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Innovation of anti-viral, anti-bacterial and water-repellent textile wall hanging, depending on nanotechnology and modern printing technologies

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Abstract
Textile hanging is the goal of this study, as it was treated with water-repellent fluorinated compound, antibacterial sulphate compound, and nano-composite antiviral composite, to be safe and durable, the printed designs with multiple techniques and special inks that show different colour changes were treated to produce a unique textile hanging.
Keywords: Anti-bacterial, anti-viral, water repellent, nanocomposite, graphene, cupper nanoparticles.

1. Introduction

Textile hanging and its design are considered as one of the most important elements in the interior design field that simulate the culture and the environment of the place and society. That is why it gains the attention of creative designers to produce a different way to the art. Due to the pandemic of coronavirus, the reaction between art and science became a must, in order to produce a unique product with special properties [1-5].

This thesis focused onto this idea, which mixes the art with the science, to produce a textile hanging that has the capability to resist microbes including bacteria and viruses specially corona virus, without any side effect or any distortion to the design [6-11].

So, the study added a value to the traditional textile hanging and also added a value to the treated traditional textiles, by collecting both into the same work. Futurism is an Italian phenomenon that included various artistic activities, such as literature, photography, sculpture as well as music, and its first manifesto was issued by the poet F.T. Marettini in 1909, in which he called for the rejection of the past and the expression only of the manifestations of the modern world, and the artists participated in the formation of its plastic direction: Boccioni, Carra, Balla, and Severini [12-16].

The present work aimed to production of several textiles hanging with such modern inks depends on color changes theories. Treatment of the printed samples with water-repellent, anti-bacterial and anti-viral substances to achieve a textile hanging that resist dust, droplets, and microbes, especially viruses. Therefore, in this the present work will experimentally studying such special effect substances as glow in the dark, photo chromic and hydro chromic inks, also will apply the water-repellent, anti-bacterial and anti-viral treatment onto the printed fabrics, this is to add a unique value to the fabric and to keep it safe from dirty and microbes.

2. Materials and methods

2.1. Chemicals &materials

acrylate emulsion polymer “BASF Company”, 1.2 Anti-bacterial, sulfate compounds “BASF Company”, 1.3 graphite powder “SPI”, 1.4 Fluorinated compound “BASF”, 1.5 White textile fabric, 1.6 photochromic inks “SPI” 1.7 Glow in the dark powder “SPI” and 1.7 hydro chromic inks “SPI”.

2.2. Methodology

The fabrics were washed and dried to be ready for printing even by silk screen or digital, after printing the samples as mentioned, the special effect inks were applied even by silk screen technique or by brush, the printed samples then were treated against Bactria and corona viruses individually, all tested samples will be measured and discussed.

2.2.1. Applications of modern printing techniques depending on color theories

This point will study the effect of such factors as UV light, water and temperature onto the printed fabrics with special inks that may change its color or emit light according to its nature.

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2.2.1.1 Studying the application and effect of glow in the dark

After all tested samples were digitally printed, the glow on the dark inks were applied onto the samples, all the samples were subjected to light source" UV was recommended" then the phosphorescence of each color was measured on the dark, the results were reported in tables 1, the results also clarified with figure 1.

2.2.1.2 Studying the application and effect of photochromic inks.

After all tested samples were digitally printed, the photo chromic inks were applied onto the samples, then the color strength of each color at sun light was measured, the results were reported in table 2, the results also clarified with figure 2.

2.2.1.3. Studying the application and effect of hydro chromic ink

After all tested samples were digitally printed, the hydro chromic ink was applied onto the samples, the hydro chromic ink must cover the area that will be tested, then all tested samples were subjected to water, the result was reported in table 3 and clarified with figure 3.

2.2.2. Studying the chemical and biotechnology treatment of tested samples

This section will study the water-repellent & anti-bacterial treatment of the fabric individually and one batch processing, the treatment study was as follow:

2.2.2.1. Studying the efficiency of anti-bacterial treatment

Four samples were treated with anti-bacterial compound with concentrations of 0.25%, 0.5%, 1%and 1.5%, as mentioned in methodology, the samples were dried and fixed at 80C^{o} and 150C^{o} respectively, the results were reported in table 4 and clarified with figure 4&5.

2.2.2.2. Studying the efficiency of water-repellent treatment

Four samples were treated with water-repellent substance "120,130,140 and 150 gm./L", the samples were dried and fixed at 80C^{o} and 150C^{o} respectively, all results were reported in table 5 and clarified with figure 6.

2.2.2.3. Studying the efficiency of anti-bacterial & water-repellent composite "one component treatment.

Four samples were treated with a pre-synthesized mixture of 0.5% anti-bacterial and different concentration of water-repellent substance "120,130,140 and 150 gm./L", the samples were dried and fixed at 80C^{o} and 150C^{o} respectively, and all results were reported in table 6 and clarified with figures 7&8.

