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Study On Use Of Nanosized Alpha Alumina From Schedule Waste As Formulation In Thermal Insulation Paint

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Abstract. Schedule waste used in this study is white aluminium dross produce from an aluminium smelting plant. It has a gibbsite crystal form, and was calcined at high temperature and transformed into α-alumina. Nano-sized powder with 76 nm primary particle size was produced by top-down method via high velocity wet milling. Comparative thermal insulation study was then performed in paints made from 15 wt% of these nano-size and micron-size alumina. The results from this study shows that the nano-size α-alumina is the best insulator, with a temperature reduction of 57 and 41% less, compared to micron-size α-alumina respectively for ceramic and steel plate.

Introduction

The aluminum industry is the largest non-ferrous metal industry in the world. Since the advent of its large scale industrial production, the demand for aluminum continuously increases, and stands at around 45 million tons in 2004. Its application has extended to a variety of economic sectors [1]. Unfortunately, the aluminum industry produces three by-products that are hazardous to people and the environment, which are white dross, black dross and salt cake. In this study white dross was used as the precursor for the production of alpha alumina and the process involves phase transformation from the aluminium hydroxide to alumina via the annealing method. White Dross is a mixture of aluminum oxide and aluminum metal, with the metal content varying from 15 to 80%. It is produced during the melting of aluminum in a furnace hearth, or during the transportation of molten aluminum between furnaces or crucibles [2].

Insulation is defined as a material or combination of materials that retards the flow of heat. The materials can be adapted to any size, shape or surface. A variety of finishes are used to protect the insulation from mechanical and environmental damage, and enhance appearances [3]. In green buildings, due to thermal insulation, the room remains cooler during summer and warmer during winter. Hence, a thermally insulated room provides comfort in both summer and winter. Moreover, due to thermal insulation, the heat transfer between the room’s interior and exterior is stifled, resulting in less quantity of energy required for maintaining the desired temperature in the room. Chemical and thermal stability, relatively good strength, thermal and electrical insulation characteristics, combined with ever available source have made alumina attractive for engineering application such as high temperature electrical insulators and high voltage insulators. There are various type of alumina produced during the different stages of processing temperatures. Of the different crystalline phases or polymorphs, α-alumina is the only stable crystalline phase [4]. Nano alumina is widely used in the field of paints and coatings due to its excellent wear resistance. Adding 1-2% nano alumina coating can greatly increase wear resistance of the coating, which is 2 to 4 times higher than the traditional coating of wear resistance. Nano-alumina also has high resistivity, and good insulation properties, and due to this, it is widely used in plastics, rubber, ceramics, paint, polyimide film, polyester film, and polyester fiber cloth and so on. It can improve coating density and dielectric breakdown strength, and other insulation properties can be improved to more than 3 times its original value [5].

The objective of this study is to determine the effect of thermal insulation by adding nano-size alumina produced from schedule waste into paints. Comparative thermal insulation study will also be conducted on control and micron-size α-alumina additive to the paint on ceramic and stainless steel materials.

Experimental

Aluminium dross sample was obtained from an aluminium recycling plant in Penanag, Malaysia. The samples was first washed with distilled water to remove impurities such as Na and K. Then a phase of α-alumina transformation was conducted on this sample by heating white aluminium dross at 1300 °C in a muffle furnace for 3 hours [6]. In order to obtain nano-size α-alumina, the calcined sample was milled using high velocity Fritsch milling machine, at 950 rpm for 4 hours. The crystalline phase, primary particle size and morphology was then determined using the XRD and TEM methods. The sample is manually sieved to prevent agglomeration due to heat generated inside the milling container. It is weighted accordingly before mixing it as an additive to the commercial white paint (Seamaster, 8200 Spot-Free emulsion paint) with paint content comprised of polymer resin, water and titanium dioxide pigment. The paint mixed with alumina was then applied on the surface of tile and stainless steel plate with coating thickness of 0.3 cm. The thermal insulation study involves putting the plate on a hot plate equipped with a temperature controller. The temperature was taken using an infra red thermometer, and the surface temperature was recorded every 10 minutes.

