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An Investigation on Acrylic Organic Coatings Including Colemanite and Zeolite for Glass Materials

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Abstract

Today, acrylic organic coatings are very important point for glass materials because glass has very huge area in the industry. Glass may physically be defined as a rigid. In chemically, the non-volatile inorganic oxides form from the decomposition of alkali and alkaline compounds, sand, and other glass constituents. Especially, human being uses the glass as decorative object, bottles, eye glasses, windows, and kitchen utensils in daily life. Colemanite is a borate mineral and a secondary mineral that forms by alteration of borax and ulexite. Zeolites are microporous, aluminosilicate minerals. It is commonly used as commercial adsorbents and catalysts. In this study, the acrylic organic coatings were tried to improve physical and chemical properties of glasses with using colemanite and zeolite. In addition, Taguchi Method was used to optimize the parameters for obtaining high quality and low-cost materials. The analysis results (TG-DTA, SEM) showed that the compositions of the all experiments were protected in terms of thermal properties with additives and physical appearances of the samples matched with reference sample. To conclude, additives are improved the properties of organic coatings and the results showed that the coatings produced could be evaluated in the industry.
Keywords: Colemanite, glass, organic coating, zeolite.

1. Introduction

Color coatings are used in many industries. One of these industry is glass industry. A form of glass occurs naturally within the mouth of a volcano when the intense heat of an eruption melts sand to form Obsidian, a hard black glassy type of stone. People first used this as tips for spears. Today, people have mastered the glass-making process and can make many different types of glass in infinitely varied colours formed into a wide range of products. Glass, chemically, is actually more like a liquid, but at room temperature it is so viscous or sticky it looks and feels like a solid. At higher temperatures glass gradually becomes softer and more like a liquid. It is this latter property, which allows glass to be poured, blown, pressed and moulded into such a variety of shapes [1].

Color coating includes many components. One of the most important material is boron. Boron is a very important component in the production of borosilicate glass, glass wool and textile type glass fiber. A very important part of the consumption of boron concentrates on these three sectors. The glass fiber sector constitutes the largest market for boron products and the world boron consumption is about 50% in this sector. Boric oxide is also widely used in the production of borosilicate glass. It makes the glass hard and heat resistant [2-5].

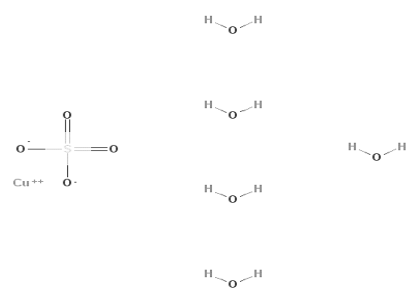
Colemanite forms in evaporite deposits together with other borates, and is one of the more stable of borate minerals. It is pyroelectric, and develops an electrical charge during a change of temperature. Colemanite has many important uses. It is a significant ore of boron, and was the most important ore prior to the discovery of Kernite in 1926. It is also used in the manufacture of heat resistant glass, and has other industrial, medicinal, and cosmetic uses. It is a popular collector mineral [6-10]. On the other hand, zeolites are aluminosilicate minerals commonly used as microporous, commercial adsorbents and catalysts. Zeolites have a porous structure that can accommodate a wide variety of cations. Some of the more common mineral zeolites are anasim, chabazite, clinoptilolite, heulandite, natrolite, phyllipsite and stilbitite. Zeolites are synthetically produced. For zeolite production, typical procedures require the aqueous solutions of alumina and silica to be heated with sodium hydroxide. Zeolites can be used for solar thermal collectors and adsorption cooling [11-15]. Moreover, potassium dichromate was used as color material like copper sulfate pentahydrate. Potassium dichromate is a common inorganic chemical reactant, most commonly used as an oxidizing agent in a variety of laboratory and industrial applications [16-20].

In this study, it was tried to develop the properties of the organic coatings by using colemanite, zeolite, copper sulfate pentahydrate and Taguchi Method was applied as an optimization method to obtain the optimum value.

2. Materials and Methods

2.1 Materials

In this study, colemanite, zeolite and copper sulfate pentahydrate were used as main additives. Colemanite ($Ca_2B_6O_{11}\cdot 5H_2O$) and zeolite ($Na_2Al_2Si_3O_{10}\cdot 2H_2O$) were supplied from Eti Maden-Bandırma and copper sulfate pentahydrate was supplied from Merck-Turkey. Acrylic organic coatings was used as a reference paint produced in Turkey.



Copper Sulphate Pentahydrate

2.2 Methos

Firstly, samples were prepared by using anhydrous borax. Experiments were optimized according to the Taguchi Method. When preparing the samples 100 g water-based acrylic organic coatings (0-6%, w/w) was taken as basis.

Viscosity of the samples were measured by using viscosimeter (Lamy Rheology) (Accuracy: +/- 1 % of the full scale; Repeatability: +/- 0,2 %; 25°C of temperature) at 250 rpm during 20 seconds and then, samples were pulled off on the glass surface which was disinfected before. After waiting a certain time, samples on the glass were observed and some quality tests were applied.

