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Plasma Technique Application for Coating Non - Woven Fabric by ($CaSiO_3$/CuO) Nano Particles for Biomedical Sector

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Abstract

Textiles are now used in a wide range of industries and purposes, including the medical field. The medical, hygiene, and health sector is a rapidly growing and vital component of the textile industry.
Growth can be attributed to the expansion and advancement of technology in both the textile and medical sectors at the same time. Surgical gowns are worn by doctors and nurses in the operating room to limit the passage of microorganisms from patients to surgical staff and thus reduce the risk of hospital-acquired infection. The primary goal of this project is to enhance the functionality and performance of surgical gowns. The study used nonwoven fabric made of polypropylene (spun bond/melt blown/spun bond), which was subsequently coated with calcium silicate/copper oxide nanoparticles (CaSiO3/CuO)-NPS using a low-temperature plasma method. Different time intervals were used for the coating (5, 10, 15 and 20 min). Scanning electron microscopy (SEM), energy dispersive X-ray analysis unit (EDX), mechanical properties, and physical testing were used to analyse the coated textiles. The antimicrobial effect was tested using the shake flask method against harmful bacteria and fungi, and the results were outstanding, indicating that this textile might be employed as a potential antibacterial protective textile for a variety of medical applications.
Keywords: Antibacterial , Medical textile ,Nano particles ,Plasma technique, Polypropylene

1. Introduction

A multi-layered non-woven fabric with membranes is used in disposable surgical gowns to give protection against liquids, airborne contaminants such as aerosols, poisons and germs, as well as to meet the requirements of surgical applications, Nonwoven fabrics are commonly used in surgical gowns because of its low cost, lightweight, durability, breathability, minimal hairiness, and disposability .Apart from protection, another factor to consider is clothing comfort. The thermal comfort qualities of non-woven surgical gowns have been studied in a small number of research [1]. Using a thermal manikin, Al. assessed the thermal comfort qualities of various disposable surgical gowns (Spunlace-normal, Spunlace-reinforced, and SMS-normal). Al. established a theoretical model that predicts thermal transmission across nonwoven structures with high accuracy [1, 2].

Sterilization is an important part of hospital management; this can be accomplished by sterilizing and covering instruments so that they remain sterile until they come into touch with patients. The packing process is critical for maintaining the sterility of medical devices and instruments. Strong and durable; barrier for germs; efficient to use; non-toxic; safe and easy to open; and a long shelf life are some of the main properties of the packing materials. Woven fabric, mainly comprised of cotton or linen, was the primary packaging material at first [3]. Spunbond-meltblown-spunbond (SMS) fabric is another technique used to protect against germs and fluids.Because the woven fabrics are washed before each usage, they may lose

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certain barrier qualities; as a result, the shelf life for instruments wrapped in this fabric is limited to seven days. On the other hand, non-woven SMS fabrics have a longer shelf life — up to three months in some cases. After the shelf life has expired, the packed instruments must be desterilized and repacked[4,5].

The benefits and drawbacks of woven and non-woven materials have been addressed in studies and reports. Cost-effectiveness, function in infection prevention, and environmental issues are the three key topics of concern. (6, 7) The woven and non-woven fabrics' reusable and disposable natures may have an impact on these three elements of packaging fabrics. Disposable goods have been found in studies to be cost-effective and to have a lower risk of post-procedural infection. According to other researchers, bacterial blockage is identical in both types of fabrics. [8,9]

The main purpose of this work is to investigate the performance of a non-woven polypropylene sample coated with nano-particles (calcium silicate/copper oxide) using a low temperature plasma process at different interval time (5,10,15,and 20).some properties are measured including antimicrobial activity ,microstructure ,air permeability , breaking load and elongation.

2- Materials and methods

2.1 A Non-woven fabric sample manufactured using (SMS) (spun bond/melt blown/spun bond) technique with weight 50gm/m² (Table 1).

Table (1): The weight of non-woven fabric synthesized from poly propylene after plasma treatment at different time intervals.

