Name of Candidate: Oytun Uğurel

Number of Candidate: D1129-046

Extended Essay Subject: Physics

Extended Essay Topic: The use of nanotechnologic surface coatings in design, construction and lifespan of buildings.

Word Count: 3131

Abstract

Although nanotechnology was not a big part of our lives in the past century, today it has a bigger role than we can see. Nano technology has a wide variety of use in engineering, mostly in physics and chemistry. The developments in these areas of science allowed engineers to create more effective surface coatings for certain materials like, walls, steel and glass. These allowed the design of more complex and pre-impossible buildings.

I chose this subject, as it is a promising technology for future, not just in buildings but other areas of our life. The development of the technology can create much more effective things in our lives. The computer science is already using this technology in creating more powerful and smaller computers that are seen in every step of our daily lives.

In the experiment, I tried to create a nanotechnologic surface coating of my own using some nanotechnologic photocatalyzers like TiO_2 and ZnO. These photocatalyzers are used in nanotechnologic designs to help a reaction start in the presence of a light source. I mixed these materials with a regular surface coating that can be found in the markets to create a nano-paint. In the end I came up with an effective surface coating which is more resistant to dirt that a regular surface coating.

Word Count: 216

Contents

Oytun UĞUREL
D1129-046

Introduction

Where is Nanotechnology? And what is it?

Have you ever looked around and thought "where is nanotechnology"? Nanotechnology is gradually becoming a vital part of our lives and its first examples can be seen in the construction industry, chemistry, physics and civil engineering. So what is nanotechnology in the first place?

Nano- is a prefix used in SI system meaning 10^{-9} thus; nanotechnology is a branch of science which deals with particles smaller than 10^{-9} meters. Generally scientist in the field molecular physics and chemistry are involved in nanotechnologic researches but recently new faculties are set up to supply the interest in this area of knowledge.

I chose this topic for my extended essay as it is both in my area of interest and also nanotechnology is an extremely new and spread branch of science as it has wide variety of uses from device physics and electronics to new materials and surface coatings.

Uses of Nanotechnology

Maybe the most daily example to the use of nanotechnology is the high-efficiency solar panels which we can see everywhere. A simple solar panel consists of a nano-thin layer of silicone and copper which reacts with sunlight to produce electricity. The only reason why it is so tick is only that it's usually between two glass plates which prevent it from damages.

Other uses of nanotechnology include new hydrogen fuel cells, special glasses which are stronger or easier to clean and in some fabrics as water repellent and as in my experiment, outdoor surface coatings. As you know today the paint industry is in a new way which is lead by nanotechnologic products. These paints usually claim that their paint "cleans itself" or it does not show dirt.

How is Nanotechnology Applied?

Idea behind this is very simple but not so easy to apply. First of all to get the result you want from the surface coating you like, first your surface should be totally covered with the material you want to use. This may not seem like something hard to achieve but when you think in a nano- scale, this starts to seem harder.

The second step is to find the right kind of materials that supply your needs. If you want a glass which does not permit water to stay on it, for example in a car's front windows, you have to use the proper materials according to that basis.

In my experiment I will try to show the effect of some nanotechnologic materials on the outdoor surface coatings of buildings. After looking into the resources of TCCE (Turkish Chamber of Chemical Engineers) and meeting with a few professors in Bilkent University I found out that the main things they use are ZnO and TiO_2.

What are ZnO and TiO_2? How Do They Work?

ZnO and TiO_2 both have a high reactivity with light and for that reason they are called photo-catalyzers. The thing they do is to catalyze the process of organic deposition, so the materials which are gathered on the surface are broken down.

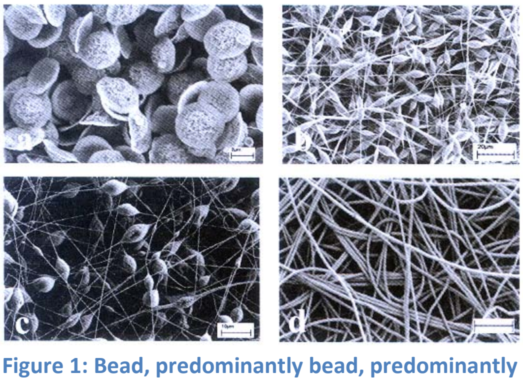


Figure 1: Bead, predominantly bead, predominantly fiber and fiber formations from a to d.

Also they both have a hydrophobic property which makes them repel the water molecules in a way. The actual thing they do is, if they are arranged in fibers (figure 1), they create a surface so dense that it does not allow water to go in between them. So the water just stays on the material as a drop, or rolls down if the surface is inclined. This also helps the materials broken down in the photo-catalytic process to be taken away with the water.