2.2.3 synthesis and applications of Graphene & cupper nanoparticles

In this section will synthesis the graphene nano- particles chemically by oxidation of graphite and reduction of graphene oxide to achieve the expected result, the synthesis steps typically follow the Hummers, method" with a little pit change, while the cupper nanoparticles were synthesized with electro chemistry technique, which is more safe and eco-friendly method. After the nanoparticles were achieved, the anti-viral efficiency of both graphene and cupper were examined specially against corona virus, as the tested fabric was treated with a composite containing the synthesized nanoparticles, the study was as follow:

2.2.3.1 synthesis of Graphene nanoparticles

The synthesis of graphene from figurate in this thesis follows the most common method "Hummers, method" with a little pit devotion, the obtained graphene was subjected to measurements to ensure about the particle size, the result was reported and discussed [17].

2.2.3.2. Studying the anti-viral efficiency of Graphene nanocomposite

Graphene nanoparticles were mixed with a composite containing polyurethane "PU" as a fixing agent and non-ionic dispersing agent, then subjected for 4 hours to ultrasound milling process. The tested fabrics were treated with the synthesized graphene composite by padding technique, squeezed and finally subjected to heat fixation at 130Co for 2min. The achieved results were reported and discussed [18].

2.2.3.3. Synthesis of cupper nanoparticles

Cupper nanoparticles were synthesized using electro chemistry technique using cupper rod and platinum rod; both cupper and platinum were connected with power supply 7 volts, the cupper rod start to decay to nano-form cupper into the ionized aqueous solution. The synthesized liquor was filtered using vacuum distillation and washed out with distilled water 3 times, the obtained powder was subjected to reduction process for 30 min. at 400 ^{0}C. The achieved particles were subjected to measurement to ensure about the molecular size, the results were reported and discussed [19, 20].

2.2.3.4. Studying the anti-viral efficiency of cupper nanocomposite

Copper-nanoparticles were mixed with a composite containing polyurethane "PU" as a fixing agent and non-ionic dispersing agent", and then subjected for 4 hours to ultrasound milling process. The tested fabrics were treated with the synthesized nano-cupper composite by padding technique, squeezed and finally subjected to heat fixation at 130C^{o} for 2min. The achieved results were reported and discussed [21, 22].

3. RESULTS & DISCUSSIONS

In this part will write down and discuss the results that were achieved practically to stand up onto the effective treatments and the ability of the special effect substance to make up the textile wall hanging.

1. Applications of modern printing techniques depending on color theories

The results of all treated samples with such special effect printing materials" glow in the dark, photo chromic and hydro chromic" were individually observed, measured, and reported down as follow:

1.1. Studying the application and effect of glow in the dark

The phosphorescence of printed samples with glow in the dark inks were observed in the dark clearly, this light emission was due to the energy loss of the excited electrons "quantum" when return back to the ground state shell, the light intensity increases with the increase of the ink concentration, the emission still occurred until all the excited electrons returned to ground state, it take about 6 hours in this case study [23-25].

Table 1 total color difference "ΔE" between blank and excited green sample

Standard sample						
Illuminant	**L**	**A**	**B**	**L**	**C**	**H**
D65/SCI	**74.60**	**-1.00**	**12.49**	**74.60**	**12.53**	**94.50**

Test sample-degree of metamerism										
Illuminant	**L**	**a**	**b**	**L**	**C**	**H**	**DE**	**DL**	**Da**	**Db**
D65/SCI	**76.33**	**0.65**	**12.40**	**76.33**	**12.42**	**86.99**	**2.40**	**1.73**	**1.66**	**0.09**
Distinction							**48**	**44**	**4**	**4**
D65/SCI	**76.33**	**0.65**	**12.40**	**76.33**	**12.42**	**86.99**	**2.40**	**1.73**	**1.66**	**0.09**
Distinction							**48**	**44**	**4**	**4**
F11/SCI	**76.33**	**0.65**	**12.40**	**76.33**	**12.42**	**86.99**	**2.40**	**1.73**	**1.66**	**0.09**
Distinction							**48**	**44**	**4**	**4**

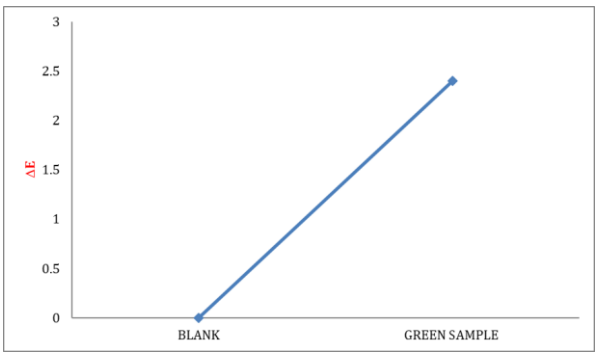


Figure 1. Total color differences "ΔE" between blank and excited green sample

From the illustrated table (1) and figure (1) found that: that light emission of the green color clearly expressed by total color differences "ΔE" between the blank sample in the ordinary light and the tested sample in the dark, ΔE was 2.4, actually this value changes with the change of color and the concentration of the ink.