Non woven Samples	Weight (gm/m²)	Thickness (mm)
Blank	50	0.32
5 min	55	0.35
10min	55	0.34
15min	55	0.33
20min	55	0.33

2.2 Preparation and characterization of $CaSiO_3$ /CuO nano particles

The calcium silicate doped with 10 molar % CuO was prepared using pure limestone (calcium carbonate, $CaCO_3$), silica gel (SiO_2) and copper (II) carbonate ($CuCO_3$) via the wet precipitation route. This method was considered as ingenious and financial method for the preparation of nanoparticles [10] .The homogenous gel obtained by this method was dried at 100 °C and fired at 550 °C for 2 hours, then milled into fine powder using ball mill. The microstructure of the prepared sample was investigated by scanning electron microscopy SEM (model Quanta 250, Holland). The average size of $CaSiO_3$ /CuO nano particles lies in the nano range between 31.7 to 40.3 nm (Figure. 1).

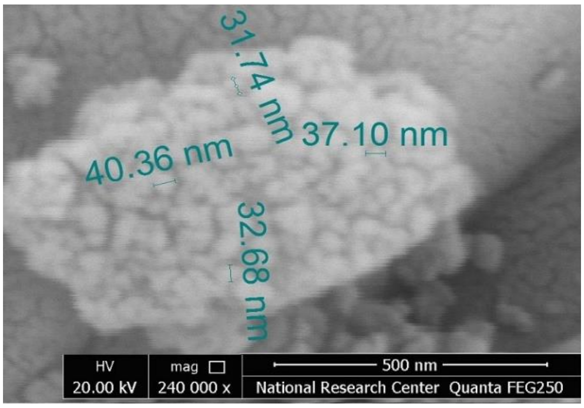

Figure 1: SEM of calcium silicate/copper oxide-nanoparticles.

2.3 Techniques

DBD plasma reactor discharges (Figure 2) were generated by a 25 kV/30 mA, 50 Hz AC power source linked to the upper electrode, while the bottom electrode was connected to earth using a resistor R of 100 or a capacitor C of 3.35 f. A resistive potential divider (1:1000) connected in parallel with the discharge electrodes was used to measure the voltage across them. The samples are put between two electrodes in a gap, and the DBD system is run at atmospheric pressure. The plasma discharge power was set to 10 watts and the duration period was set at 5-10-15-20 minutes.

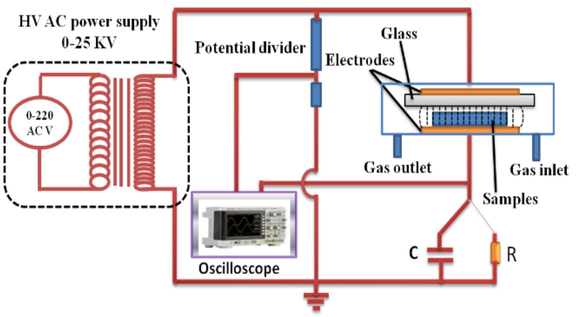

Figure 2: The schematic diagram of DBD cell used for treatment of fabric Samples

2.4 Scanning electron microscope (SEM)

Microstructure and morphology of samples coated with $CaSiO_3$ /CuO nano particles at different time intervals (5, 10, 15 and 20 min) were investigated by scanning electron microscopy SEM /supplemented with EDXmodel (Philips XL 30).

2.5Tensile strength (ASTM D5035, 2003), rip strength (ASTM D2261, 2002), and air permeability (ASTM D737, 1996) were used to determine the mechanical parameters of the fabrics. Some mechanical properties were conducted for samples including breaking load, elongation, air permeability and bursting strength (ASTM D3786), three replicates were taken for each sample .In fabric strength testing, the machine direction refers to the direction of fabric forming and the length of the fabric roll, whereas the cross-machine direction refers to the breadth of the fabric roll and the average values were taken. The average values for the fifteen readings were determined using the five highest peak forces for each replication. [11].

2.6 Antimicrobial activity

Antimicrobial activity of both blank non-woven fabrics and non-woven coated by ($CaSiO_3$ /CuO)-NPs) particles using the plasma technique was applied using shake flask method [12-13].against both pathogenic bacteria either gram positive bacteria (Staphylococcusaurous ATCC 6538) or gram negative bacteria [(Escherichia coli ATCC 25922) & (Pseudomonas aeruginosa ATCC 27853)] and pathogenic fungi (Candida albicans ATCC 10231).