What is the experiment?

In the experiment I will try to make a nanotechnologic surface coating of my own using TiO_2 and ZnO and compare it with a regular surface coating. My hypothesis and variables during the experiment will be:

Hypothesis and Variables

Hypothesis:

The nanotechnologic surface coating I make is more resistant to dirt than a regular surface coating.

Variables:

Independent Variable:

- The color of the surface coating
- The type of the surface coating

Dependent Variables:

- Dirtiness of the surfaces at regular time intervals

Controlled Variables:

- All the weather conditions should be same
- Coating should have the same thickness

How and why these variables are chosen?

Choosing the variables was not so easy, as there can be many variables according to the conditions we are in. So I tried to condense all the independent variables into two. Type of the surface coating is the main independent variable. What is meant by type is that whether it is nanotechnologic or regular.

The second independent variable is the color of the surface coating. Here I tried two different colors of surface coating, as light colors and dark colors may be deceiving. So I prepared two pairs of surface coatings. One is white and one is brown and they are separated in themselves as nanotechnologic and regular (which is my first independent variable).

My dependent variable is the dirtiness of the surface coating. As the materials in the nanotechnologic surface coatings act as a photo-catalyzer and hydrophobic agent, it is expected to get less dirty. So in the end, a color difference (which symbolizes the degree of dirtiness) is expected. The problem with this variable is that there is not a generally accepted scale for the degree of dirtiness of a surface. So I will use the masses of the plates I applied the coating as an indicator of their dirtiness and at the same time take their photos to show the qualitative aspect.

The controlled variables are very important in this experiment as the coatings are very sensitive to light and water. Those conditions should be kept same during the whole for all the surfaces. It is not necessary to maintain the same temperature or humidity but all the subjects should be in the same conditions with the others. (For example if one is on the roof all the others should be on the roof too)

The last controlled variable is the thickness of the surface coating. All the surface coatings should be applied with the same thickness, as it can affect the efficiency of the nanotechnologic materials. So in my experiment I will apply 3 layers of each surface coating.

Design

Materials:

- 6 pieces of 150x50cm thin wood
- 6 pieces of 150x50cm isolation material
- Constructional plaster
- Water
- A spatula
- Zinc oxide
- Titanium dioxide
- A regular outdoor paint with colors white and brown
- 3 x 500mL graduated cylinder
- 2 x paint brushes
- A photo-camera
- An electronic balance
- A mixer
- Glue

Method:

First of all you need to preserve zinc oxide and titanium dioxide in a closed container with no exposure to water or sunlight, as they are very reactive.

The experimentation process consists of three main parts. First is the preparation of the surface, then preparation of paint and third is the "waiting" process:

Preparation of painting surface:

1. Take a piece of thin wood and glue its surface.
2. Stick the isolation material on to it and wait for glue to dry.

3. When it is dry, prepare some plaster and apply it onto the isolation material.
4. Write "1" onto back of it for identification.
5. Repeat the same steps for other 5 surfaces and write 2, 3, 4, 5, and 6 at the back.

Paint preparation:

1. Fill the first graduated cylinder with the white paint
2. Fill only 1/3 of the second and third cylinder with same paint
3. Put 1 mole ZnO into the second cylinder and mix it with the mixer. (Be careful, if you use a different graduated cylinder than mentioned in the materials, the paint you have at the end should be 2 molar. For example if you use a 1L cylinder you will have to put 2 moles of ZnO into it.)
4. Then put some more paint until it is filled 2/3 and mix it.
5. Then fully fill the cylinder and mix it again.
6. Now repeat steps 3-5 with TiO_2. (You can use a smaller cylinder for TiO_2 as it is harder to find than ZnO, so you will need less TiO_2.)
7. Now repeat the steps 1-6 with brown paint.

Painting and Waiting

1. Now take the prepared surfaces and paint 1 with white and 2 with brown regular paint.
2. Paint plates number 3 with white and 4 with brown ZnO paint.
3. Paint number 5 with white and 6 with brown TiO_2 paint.
4. Wait for at least 3 hours until the paint is dry and repeat steps 1-3, until all of the plates have 3 layers of paint on it.
5. Fix all six plates outdoors where they can get same amount of sun and rain.
6. Take a photo of each plate with 2 weeks of intervals and record their masses.
7. Do this for 6 months and record all the photos and masses.