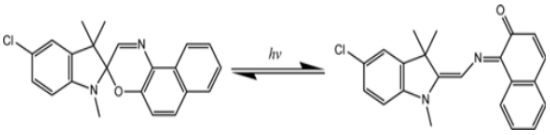
1.2 Studying the application and effect of photo-chromic ink.

The color change of the design from colorless to colored was noticed when the sample was exposure to UV light, sunlight has about 5% UV, so it shows a clear and speed color change. The appearance of colors may be due to the excitation of the pigment molecules that help to make new bonds in between,

leads to form a bigger molecule with high resonance, that is why the color of the pigment molecule was shifted from non-observed to an observed area, which is between UV and IR.

In the other hand the effect of UV may be enhance the formation of double bond into the pigments molecules that create such temporary chromophoric groups which may the responsible for the achieved colors [26, 27].

Silica features a large number of "nano-sized" microscopic pores that make an ideal host for photochromic molecules as these tiny pores give enough free volume for the photochromic molecules to complete the photochromic transformation [28, 29].



Scheme 1. The photochromic effect

Table 2. Total color differences "ΔE" between blank and excited purple photo-chromic sample

Standard sample						
Illuminant	**L**	**A**	**B**	**L**	**C**	**H**
D65/SCI	71.81	5.01	10.79	71.81	11.90	65.12

Test sample-degree of metamerism										
Illuminant	**L**	**a**	**b**	**L**	**C**	**H**	**DE**	**DL**	**Da**	**Db**
D65/SCI	56.71	21.65	-7.03	56.71	22.77	342.00	28.68	-15.09	16.65	-17.82
Distinction							48	44	4	4
D65/SCI	56.71	21.65	-7.03	56.71	22.77	342.00	28.68	-15.09	16.65	17.082
Distinction							48	44	4	4
F11/SCI	56.71	21.65	-7.03	56.71	22.77	342.00	28.68	-15.09	16.65	-17.82
Distinction							48	44	4	4

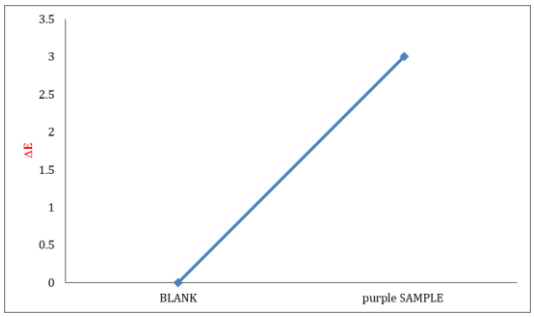


Figure 2. Total color differences "ΔE" between blank and excited purple photo-chromic sample

From the illustrated table (2) and figure (2) found that: the color of photo-chromic inks was changed clearly when the samples were exposure to UV-light, as the printed design was shown, so the total color difference "ΔE" between the un-excited and excited sample can be measured to express clearly how far is the color shift, in this study ΔE was changed to achieve 28.68, this value actually changed with the change of the color, printed layer and the color concentration.

1.3 Studying the application and effect of hydro-chromic ink.

Smart textiles, which provide natural fibers with appealing and interactive qualities, are promise for the future of the textile industry. In this context, it is feasible to highlight chromic materials, such as hydro-chromic, which change their visual qualities (color) in response to an external input (water). The

goal of this project is to functionalize and characterize cotton knitted fabric with a hydro-chromic chemical while investigating the print's reversibility and fastness features. The particles were found to be well disseminated and adhered to the natural fiber surface, with no notable changes in color after further washing and rubbing fastness cycles [30, 31].

Table 3 total color differences "ΔE" between blank and wet hydro-chromic sample

Standard sample						
Illuminant	**L**	**A**	**B**	**L**	**C**	**H**
D65/SCI	**90.93**	**0.36**	**2.56**	**90.93**	**2.58**	**81.96**

Test sample-degree of metamerism										
Illuminant	**L**	**a**	**b**	**L**	**C**	**H**	**DE**	**DL**	**Da**	**Db**

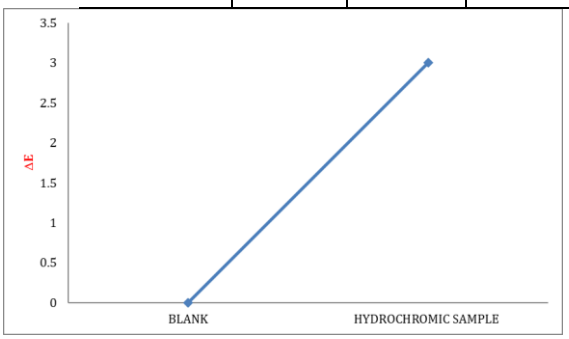


Figure 3. Total color differences "ΔE" between blank and wet hydro-chromic sample–