Results and Discussion

Preparation of Nano-size alumina from aluminium dross waste. The aluminium dross sample was initially analyzed by the XRD method to determine its crystalline phase. The results is shown in Fig. 1. From the analysis, the diffractogram of the sample matched that of aluminium trihydroxide crystals, commonly called gibbsite. This can be clearly seen as the peaks from the sample and the gibbsite reference database ICSD 98-001-7326 is similar. The sample then undergoes a calcination process, and from this, a phase transformation occured and resulted in sharp peaks shown in the XRD diffractogram of Fig. 2.

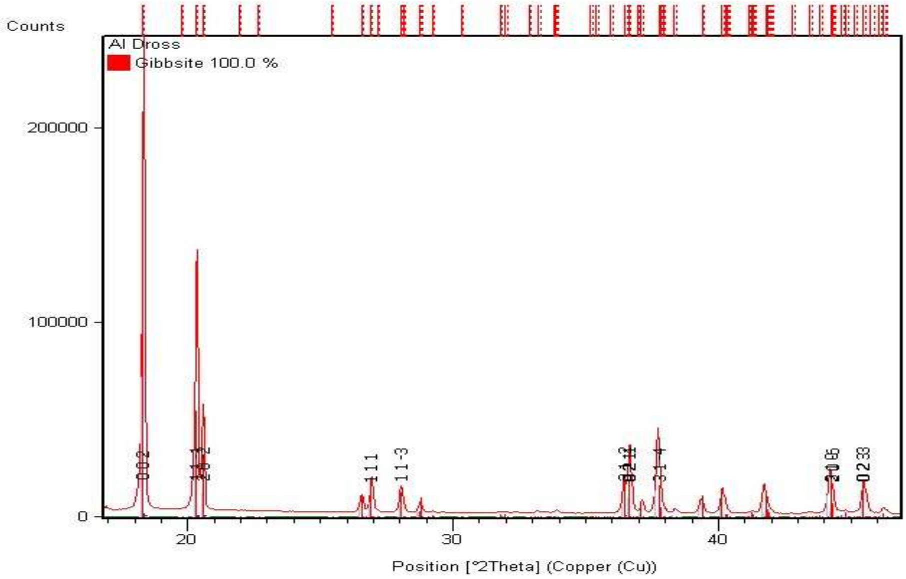

Fig. 1. XRD diffractogram of aluminium dross sample.

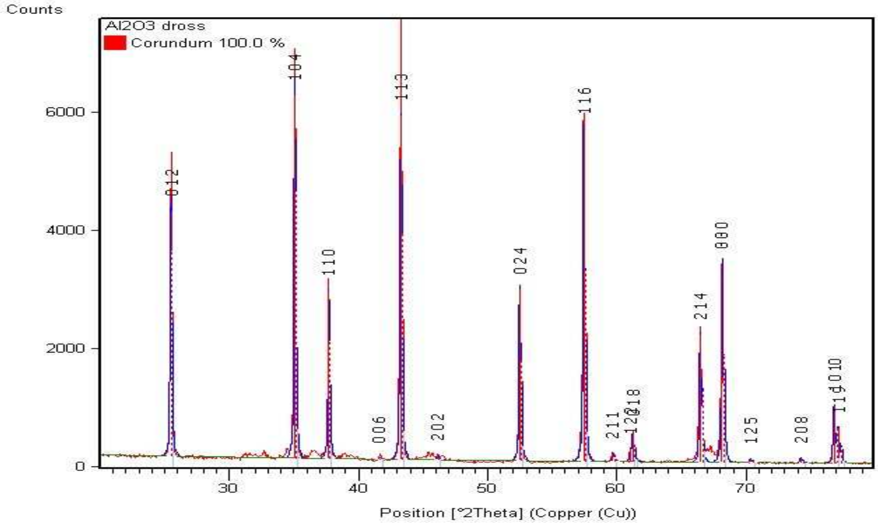

Fig. 2. XRD diffractogram of calcined sample.