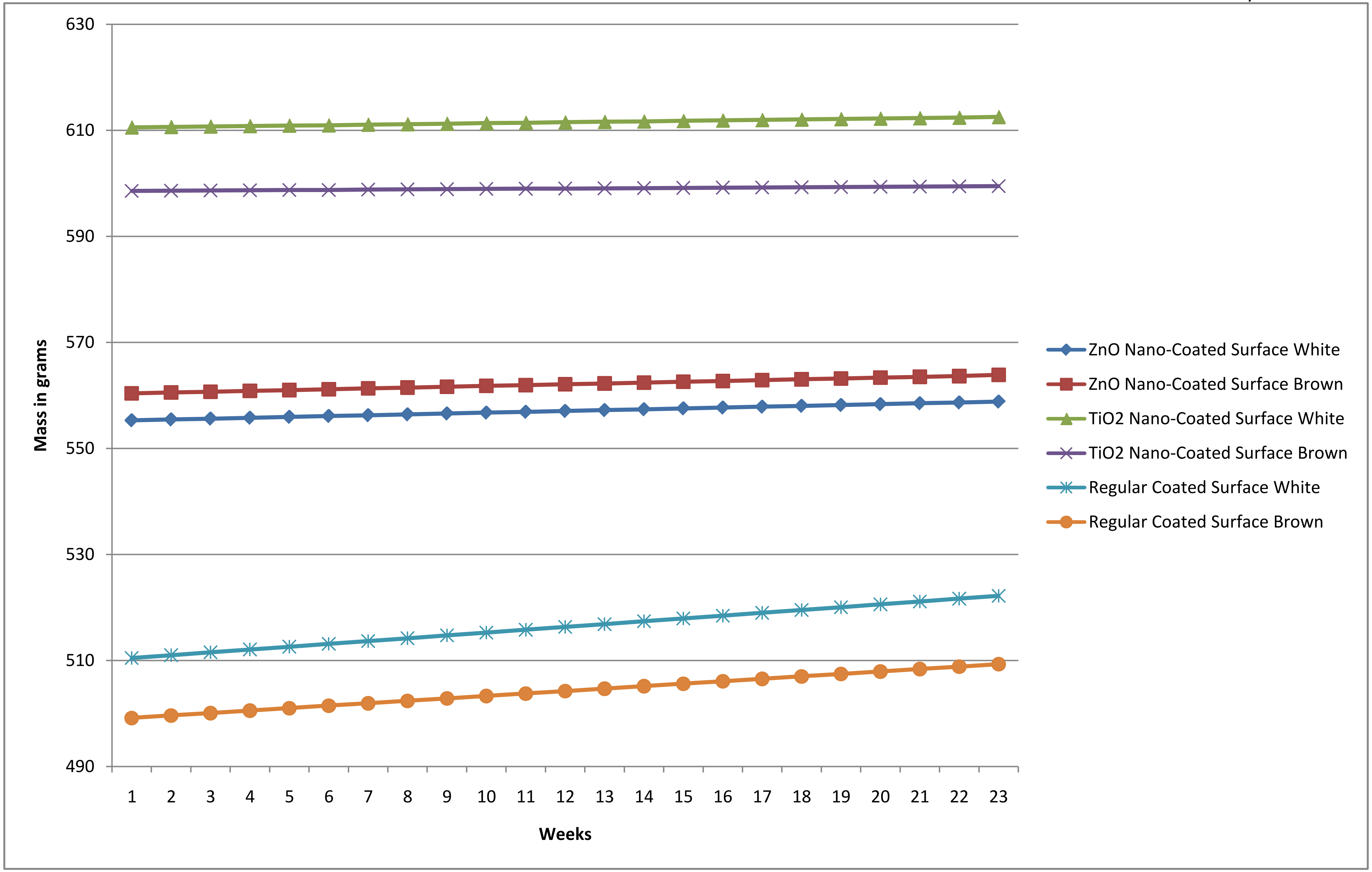
Data Collection and Processing

Data Collection

The data collection process consists of taking photos of the painted surfaces for qualitative observations and weighing them at certain time intervals. The table below shows the quantitative data collected throughout the process.