Table 4. The relation between anti-bacterial concentration and bacteria reduction percentage onto cotton fabric

Sample No.		*S. aureus*		*E. coli*	
		Colonies No. CFU× 10^5	Reduction %	Colonies No. CFU× 10^7	Reduction %
Antibacterial Cotton Sample	Blank	5.4	0	27.2	0
	Printed samples	4.1	24.07	23.8	12.5
	0.25	2.6	51.85	20.5	24.64
	0.5	1.05	80.56	13.2	51.48
	1.0	0.78	85.56	7.6	72.06
	1.5	0.25	95.37	5.8	78.68

From the illustrated table (3) and figure (3) found that: the total color differences ΔE between the dry white film and the wet design was 12.29, as the printed design was appeared in presence of water while hydro chromic white was disappeared, this appearance mechanism is typically reversible, and has a lot of applications specially in medical and child cloth.

2. Studying the chemical and biotechnology treatment of tested samples

This section was studied the water-repellent & anti-bacterial treatment of the fabric individually and one component batch, the treatment study was as follow:

2.1. Studying the efficiency of anti-bacterial treatment

With the prevalence of antibiotic-resistant bacteria, novel antibacterial strategies are urgently needed. In recent years, several antibiotics-independent physical approaches have attracted high attention and interests [32].

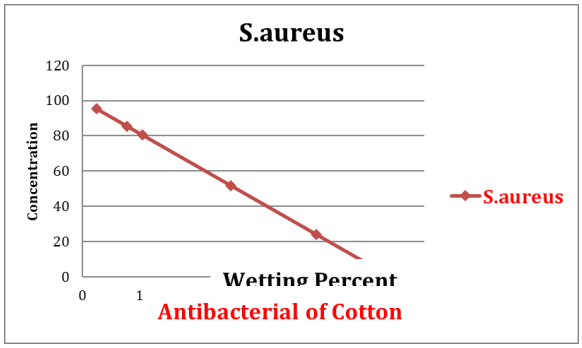


Figure .4 Relations between anti-bacterial concentration and reduction percentage (*S. aurous*) onto cotton fabric

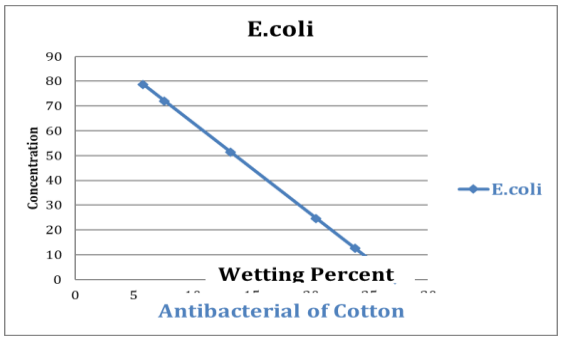


Figure 5. Relation between anti-bacterial concentration and reduction percentage (E-coli) onto cotton fabric

The reduction in bacterial growth on cotton fabric increased as the anti-bacterial concentration was raised; the maximum reduction was achieved at a concentration of 1.25. The treatments demonstrated acceptable results for both types of bacteria, as shown in the illustrated table (4) and figures (4&5).

2.2. Studying the efficiency of water-repellent treatment

In recent years, the interest to develop and investigate the highly hydrophobic and super hydrophobic surfaces essentially increased. Water repellency is very important for materials of various functionalities from textiles, used for tailoring the tents, umbrellas, working clothes, to fabrics for surgical personal wear.

When imparting the water repelling properties to a material by deposition of a coating, it is often may be important to preserve the texture, the density and the coloring of the initial fabric. Presently, among plenty of methods and hydrophobizing agents, only a few are readily applicable for textile goods. The current research is directed to partial filling of this gap [33].

Table 5 Studying the Wettability of cotton Samples

Samples: %	Time: sec
Blank	6
Printed samples	30
9	210
10	304
11	310
12	370

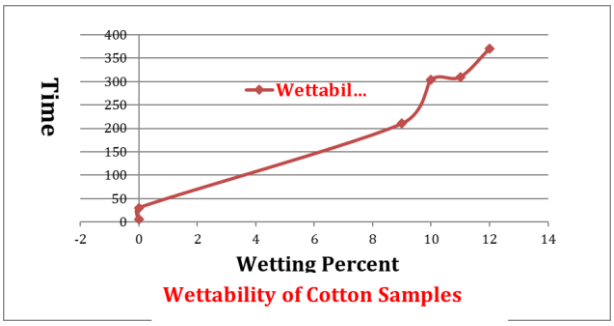


Figure 6. Studying the Wettability of cotton Samples

Table 5 and figure 6 show that the wettability of the treated samples decreased as fluorinated compound concentration increased, with the figure showing that the time for wettability increased as treatment concentration increased.