According to test results, optimum sample was selected. Taguchi results was shown on the Table 1. Levels in Taguchi Method and viscosity values determined between 1334-1518 mPa.s) were given in Table 1 for organic coatings.

Table 1. Levels and results of Taguchi Method

No	Colemanite	Zeolite	$CuSO_4.5H_2O$	Viscosity (mPa.s)
1	1	1	1	1375
2	1	2	2	1491
3	1	3	3	1472
4	2	1	2	1334
5	2	2	3	1460
6	2	3	1	1410
7	3	1	3	1482
8	3	2	1	1518
9	3	3	2	1489

2.3 Applied Tests

ISO 2409:2013 Cross-cut test, ISO 2884-2:2003 determination of viscosity using rotary viscometers, ASTM D714-02 evaluating degree of blistering of paints, hiding power test, hydrophobicity test, TG-DTA (Thermal Gravimetric-Differential Thermal Analysis; SII Nanotechnology – SII6000 Exstar TG/DTA 6300) and SEM (Scanning Electron Microscope; Zeiss EVO® LS 10) analysis were applied.

TG-DTA, SEM were used to determine flame retardancy and morphological properties of organic coatings, respectively.

3. Results and Discussion

Figure 1 shows that the Taguchi graph of the experiments. Experimental results are transformed into a signal-to-noise (S/N) ratio. It uses the S/N ratio as a measure of quality characteristics deviating from or nearing to the desired values. There are three categories of quality characteristics in the analysis of the S/N ratio, i.e. the lower the better, the higher the better, and the nominal the better. Experiment 4 was optimum point when the results were calculated in terms of viscosities.

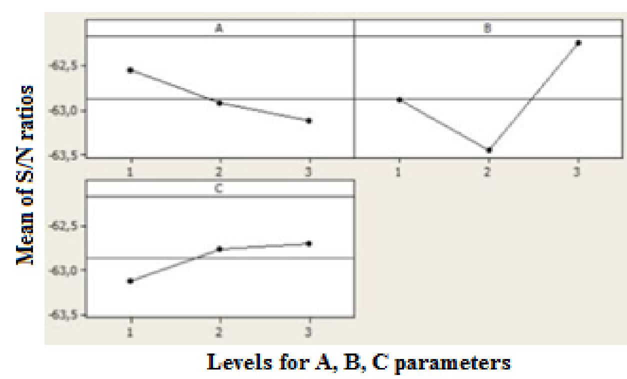


Figure 1. Graph of Taguchi Method

Hydrophobicity test was applied to look at the reflex of the organic coatings against the water. Figure 2 shows that the result of hydrophobicity test. As a result, the surface of the samples had hydrophobic properties.

Figure 2. Hydrophobicity test of optimum sample.

Drying test was applied to measure the drying quality of organic coatings. Figure 3 shows that the result of drying test. It was observed that the samples were dried after 24 hours.

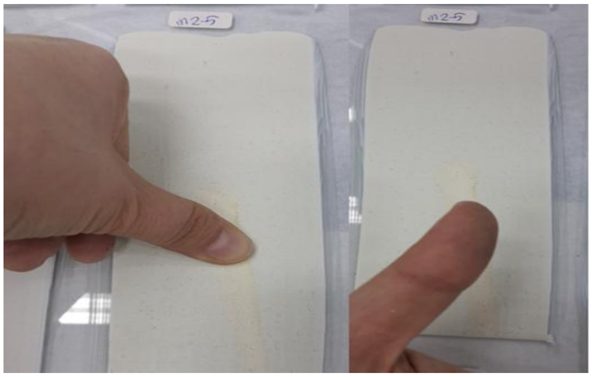


Figure 3. Drying test of optimum sample.

Cross–cut test was applied to measure strength of the organic coatings. Figure 4 shows the result of cross cut test. Because of the cross-cut tests, the squares that were seen on the adhesive tapes did not have the water-based acrylic coatings.

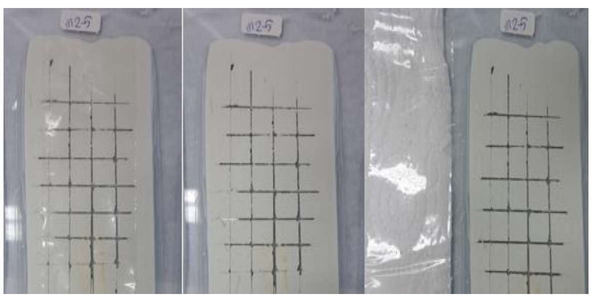


Figure 4. Cross-cut test result of optimum sample.

Hiding power test was applied and the positive results were acquired. Figure 5 shows that the hiding power test results.

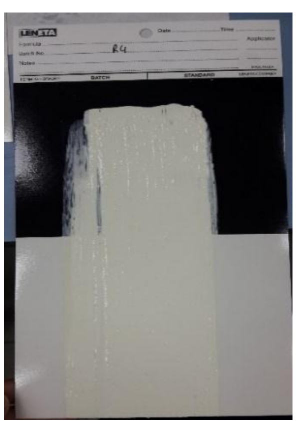


Figure 5. Hiding power test of optimum sample.