The crystalline phase of the calcined sample was identified as α alumina (ICSD 98-001-7463). The wet milling technique proved to be a better method than the dry milling technique in producing nano-sized powder. Karagedov and Lyakhov (2003) had shown that due to the heat and high temperature involves in the dry milling process, recrystallization of the primary particles may take place after a certain period of time [5]. This eventually results to a larger the production of larger particles. In wet milling, the present of liquid tends to lower the temperature during milling and hence resulted to minimal effect for recrystallization. Another advantage of the wet milling technique is that a longer milling time can be used as compared to the dry milling technique. We had chosen a smaller 1 mm ball, as theoretically, the smaller the size of the milling ball, the smaller the size of the milled particle [6]. Fig. 3 shows the effect of milling time on the peaks of the α-alumina.

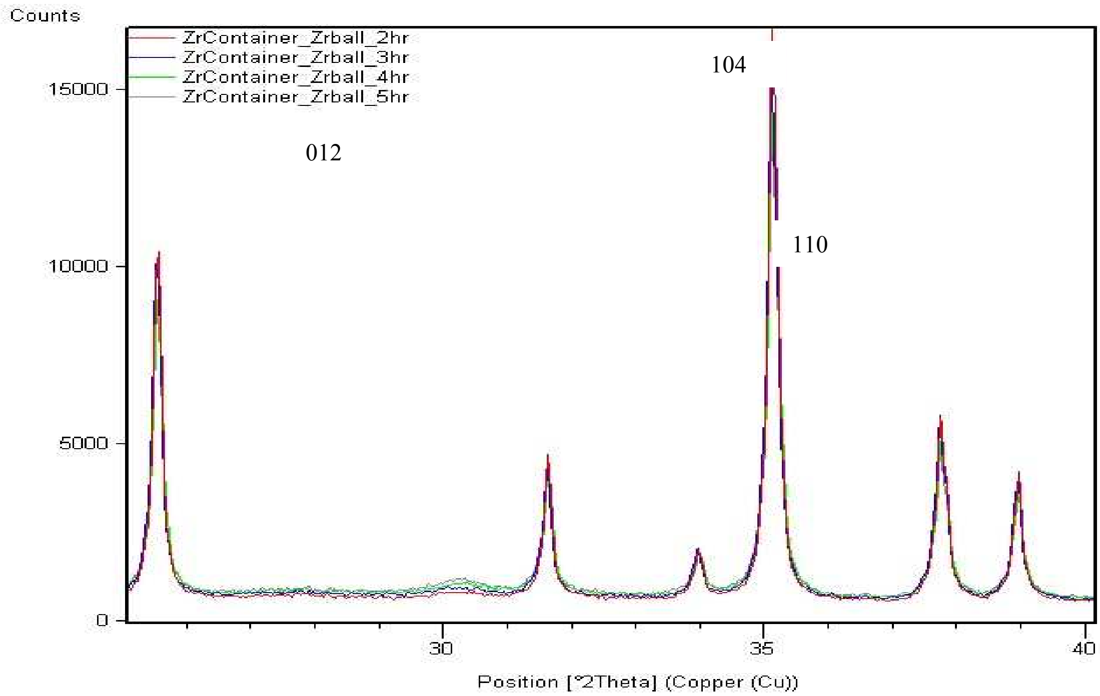

Fig. 3. Effect of milling time on peaks of milled α alumina.

The full-width at half-maximum (FWHM) value for this peak was then used to calculate both crystallite size and lattice values using Scherrer and Tangent methods, respectively [8]. Smallest crystallite size achieved is 76.0 nm, and this was obtained after milling for five hours. The TEM analysis performed on the milled alumina sample also supported the XRD result and Figure 4 shows the TEM image of a milled alumina with crystallite size in the range of 60-90 nm.