2.3. Studying the efficiency of anti-bacterial & water-repellent composite "one component treatment.

In order to facilitate the process, both anti-bacterial and water-repellent treatments were one-time processed, to ensure about the efficiency the samples were measured and compared with the single treatment process.

Table 6. Studying the efficiency of anti-bacterial & water-repellent composite "one component treatment

y		*S. aureus*		*E. coli*	
		Colonies No.	Reduction	Colonies No.	Reduction
		CFU× 10^5	%	CFU× 10^7	%
Antibacterial &Wettability	Blank	5.4	0	27.2	0
	Blank + Printing paste	4.1	24.07	23.8	12.5
	9	0.26	95.19	5.9	78.31
	10	.044	91.86	7.6	72.06
	11	.023	95.74	8.1	70.23
	12	.046	91.49	8.1	70.23

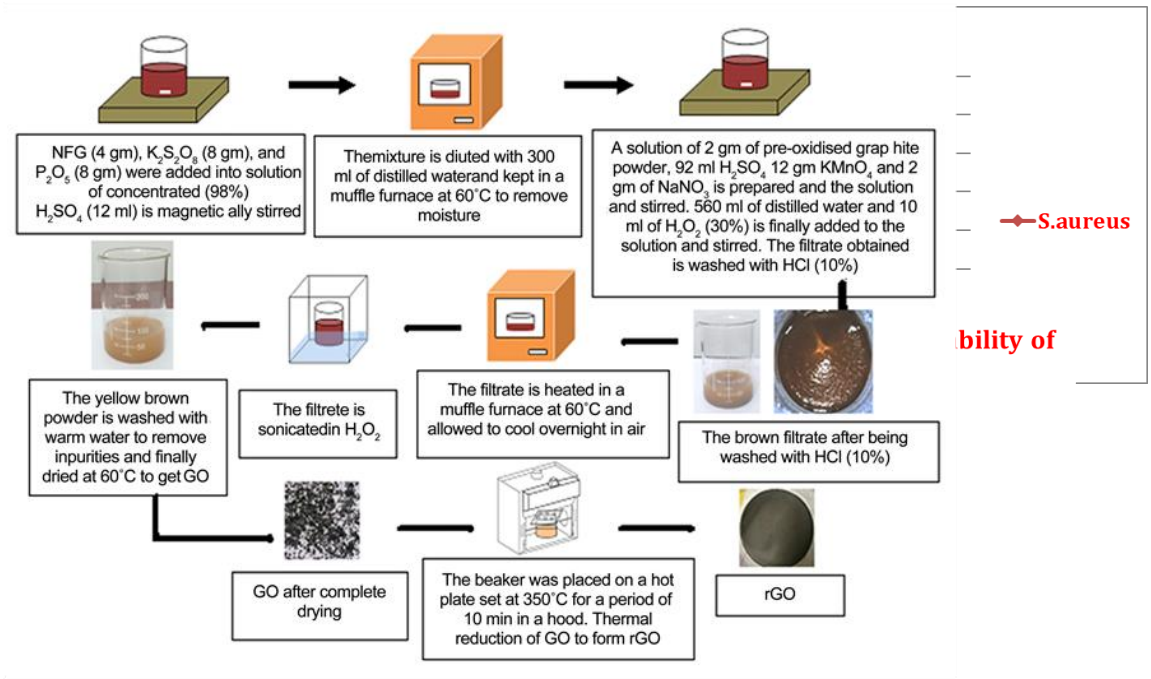


Figure 7. Studying the efficiency of anti-bacterial & water-repellent composite "one component treatment (*S. aurous*).

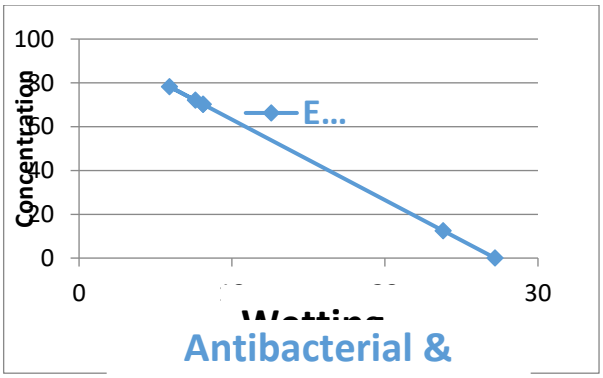


Figure 8. Studying the efficiency of anti-bacterial & water-repellent composite "one component treatment (*E.coli*).

From illustrated table (6) and figures (7&8) found that: the efficiency of the anti-bacterial treatment was decreased when combined with the water-repellent treatment as it shows results of 70.23 for E-coli and 91.49 for S-aureus, while the single anti-microbial treatment showing values of 78.68 for E-coli and 95,37 for S-aureus, although the obtained results for one-batch treatment still within an acceptable result**.**

2.5. Synthesis of graphene nanoparticles depending on Hummers' method

The graphene nanoparticles synthesized in several steps including oxidation of graphite crystals and reduction of graphene oxide that simulates the modified hummer method as shorty expressed in the illustrated figure [34].