Mass / Weeks	ZnO Nano-Coated Surface White(g) (±0.001)	ZnO Nano-Coated Surface Brown(g) (±0.001)	TiO_2 Nano-Coated Surface White(g) (±0.001)	TiO_2 Nano-Coated Surface Brow(g) (±0.001)n	Regular Coated Surface W(g) (±0.001)hite	Regular Coated Surface Brow(g) (±0.001)n
1	555.300	560.365	610.558	598.561	510.474	499.157
2	555.460	560.521	610.645	598.601	511.006	499.618
3	555.621	560.677	610.732	598.646	511.538	500.079
4	555.779	560.833	610.819	598.686	512.078	500.540
5	555.948	560.989	610.906	598.727	512.602	501.001
6	556.111	561.141	610.950	598.723	513.134	501.467
7	556.258	561.301	611.080	598.802	513.666	501.923
8	556.421	561.457	611.167	598.846	514.198	502.389
9	556.582	561.613	611.254	598.881	514.725	502.845
10	556.744	561.769	611.344	598.927	515.262	503.306
11	556.900	561.925	611.428	598.965	515.794	503.767
12	557.060	562.081	611.515	599.002	516.327	504.228
13	557.222	562.237	611.602	599.046	516.858	504.689
14	557.381	562.393	611.681	599.084	517.395	505.150
15	557.547	562.547	611.776	599.128	517.922	505.618
16	557.701	562.705	611.863	599.169	518.454	506.072
17	557.860	562.861	611.950	599.202	518.986	506.533
18	558.022	563.017	612.033	599.241	519.521	506.991
19	558.183	563.166	612.124	599.281	520.050	507.455
20	558.346	563.329	612.211	599.320	520.582	507.916
21	558.511	563.485	612.298	599.361	521.114	508.378
22	558.666	563.618	612.388	599.402	521.657	508.838
23	558.826	563.851	612.511	599.447	522.188	509.300

Table 1: Showing masses of different coated surfaces.



Graph 1: Showing masses of painted plates during the 23 week process, in which they were left outdoors.

Qualitative data collected for the experiment can be found in the appendix 1.

Data Processing

Using these data we can find how fast a surface gets dirty. To do this we just need to find the tangents of the lines. By doing the calculations in appendix it's found that the tangents are:

- 0.153(± 0.002) for ZnO Nano-Coated Surface White
- 0.151(± 0.002) for ZnO Nano-Coated Surface Brown
- 0.084(± 0.002) for TiO_2 Nano-Coated Surface White
- 0.038(± 0.002) forTiO_2 Nano-Coated Surface Brown
- 0.509(± 0.002) for Regular Coated Surface White
- 0.441(± 0.002) for Regular Coated Surface Brown

Conclusion

Interpretation

For the interpretation of the results I used one qualitative and one quantitative data set, which in the end can show how a nanotechnologic surface coating can work.

The qualitative results, in this case consists of photos of coated surfaces, show us a slight color change. In our daily life we usually understand whether things are clean or not from their appearances and thus from their colors. If a surface is dusty it looks grey, if a cloth is dirty it looks darker. Here, the darker color of non-nanotechnologic paint indicates that its surface is less clean, when we compare it with the nanotechnologic one.

The quantitative data, the mass of the coated surfaces also show us that mass accumulation on the nano-coated surface is less so the surface with this kind of coating is cleaner. Also the tangents of the lines in graph 1 show us how fast the surfaces get dirty. The bigger the tangent is the faster a surface gets dirty. And as the regular white coating has a tangent of 0.509 it has the highest speed of mass accumulation on it.

Use

In buildings nanotechnology is not just important for the appearance. The dirtier a surface gets, which is the supposed surface of a building, the harder it is to control some vital variables in its health. The simplest example is heating. As surfaces get dirtier, it will be harder to maintain the temperature inside the building. This may cause the building to get damaged as the temperature and thermal expansion is directly related.

Different components in a building has different thermal expansion coefficients, thus the constant friction caused by different amounts of expansion can cause a building to weaken. If a building is made out of ferro-concrete, and most of the buildings are, there is steel rods and concrete. The thermal expansion coefficients of steel and concrete are very different, so the change in the size of steel will be very different for that of concrete. Coating a surface with a nanotechnologic material can lessen this effect and extend the life of a building. This example shows us that the nanotechnologic surface coatings do not have to be on surface to show their effect.

Result

In my experiment, I tried to show how nanotechnology works and how it can be applied. Although the technology is not easy to maintain, it can be applied in engineering buildings to make stronger and more reliable buildings. The results show that TiO_2 minimalises the static friction and thus static attraction of small particles, keeping the surface cleaner.

Error Sources and Improvements

The experiment procedure contained some flaws that may have caused errors in the data collected and thus results obtained. Although other errors are present the main sources that can affect the results are:

- Uncontrolled weather conditions,
- Method of application of coating to the surface,
- And the method of mixing the nano particles.

The main problem, the uncontrolled weather conditions, can cause some errors in the results as the temperature varies during the experiment which can compromise the effect of nano-particles. Too less temperature can prevent the particles from working, whereas the high temperature may cause them to denaturalize, or react with other materials which in normal conditions they would not/should not react. This error may be corrected by creating a controlled environment for plates and apply artificial weather conditions. For example a leaf blower can be used to create wind at certain times, an automatic flower watering system can be used to simulate rain and a combination of UV, IR, and standard lights can be used to simulate sunlight.