While TG only measures changes caused by mass loss, DTA also shows changes in material where no mass loss occurs. Comprehensive study of a materials thermal behaviour could be done with combining the two techniques (TG-DTA). Carefulleness required with performance of the experimental procedure to obtain correct weight loss curves and thermograms [21]. TG-DTA curves showed that the decomposition of water-based acrylic coatings occurred in such way that in first step the hydration water is lost. Then, the decomposition of additives was observed. These events appeared as endothermic processes in DTA curve. When reference water-based acrylic coatings were compared with water-based acrylic coatings containing colemanite, zeolite and copper sulfate pentahydrate. The samples (6-10 mg) were loaded into a silisium pan and heated from 20 to 500°C at 10°C/min under N_2 flow. The thermal profiles were obtained under isothermal conditions. TG analysis of as-prepared powder gave 65-97% a sharp weight loss between 20-500°C for organic coatings. A peak occurred within the temperature range 350-450°C by an endothermic reaction. After further heating, one endothermic peak occurred at about 400°C. This was consistent with the DTG analysis. (Figure 8). On the TG curve, a sharp weight loss (13.99%) begins to happen when the temperature is around 232°C as expected from the results of various authors [13, 14]. This process is corresponding to loss of water of crystallization through condensation of B–OH groups. It was observed that the water-based acrylic coatings had same degradation temperature when the additives were added and the compositions of the all experiments were protected in terms of thermal properties up to 400°C (Figure 6, 7).

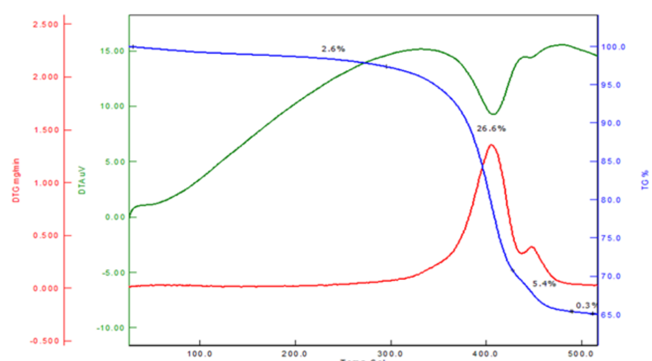


Figure 6. TG-DTA analysis of the reference water-based acrylic coating.

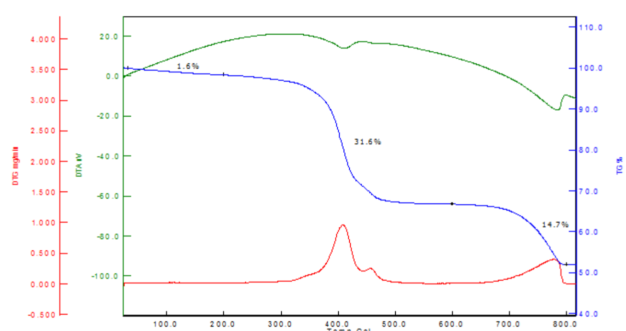


Figure 7. TG-DTA analysis of optimum sample.

SEM results showed that the physical morphology of reference water-based acrylic coating was similar with optimum sample (Figure 8, 9). The size distribution got changed due to the agglomerated structure in the reference water-based acrylic coating. Regular particles were formed in optimum sample. Regularity is an important parameter to apply acrylic coatings on surfaces.

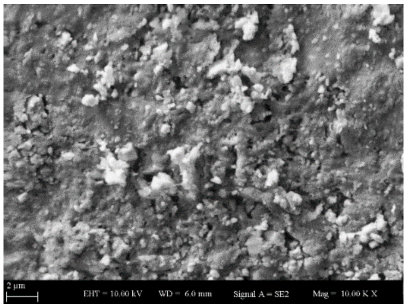


Figure 8. SEM analysis of the reference water-based acrylic coating.

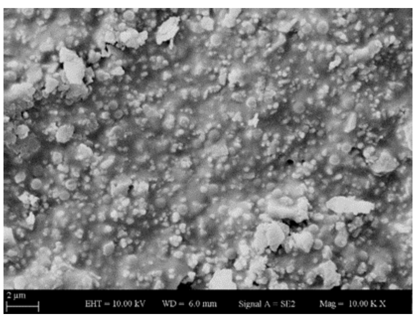


Figure 9. SEM analysis of optimum sample.

4. Conclusion

Consequently, the optimum parameters were determined by using Taguchi as an optimization method. The optimum parameters were found as experiment 4. The test results (hydrophobicity, cross-cut, hiding power etc.) showed that the additives improved the physical properties of water-based organic coatings for glass materials. It was understood that via TG-DTA, the compositions of the all experiments were protected in terms of thermal properties with additives. In addition, physical appearances of the samples matched with reference sample. It was seen that the coatings could be evaluated in industrial applications.

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