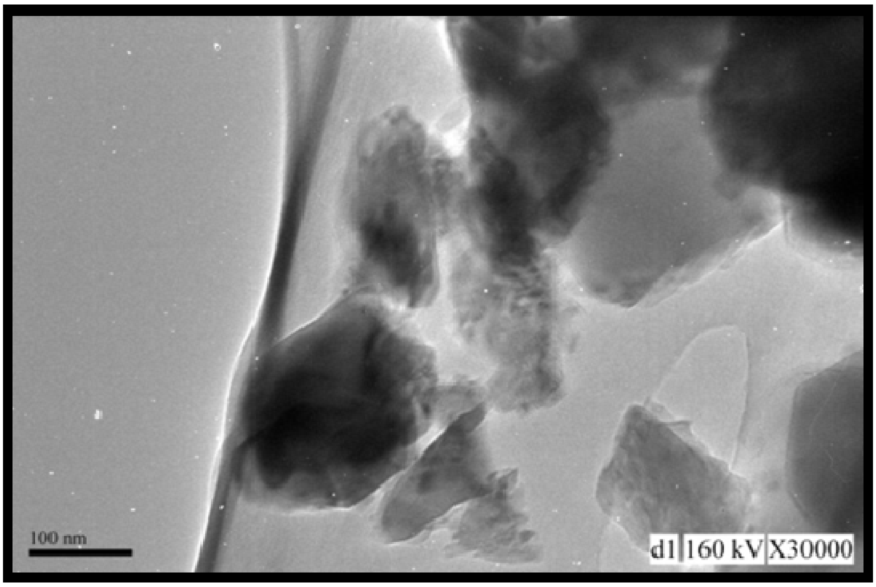

Fig. 4. TEM micrograph of milled α alumina.

The paint mixed with the nano-sized alpha alumina was then applied on the surface of tile and stainless steel plate with coating thickness of 0.3 cm (Figure 5). Comparative study on the thermal insulation property of micron and nano-size alumina paints was also performed.

Fig. 5. Image of alumina thermal insulation paint on steel plate.

Prior to the study on determining the effect of nano-size alumina on the thermal insulation property, a study on determining the optimum amount of α-alumina as additive to the paint was performed. In this study, different percentage alumina was added to the paint, ranging from 5, 10, 15 and 20%. Control paint, without any alumina, was also used in the study. As pointed out in Figure 6, the control paint registers the highest temperature after 40 minutes of heating and as the time progress the temperature stabilizes at 250 °C. Paints that contain different quantity of alumina added show different responses upon heating. The temperature reduces in corresponds to the following added alumina 5, 20, 10 and 15% respectively. Another interesting observation from this result is the heating time requires to achieve constant temperature differs for the different samples. The control sample requires 30 minutes to achieve this while that of 5 and 10%, it require 40 minutes of heating. Samples 15 and 20% required longer heating time of 50 minutes to achieve this point. It is interesting to note that the temperature reduction is not directly proportional with the increase in weight of alumina added, in particular, that of 20%, which register a lower decrease than that of the 10 and 15%. In general, the thermal insulation that occurs here is the result of heat that is absorbed by the alumina particles present in the paint. Effective heat absorption is much depended on the homogenous dispersion of the powder on the surface. We might presumably assume that 15% alumina is the optimum amount for the homogenous dispersion of the powder on the paint, and an increase in the amount of alumina added will eventually result in particle agglomeration, preventing homogenous dispersion into the paint and surface, thus decreasing its effectiveness as a thermal insulator.