The method of application of the coating to the surface is very important as non-equal amount of paint used to coat plates can affect the results as the thickness effects the amount of nano-particles and so the amount of resistance to dirt. Also as the paint is applied by brush, the brush patterns can create a more comfortable surface for masses to accumulate on. This problem can be prevented by using a professional sprayer to apply the coating. So both the thickness would be same and the brush patterns will be eliminated.

Finally one of the most important sources of errors is the method of mixing the nano-particles to the regular paint. The nano-particles like TiO_2 and ZnO are very sensitive and can accumulate and lose their function. Prevent this is very hard as either it needs other chemicals to prevent it from accumulating, which is hard to find, or needs to be immediately applied on the surface before they can accumulate.

Word Count: 3131

Appendix 1

Photo 1: Showing plates number 3 and 5 coated with ZnO and TiO2 reinforced paints respectively.

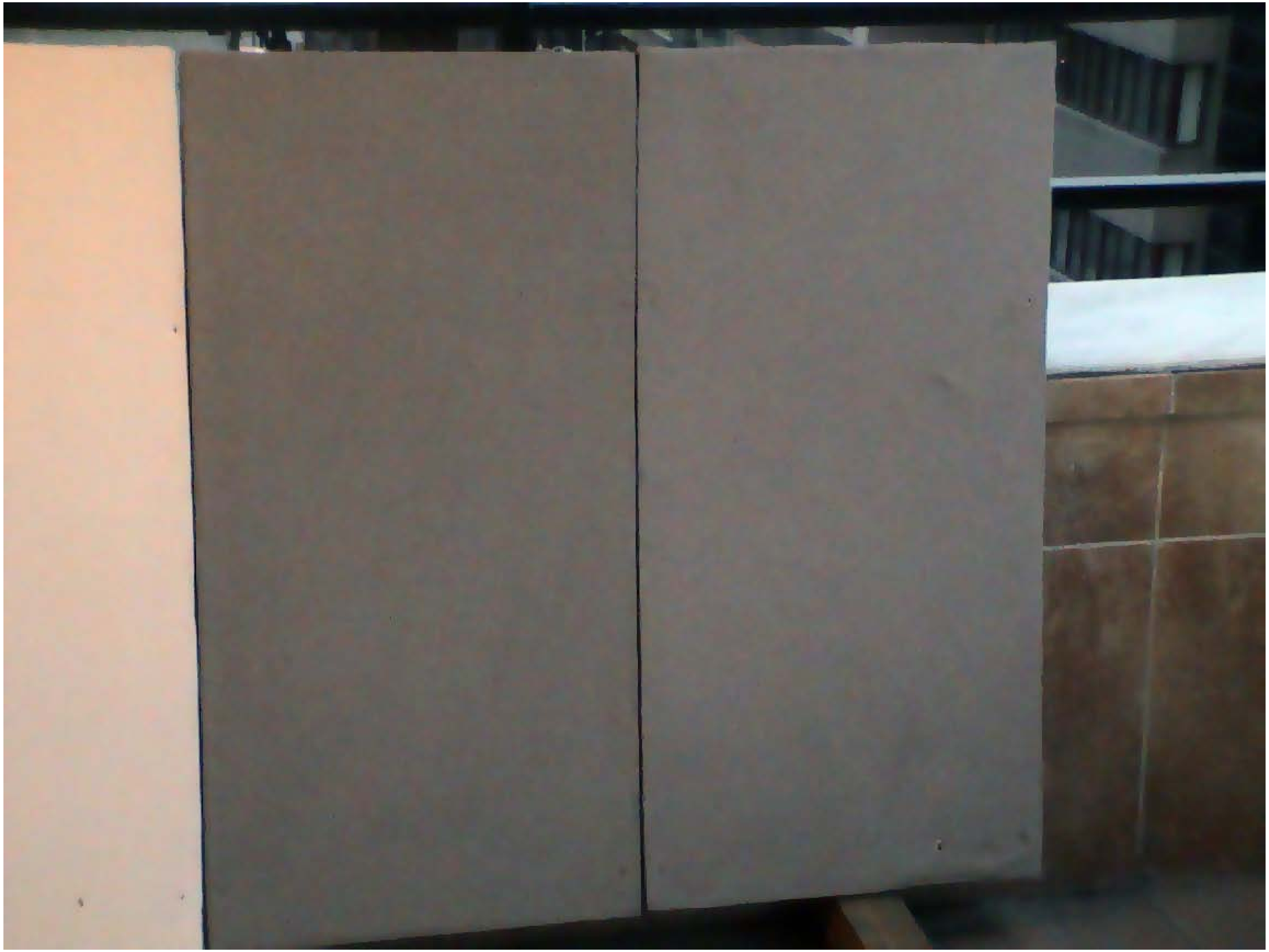


Photo 2: Showing plates number 4 and 6 coated with ZnO and TiO_2 reinforced paints respectively.

