



Analysis of repulsed dust from electrostatic curtain using different voltages

Manal Madhat Abdullah¹, Mazin Al-Ansari¹ & Rasha Ayad¹

¹ University of Baghdad- College of science- department of Physics, Baghdad-Iraq

Email: Manal.madhat@yahoo.com

Article info

Original: 20 Aug. 2014
Revised: 03 Dec. 2014
Accepted: 10 Dec. 2014
Published online:
20 March 2015

Abstract

Naturally dust particles are statically charged, they settle down on different surfaces. Experiments were conducted to study the rolled off dust particles from the surface of an electrostatic curtain. The value of the applied dc voltages to the electrostatic curtain is considered along with the diameters of accumulated dust particles. For this purpose, dust was collected and classified into three categories depending on the values of the particle diameter (20, 40 and 56 μm).

Fluorescence X-Ray results showed that the dust is composed of various elements such as lead, silver, nickel, copper and many others. The presence of those elements on the charged electrostatic curtain depends on their electrical conductivity and molecular weight.

Introduction

Dust is defined as small, dry solid particles, below 75 μm in diameter, which are projected into air by natural forces such as wind and volcanic eruptions, and by mechanical or man-made process such as crushing, grinding, milling, drilling, demolition, shoveling, screening, bagging and sweeping. Dust particles are usually in the size range from about 1 to 100 μm in diameter, and they settle under the influence of gravity. It is found in homes, offices and other human environments. As examples, dust particles found in our environment are [1]:

- 1- Mineral dust, such as those containing free crystalline silica (e.g., quartz, coal and cement dusts).
- 2- Metallic dust, such as lead, cadmium, nickel and beryllium dusts.
- 3- Other chemical dusts, e.g., many bulk chemicals and pesticides.
- 4- Organic and vegetable dusts, such as flour, wood, cotton and tea dusts pollens.
- 5- Biohazards, such as viable particles, moulds and spores.

There are several characteristics of dust. One of them is the shape, where the most frequently used parameter is sphericity, which is defined as the ratio of the surface area of a sphere having the same volume as the particle to the actual particle surface area.

Other two useful parameters are the equivalent diameters that may refer to either volume or surface area. The equivalent volume diameter is the diameter of a sphere of the same volume, and similarly the equivalent surface diameter is the diameter of a sphere with the same surface. Another important quantity of a particle is its specific surface area, which is defined as the particle's surface area divided either by its mass or by its volume. It is expressed through the sphericity and the equivalent volume diameter.

The density of the particle, ρ_p , is the density of the bulk material of which the particle is made. However, when the volume measured includes closed pores within the particle, or the particle itself is produced by agglomeration or coagulation of smaller

$$\rho_p = (1 - e_i) \rho_s + e_i \rho_s + e_i \rho_f = \phi_i \rho_s + (1 - \phi_i) \rho_f \dots\dots\dots(1)$$

Where e_i , the internal porosity, is the ratio of the volume of internal pores to the external particle volume, ϕ_i is the solid volume fraction, ρ_p is the density of the solid material and ρ_f is the density of the fluid present in the pores.

In practical measurements, a given amount of dry powder is weighed and its volume is determined by the volume of fluid it displaces [2].

The well known gravitational force acts on dust particles in nature causing their settling down. Also, van der Waals forces act between dust particles. When two particles are brought into contact, they are subjected to capillary, electrostatic and van der Waals forces. Capillary forces are caused by condensed moisture on the surface of the particle. Electrostatic forces depend on the charges present in the particles. Particles of dissimilar materials interchange charges when in contact, and the charges become trapped in non-conducting particles. In a powder that is neutral on the average, there is a distribution of charges of both signs, with individual particles positive and negatively charged. Since particles tend to reorient among themselves in order to minimize the electrostatic energy, there is always an attractive electrostatic interaction between particles [3, 4, and 5].

Van der Waals forces between particles have their origin in the forces between their constituent molecules. It is well known that molecules attract each other even if they are totally neutral. The origin of the attraction can be understood as follows: in any molecule, the instantaneous positions of the electrons around the nuclear protons give rise to a finite electric dipole, which in turn originates an electric field that polarizes a nearby molecule inducing a dipole on it. The two dipoles give rise to an attractive force between both molecules with a finite time average. When the time that the electric field takes to reach the other molecule is comparable to the period of the fluctuating dipole, the two dipoles are no longer aligned in the most favorable position and the attraction forces decrease. This effect is called the retardation effect. A third molecule will modify the resulting fluctuating dipoles of the first two molecules and consequently these molecular forces are not pair wise additive. However, these forces are amenable to a simplified treatment assuming that the interaction potential between two molecules a and b, separated by a distance r_{ab} , is the Lennard-Jones potential [6]:

$$V = - \frac{C_{ab}}{r_{ab}^6} + \frac{D_{ab}}{r_{ab}^{12}} \dots\dots\dots(2)$$

Where the first term of the right-hand side, the attractive part, is the van der Waals interaction potential, with C_{ab} being the London constant, and the second term is the Born repulsive term [6].