Figure 9 the procedures of graphene synthesis

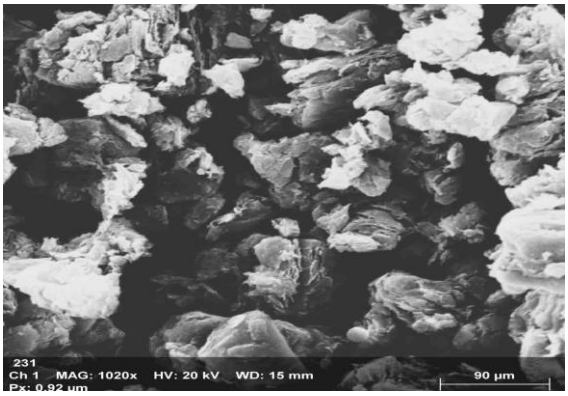


Figure 10. The particle size of synthesized graphene

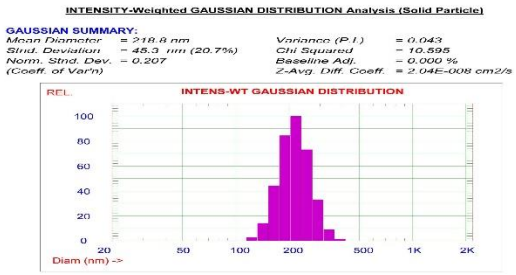


Figure 11. Molecular distribution of the synthesized graphene

As a result, raw graphite particle size influences graphite oxidation. The oxidation degree of graphite increased as graphite particle size decreases. Discovered that the oxidation duration is highly influenced by the particle size of the original graphite. Reduced particle size reduces oxidation time, showing that small graphite particles are acceptable for large-scale graphene oxide (GO) synthesis. Because of their lower resistance, graphite particles with relatively small diameters should save significantly more time than bigger graphite particles under identical conditions [35, 36].

From the measurement of the synthesized particles as the figures display found that: the graphene nanoparticles were successfully prepared within a suggested size that is typically suites the final applications.

2.6. Studying the anti-viral efficiency of Graphene nanocomposite

After the samples was treated with graphene composite as mentioned into practical procedures, the treated samples were subjected to the suitable measurement to ensure about the anti-viral efficiency, the results were succeeded as the illustrated table clarified.

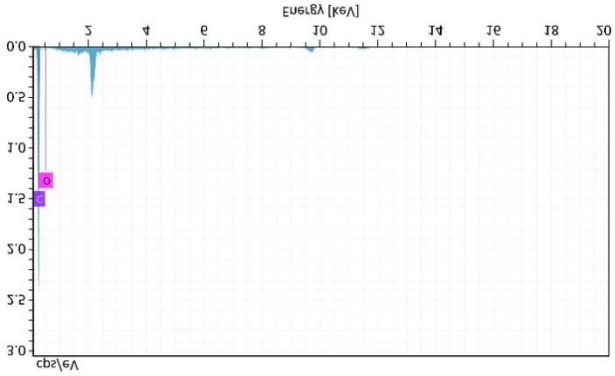


Table 7 Antiviral Activity for the tissue after treatment with graphene

Conc. of graphene on tissue per mg	Duration of incubation with virus	Virus Control without treatment (PFU/ml)	Viral Titer Post-Treatment (PFU/ml)	Viral Inhibition (%)
25	20 min	$3.0 * 10^6$	$1.4 * 10^6$	53.3 %
50	20 min	$1.0 * 10^6$	$2.2 * 10^5$	78 %
75	20 min	$1.0 * 10^6$	$1.0 * 10^5$	90 %

Antiviral activity against Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV2) hCoV-19/Egypt/NRC-03/2020 (Accession Number on GSAID: EPI_ISL_430820) according to ASTM E1053-20

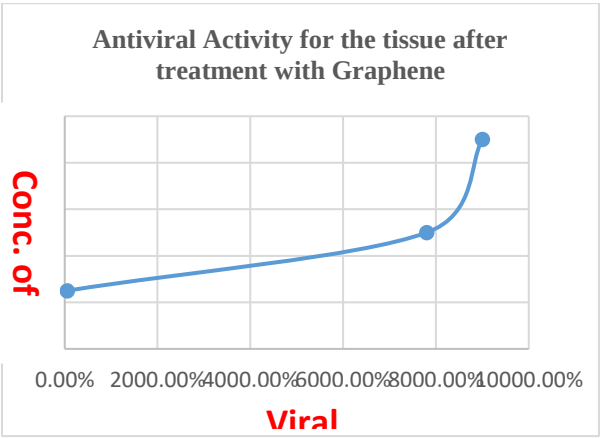


Figure 12 relations between the coronavirus activity and graphene concentration

Table 7 and figure 12 showing an excellent anti-viral activity of the treated samples toward coronavirus, this is the goal of this thesis that make the textile wall- hanging resist the virus which help so much to avoid the spread of this pandemic.