Photo 3: Showing plate 6 painted with it's half painted with regular paint to show the contrast.

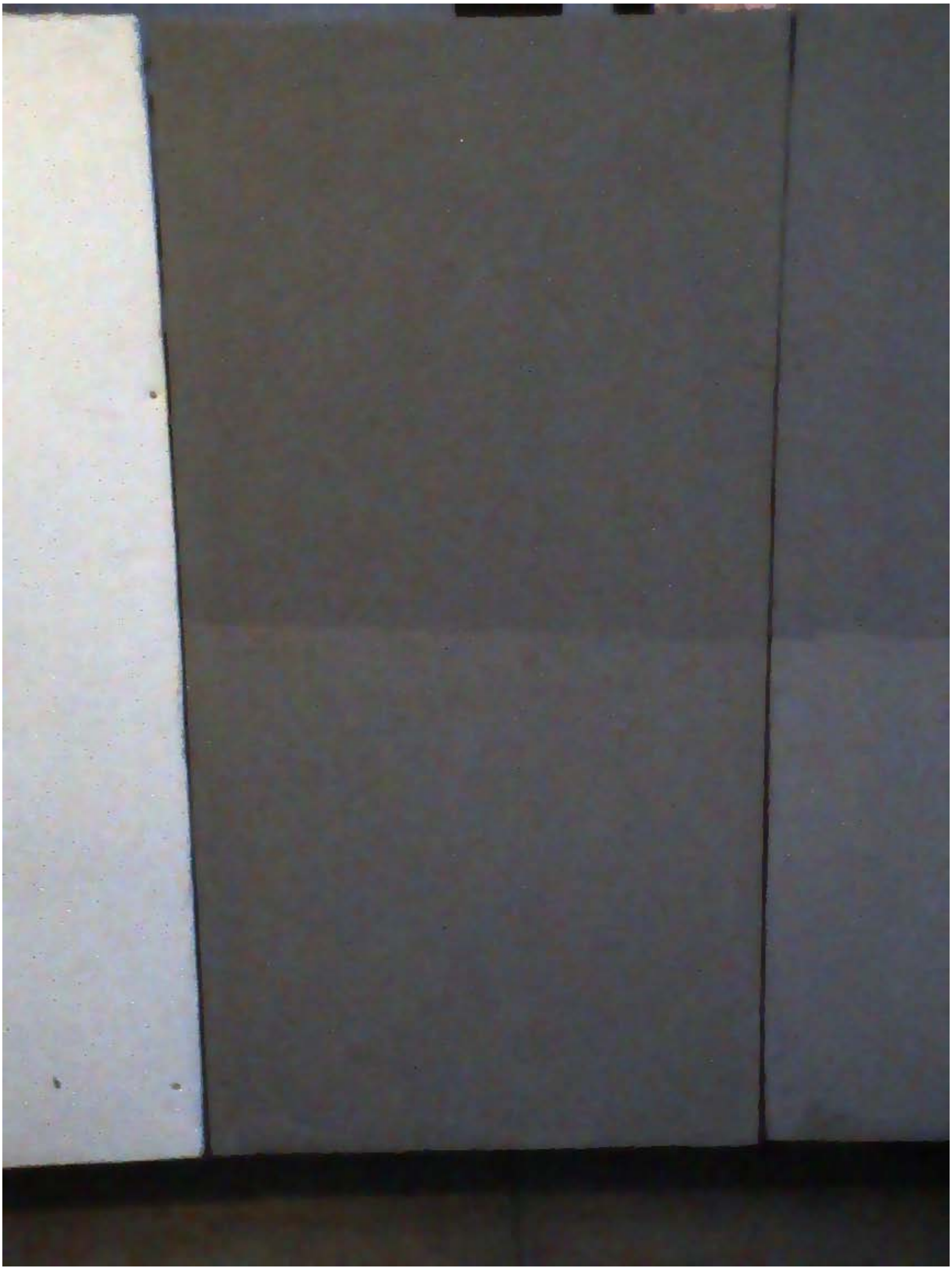


Photo 4:Showing plate 4 painted with it's half painted with regular paint to show the contrast.

Photo 5:Showing plate 3 painted with it's half painted with regular paint to show the contrast.

