogel type 3 as a paint additive and the minimum adhesivity was obtained with the utilization of aerogel type 2. In addition to this, it has been observed that peeling amount decrease with the increasing amount of aerogel utilization.

3.3.2 The analysing of the adhesivity graphics for solvent based paint

The effect of aerogel types and aerogel amounts on adhesivity for the solvent based paint are shown in Figure 27 and Figure 28.

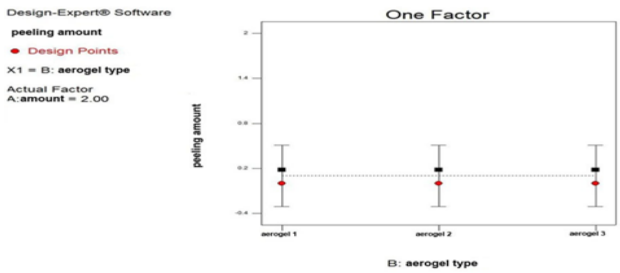

Figure 27. Aerogel type vs. peeling amount graphic for the solvent based paint

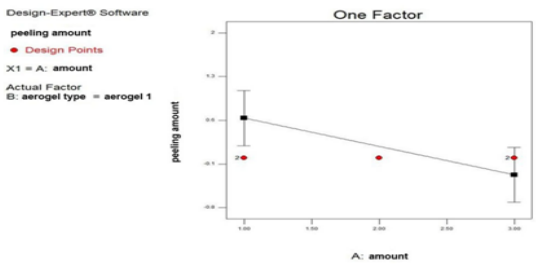

Figure 28. Aerogel amount vs. peeling amount graphic for the solvent based paint

The graphics demonstrated that as a parameter, aerogel type cannot be compared with each other. Because in case of utilization of all types of aerogel as a paint additive, the solvent based paint wasn't peeled. On the other hand, it can be said that aerogel utilization with increasing amount, decrease the peeling amount for the all types of aerogel.

4. CONCLUSION

In this study, experimental and numerical work were performed to investigate the silica aerogels effect on the paints characteristics. Based on the experimental and numerical studies, conclusions can be drawn as follows:

(1) The viscosity measurements show that the best results were reached in case of using of the aerogel 1 for solvent-based paint and aerogel 2 for water-based paint. It has been observed that the viscosity increase with the increasing amount of aerogel in both types of paint.
(2) When compared, the hydrophobic properties, the best results were obtained in the using of aerogel 2 for water-based paint and using of aerogel 1 for the solvent-based paint.
(3) For the adhesivity, it can be said that it has an improving effect of all aerogel types for solvent based paint. For water based paint, the best results are obtained in aerogel 3, and in general, the amount of peeling is reduced as the amount of aerogel increases in all aerogel types.

The result of experiments demonstrated that silica aerogels have a positive effect on paint characteristics.This study is going to continue with the thermal conductivity measurements of the samples.

5. REFERENCES

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