Experiment

The electrostatic curtain, (figure 1), was prepared by thermal spraying of a thin film of SnO2 on the surface of a glass sheet, the details are published in a previous study [7]. The dust powder was ranked and sifted according to the size of dust grains (20, 40 and 56 micrometer). Samples were in equal weight (0.1 g).

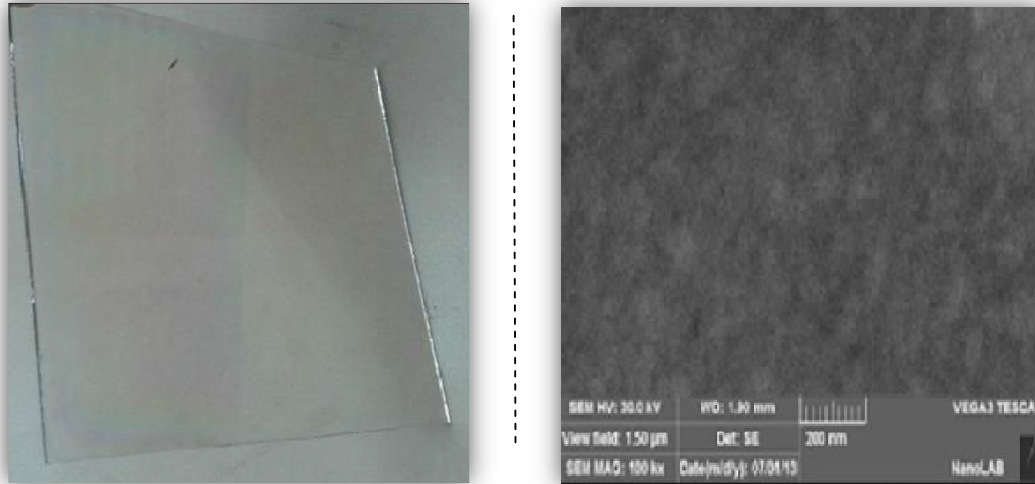


Figure-1: (a) image shown SnO₂ thin film on glass substrate, used as transparent, low resistance, conductive glass for dust shield, (b) SEM image of the clean shield [7].

The samples were spread as a film on the 45o tilted surface of the electrostatic curtain. The curtain was energized by a solar cell via a charging circuit. Considering different particle diameters and different energizing voltages, X-ray fluorescence device (Jiangsu SKYRAY EDX P 730 Instrument Co., Ltd) was used to analyze the components of the dust repelled off the energized electrostatic curtain surface. The results were arranged in three sections depending on the size of dust particles (20, 40 and 56 micrometer). Each section (each particle size) is subdivided into three parts depending on the voltages applied to the conductive glass (1, 4 and 7 volt).

Figure 2 shows the electrical circuit diagram.

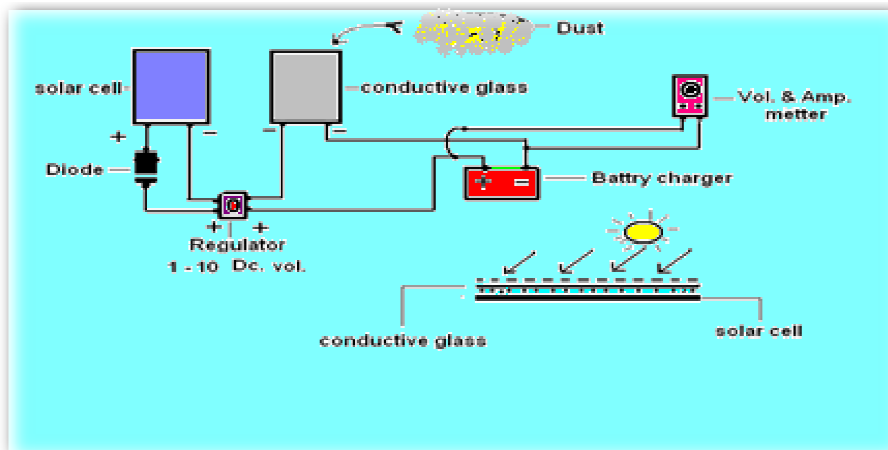


Figure -2: Circuit diagram used in charging the electrostatic curtain.

Results

X-Ray Fluorescence Test for Dust Samples

In order to examine the composition of the dust, a basic reference test for dust was made. The result showed presence of so many elements as listed in table (1). These elements differ in their molecular weight, conductivity and diameter. Unfortunately, some of them are very harmful for the environment and human health. Results are organized and discussed in the following sections and tables.