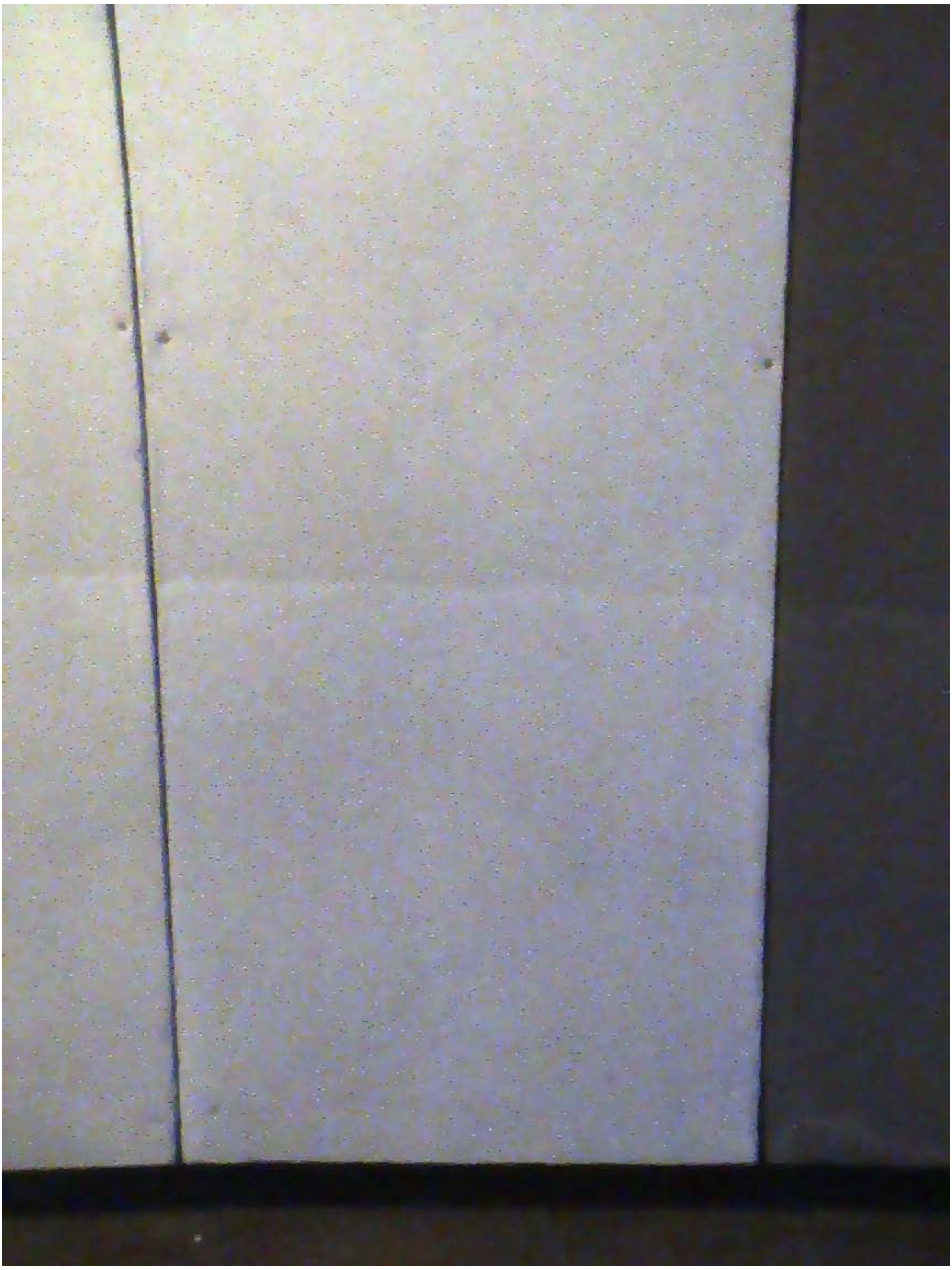


Photo 6:Showing plate 5 painted with it's half painted with regular paint to show the contrast.

Photo 7: Showing all four nano-reinforced paint coated surfaces. With half of them later coated with regular paint to show the contrast.