The study also shows that the anti-viral activity was increased with the increase of the graphene concentration onto the treatment composite. The measurement of anti-Viral activity was done according to ASTM E1053-20.

The virus Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) hCoV-19/Egypt/NRC-03/2020 (Accession Number on GSAID: EPI_ISL_430820) virus suspension is applied on an inanimate, nonporous surface. The test substance is added over the film. Control carriers receive the same condition. After exposure at the appropriate temperature (usually 20 ± 2 °C) for the recommended time, the elutes from control and test carriers are assayed for infectivity by plaque reduction assay.

Assay was carried out according to the method of (Hayden et al., 1980). In a six well plate where Vero E6 cells were cultivated for 24 h at 37ºC. The control untreated and treated virus was incubated with the tested sample for 20 min and 3 different concentrations (incubation sample with virus for: 20 minutes with concentrations 25,50 and 75 from graphene). Growth medium was removed from the cell culture plates and the cells were inoculated with (100 µl / well) virus dilution. After 1 h contact time for virus adsorption, 3 ml of DMEM supplemented with 2% agarose was added onto the cell monolayer; plates were left to solidify and incubated at 37ºC till formation of viral plaques (3 to 4 days). Formalin (10%) was added for two hours then plates were stained with 0.1 %crystal violet in distilled water. Control wells were included where untreated virus was incubated with Vero E6 cells and finally plaques were counted and percentage reduction in plaques formation in comparison to control wells was recorded as following:

% Inhibition= viral count (untreated) - viral count (treated)/viral count (untreated) x 100

2.7. Synthesis of cupper nanoparticles depending on electro-chemistry

After the cupper nano- particles was synthesized using electro-chemistry technique, the prepared particles were subjected to measurements to ensure about the particle size, the achieved results were within an acceptable limit as the illustrated figures 13 and 14 were clarified.

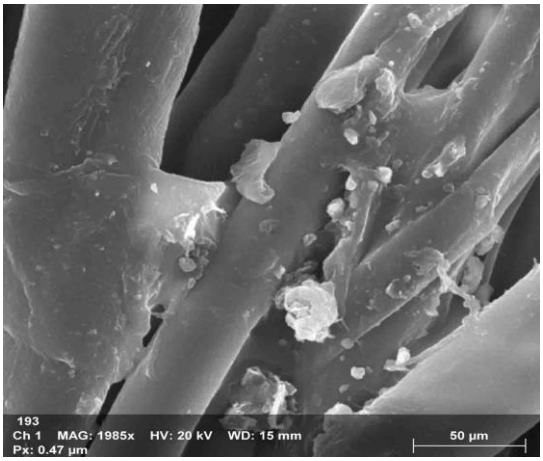


Figure 13. The particle size synthesized cupper-nano particles

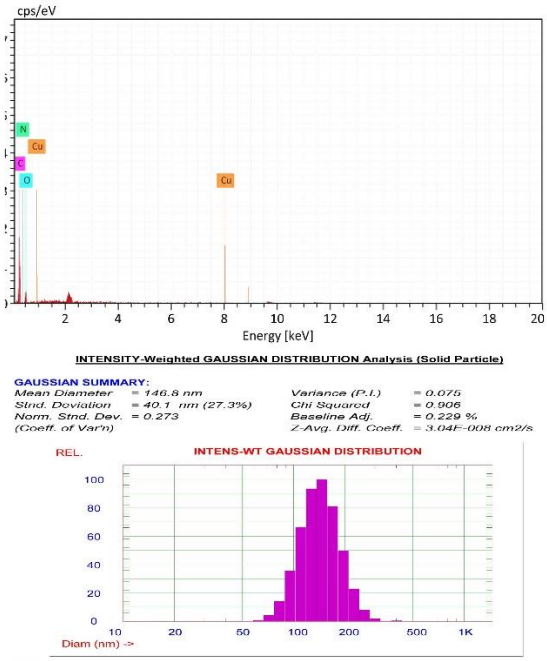


Figure 14. Molecular distribution of the synthesized cupper nanoparticles

From the measurement of the synthesized particles as the figures display found that: the cupper nanoparticles were successfully prepared within a suggested size that is typically suites the final applications.

4.8. Studying the anti-viral efficiency of cupper nanocomposite

After the samples was treated with nano-cupper composite as mentioned into practical procedures, the treated samples were subjected to the suitable test to ensure about the anti-viral efficiency, the results were succeeded as the illustrated table 8 was clarified.