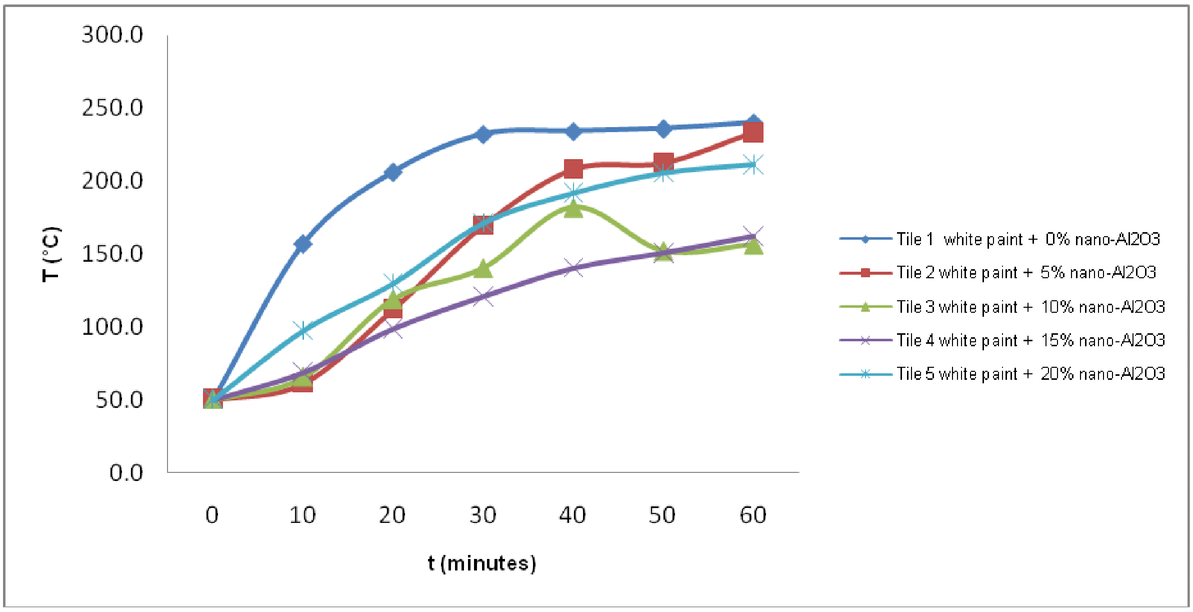

Fig. 6. Graph of effect of temperature on different amount of added alumina.

Using the optimum mixture of 15% alumina, we then performed a comparative study of micron and nano-size alumina on the thermal insulation properties of the added paint. The micron-size alumina has an average particle size of 2 µm. Control paint, without any addition of alumina, was also used for this purpose. Table 1 shows the reduction in surface temperature for the ceramic plates after being coated with different paints. From the results, it is surmised that the addition of nano-size alumina can result in a better thermal insulation compared to the micron-size alumina. This can be seen from the lower surface temperature of paint coated with nano-size alumina, compared to the micron-size alumina. The result also shows that the percentage of temperature reduction of the nano-size alumina is much larger compared to micron-size alumina at 57% and 48%, respectively.

Table 1. Temperature recorded for different paints on ceramic plate.

Thermal property		**Type of paint**		
	Without paint	Control (no alumina)	Micron-size alumina	Nano-size alumina
Surface Temperature (°C)	362	234	186	153
% reduction (as compared to without paint)	-	35%	48%	57%

A similar study was also performed on a steel plate sample, and the result is shown in Table 2. The study was done at lower heating temperatures, where the steel plate surface without paint registered at 146 °C. Using micron-size alumina paint, the surface temperature was reduced to 100 °C, or registered a thermal reduction of 31%, while nano-size alumina registered a much lower surface temperature of 86 °C, and thermal reduction of 41%.

Table 2. Temperature recorded for different paints on steel plate.

Thermal property	**Type of paint**			
	Without paint	Control (no alumina)	Micron-size alumina	Nano-size alumina
Surface Temperature (°C)	146	105	100	86
% reduction (as compared to without paint)	-	28%	31%	41%

One of the major differences between the micron-size and nano-size alumina is the smaller crystal size of the latter, resulting in a larger surface area of the nano-size alumina [9]. The larger surface area of the crystal makes it absorb energy more efficiently, hence contributing to the higher temperature reduction of this paint, as compared to the micron-size alumina. This make the nano-size alumina a better choice for thermal insulation compared to the micron-size alumina.

Conclusion

Nano-sized alpha alumina with primary particle size of 76 nm was produced by annealing followed by wet milling of aluminium dross sample. The study also shows that the maximum surface temperature reduction can be obtained by addition 15% of this nano-sized alumina powder on to commercial white paint. Comparative study with micron-sized alumina shows that the reduction of surface temperature for nano-sized alumina is much higher than micron-size alumina.

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