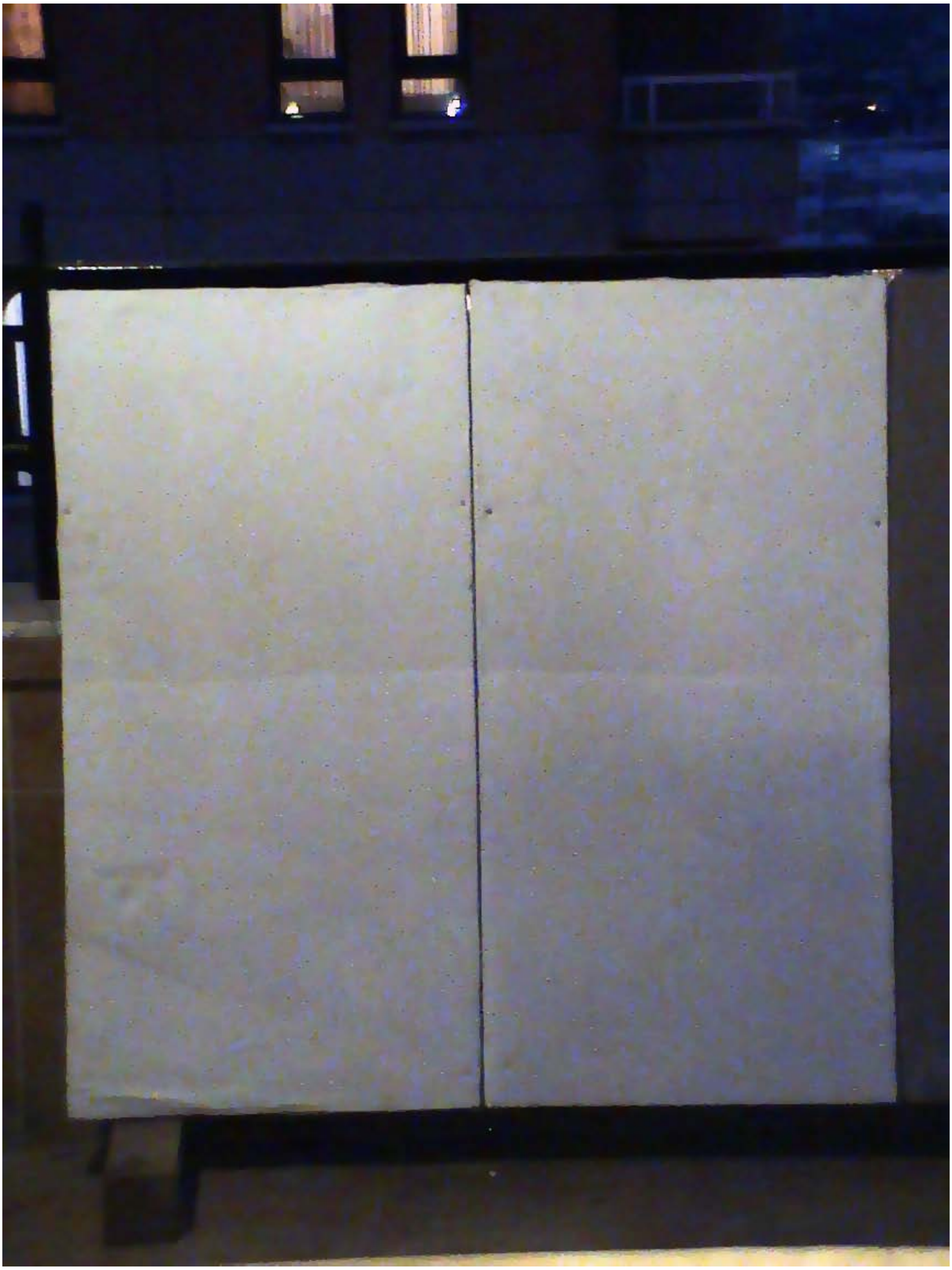


Photo 8: Plates number 3 and 5.

Photo 9: Plates number 4 and 6

Appendix 2

Tangents for the lines are found by the simple operation:

(final mass - initial mass)/number of weeks, so:

- Tangent for ZnO Nano-Coated Surface White

$$\frac{558.826\ (\pm 0.001) - 555.300(\pm 0.001)}{23} = 0.153(\pm 0.002)$$

- 0.151 for ZnO Nano-Coated Surface Brown

$$\frac{563.851(\pm 0.001) - 560.365(\pm 0.001)}{23} = 0.151(\pm 0.002)$$

- 0.084 for TiO_2 Nano-Coated Surface White

$$\frac{612.511(\pm 0.001) - 610.558(\pm 0.001)}{23} = 0.084(\pm 0.002)$$

- 0.038 forTiO_2 Nano-Coated Surface Brown

$$\frac{599.447(\pm 0.001) - 598.561(\pm 0.001)}{23} = 0.038(\pm 0.002)$$

- 0.509 for Regular Coated Surface White

$$\frac{522.188(\pm 0.001) - 510.474(\pm 0.001)}{23} = 0.509(\pm 0.002)$$

- 0.441 for Regular Coated Surface Brown

$$\frac{509.300(\pm 0.001) - 499.157(\pm 0.001)}{23} = 0.441(\pm 0.002)$$

Resources

- UCTEA Chamber of Chemical Engineers Presentations 2006
  ISBN: 9944-89-125-8

- Emrah Özensoy – Chemical Engineer, Member of NNRC (National Nanotechnology Research Center, Bilkent University, ANKARA)