Table 8 Antiviral Activity for the tissue after treatment with nano-copper

Name of Sample	Duration of incubation	Virus Control (PFU/ml)	Viral Titer Post-Treatment (PFU/ml)	Viral Inhibition (%)
Copper (Cu)	30 min	$2.2 * 10^6$	$0.5 * 10^6$	**77.3**
		$1 * 10^6$	$0.3 * 10^6$	**70**

After testing anti-viral activity for sample of treated tissue with cupper nanoparticles showed that high anti-viral activity against sever acute respiratory syndrome coronavirus 2(SARS-COV-2) with inhibition percent of 77.3% after period of 30min.

As illustrated table shows that: the cupper nanoparticles achieved a successful result as anti-viral; this is another goal of this thesis, which makes the textile wall- hanging resist the pandemic of coronavirus the anti-viral test was done as mentioned.

5.The end product of the innovated designs

Considering that the future theory is linked to the theory of relativity of the scientist "Einstein" and draws its footsteps in the observations and cosmic scientific results reached by this scientist, when it enabled him to the foundations on which he built his theory by predicting the curvature of light rays emitted by stars when they pass near the sun by the effect of the surrounding gravitational field [37].

Since the purpose of the futurism is to give the artistic effect of the sensitivity of the movement, it has been taken into account that abstract forms show what is behind them and beyond, as it was taken into account that the living forms merge with the silent forms at the intersection of the lines in order to give an effect at the intersection of spaces and show visible and invisible forms, and be an important factor in clarifying the temporal and spatial movement representing the fourth dimension, including giving the effect to the viewer through the sensitivity of the movement [38].

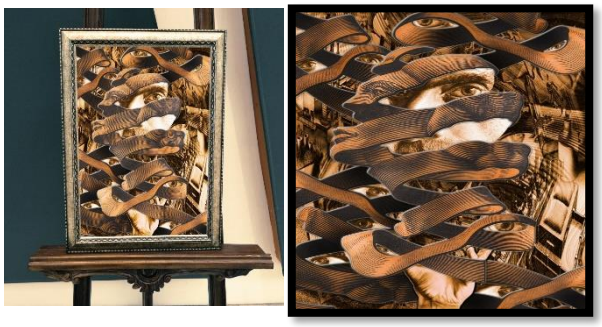
The design of textile printing wall hanging is considered a work of art that is subject to all the elements of the artwork, with the difference that it appears through a medium, i.e. it has the characteristics of utilitarianism (textiles), and it is treated with dyes from which certain types have been chosen that suit the functional purpose of the pendant, especially in the case of using it for a dual purpose as a pendant and a curtain at the same time. This type of textile printing designs contains a high degree of aesthetic and artistic content that may come close to plastic art [39, 40].

5.1 Designs and proposed Hypothetical employment.

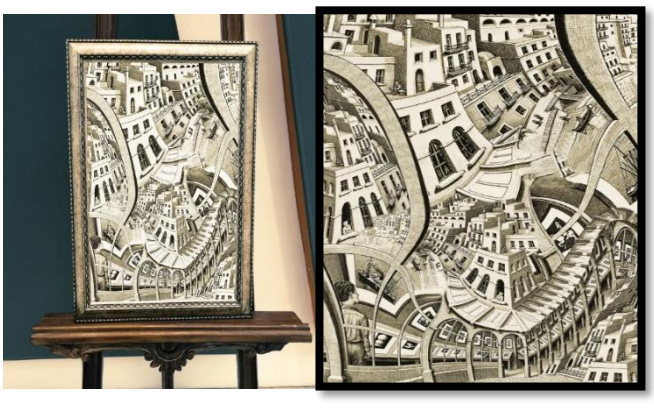
Proposed Hypothetical Employment (1) Design (1)

Proposed Hypothetical Employment (2) Design (2)

Proposed Hypothetical Employment (3) Design (3)

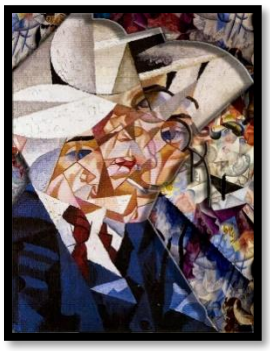


Proposed Hypothetical Employment (4) Design (4)



Proposed Hypothetical Employment (5) Design (5)


Proposed Hypothetical Employment (6) Design (6)

Proposed Hypothetical Employment (7) Design (7)


4. Conclusion

Applying artwork of various designs on fabric using a digital process, either polyester or cotton fibres. Adding value to the printed textile wall-hanging by employing different modern inks such as glow in the dark, photo-chromic, and hydro-chromatic inks based on colour change theories of each according to the external influence. Treatment of the printed textile wall hanging with various materials to achieve the thesis goal (water-repellent, anti-bacterial, and anti-viral). Finally, the study concludes that: creation of textile wall hanging with water-repellent, anti-bacterial, and anti-viral efficiency, the spectacular success of the study is the resistance to corona viruses.

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