Table -1: The composition of typical dust:

Element	Availability (ppm)	Molecular Weight (g/mol)	Electrical conductivity (S/cm)
Calcium (Ca)	111669.00775	40.078	2.98×10^7
Tin (Sn)	1555.09577	118.71	0.917×10^7
Iron (Fe)	28490.90414	55.845	1×10^7
Titanium (Ti)	2012.57804	47.867	0.238×10^7
Zinc (Zn)	511.78923	65.409	1.69×10^7
Manganese(Mn)	362.47426	54.938049	0.69×10^7
Strontium (Sr)	394.37986	87.62	0.758×10^7
Zirconium (Zr)	210.09176	91.224	0.238×10^7
Copper (Cu)	180.33809	58.6934	1.43×10^7
Nickel (Ni)	166.71896	250.03961	5.96×10^7
Lead (Pb)	137.35998	207.2	0.455×10^7
Gallium (Ga)	65.18051	69.723	0.37×10^7
Atrium (Y)	41.61326	88.90585	0.168×10^7
Rubidium(Rb)	33.43892	85.4678	0.781×10^7
Chrome (Cr)	19.68949	51.9961	0.8×10^7
Antimony (Sb)	3.06229	121.761	0.24×10^7
Arsenic (Ar)	1.72596	74.9216	0.3×10^7
Silver (Ag)	0.13623	107.8682	6.3×10^7

Later, the electrostatic curtain was energized with different values of dc-voltage and the repelled off dust was tested. The results are presented in the following:

1- The Missing elements from dust sample with d= 20 micrometers

Table (2) shows the results for particle diameter equal 20 μm at different voltages applied to the conductive glass. In table (2), one notices that increasing the voltage from 1 volt to 4 volts results in rolling down of lead, rubidium and chromium.

Table-2: The missing elements from the dust sample for particle diameter of 20 micrometers at different energizing voltages.

Missing element at V=1 volt	Missing element at V=4 volt	Missing element at V=7 volt
Sn	Sn	Sn
Cu	Cu	Cu
Ni	Ni	Ni
Sb	Sb	Sb
As	As	As
Ag	Ag	Ag
	Pb	Pb
	Rb	Rb
	Cr	Cr

2- The Missing elements from dust sample with d= 40 micrometers

In table (3), one can find out the missing elements with 40 micrometer diameter rolling down a glass energized with different voltages. Rubidium was missed in higher voltage values.

3- The missing elements from dust sample with d= 56 micrometers

Table (4), displays the results related to dust particles with diameters (56) μm. At the highest voltage, 7 volts, one can notice the absence of copper and nickel.

From tables (2), (3) and (4), one can notice that some particles were repelled and rolled off the surface once the surface is energized. Also, one can notice that increasing the voltage causes the absence of more elements

like Zr, Cu, Ag, Sn, Sb, As, Ni and Pb. Referring to table (1), that behavior may be attributed to the impact of the outcome of several factors like the particles small presence percentage, their relatively light weight, their geometric shape and their high electrical conductivity. For example, see Ag and Cu properties in table (1).

Table-3: The missing elements from the dust sample for particle diameter of 40 micrometers at different energizing voltages.

Missing element at V=1volt	Missing element at V=4volt	Missing element at V=7 volt
Sn	Sn	Sn
Cu	Cu	Cu
Ni	Ni	Ni
Cr	Cr	Cr
As	As	As
Ag	Ag	Ag
Pb	Pb	Pb
	Rb	Rb

Table-4: The missing elements from the dust sample for particle diameter of 56 micrometers at different energizing voltages.

Missing element at V=1volt	Missing element at V=4 volt	Missing element at V=7 volt
Sn	Sn	Sn
	Cu	Cu
	Ni	Ni
Cr	Cr	Cr
As	As	As
Ag	Ag	Ag

An overall review of tables (2), (3) and (4) reveals that the elements that roll down the surface are not so critical to the particle diameter or the applied voltage. Meanwhile, their amount may change directly with the applied voltage.

Conclusions

- The particles were repelled and rolled off the surface when the surface is energized. Increasing the energizing voltage may lead to the loss of some heavy and electrically conductive element particles like lead, copper and silver.
- The elements that roll down the surface are not so critical to the particle diameter or the applied voltage. Meanwhile, their amount may change directly with the applied voltage.

Reference

- (1) Holmes and Hannah, *The Secret Life of Dust*. Wiley. ISBN 0-471-37743-0, 2001.
- (2) L. Svarosky, *Powder Testing Guide: Methods of Measuring the Physical Properties of Bulk Powders* (Elsevier Applied Science, Oxford, 1987).
- (3) Adam J. Forsyth, Martin J. Rhodes, A Simple Model Incorporating the Effects of Deformation and Asperities into the van der Waals Force for Macroscopic Spherical Solid Particles, *Journal of Colloid and Interface Science*, Volume 223, Issue 1, 1 March, pp 133–138, 2000.
- (4) B. Gady, D. Schleef, R. Reifenberger, D. Rimai and DeMejo, L. P., *Phy. Rev. B* 53 8065, 1996.

- (5) K. Rietema, *The Dynamics of Fine Powders* (Elsevier, UK, 1991).
- (6) J. Israelachvili, *Intermolecular and Surface Forces* (Academic Press), New York, USA, 1992.
- (7) M. M. Abdullah, R. Ayad and M. Al-Ansari, SnO₂ Transparent Self- Cleaning Dust Shield for Solar Panels , *International Journal of Application or Innovation in Engineering & Management (IJAIEM)*, Vol. 2, Issue 11, Nov. 2013.