The antimicrobial activity was carried out by measuring the optical density (OD) at 600 nm. In this method from both the bacterial and fungal cultures that maintained on nutrient agar slants a loopful were transferred aseptically and inoculated into 5.0 ml sterile nutrient broth medium, incubated overnight at 37°C, which act as the fresh working stoke cultures that were used in the test procedures. The inoculums size of these pathogenic strains was prepared from the fresh working stoke cultures and adjusted to approximately 0.5 McFarland standard (1.5 × 108 cfu /ml) 25.0 µL of both bacterial and fungal suspensions were inoculated into 100.0 conical flasks contains 20.0 ml nutrient broth medium (NB) inoculated with 25.0 µL form prepared both Bacterial & Fungal inoculum suspensions, the treated textile from each sample was applied on these tested microorganisms, and incubated for 24 hours at 37°C. The growth of these selected pathogenic strains was detected by optical density (OD) at 600 nm. The antimicrobial activity was measured throughout the relative [OD (%)] reduction of these pathogenic strains after treated with the treated textile samples compared to the control sample. All results were expressed according the following equation[14-15].

Relative reduction [OD Reduction (%)] = (A- B /A) × 100

Where :

A: the number of microorganisms present on control flask contains bacterial strain only without any thing.

B: the number of microorganisms present on shake flask for non-woven fabrics coated by ($CaSiO_3$ /CuO)-NPs particles.

3- Results and discussion

3.1 Scanning electron microscope (SEM)

The SEM micrographs of blank non-woven fabrics and the selected non-woven coated by ($CaSiO_3$ /CuO)-NPs particles using the plasma technique after different time intervals (15 and 20 min), are shown in (Figures 3, 4 and 5).

The surface morphology of samples was magnified, as the blank sample show a smooth surface of fibers, on the other hand the treated sample show the nano on the surface and between fibers.

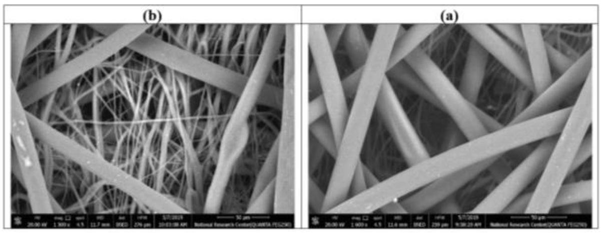

Figure 3: The SEM micrographs (a,b) of blank non-woven fabrics

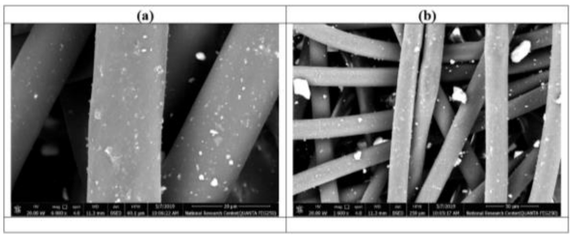

Figure 4: The SEM micrographs (a,b) of the non-woven fabrics coated by ($CaSiO_3$ /CuO)-NPs particles using the plasma technique after 15 min

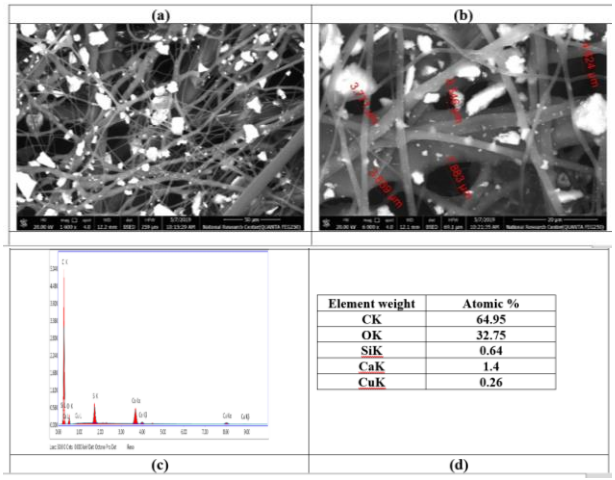

Figure 5: The SEM micrographs (a,b) and EDX analysis (c,d) of the non- woven fabrics coated by ($CaSiO_3$ /CuO)-NPs particles using the plasma technique after 20 min

3.2 The antimicrobial activity

The antimicrobial activity of non-woven fabric synthesized from poly propylene coated by calcium silicate/copper oxide nanoparticles carried out using the shake flask method at different time intervals (5 min-10 min-15 min -20 min) are shown in Table (2).

In general, the results of the coating non-woven fabric showed that increasing in its antimicrobial activity with an increasing in its coating time for all samples especially (20min.).The coated non- woven fabric with time interval 20 min surpassed all other times in all pathogenic bacterial strains recording results as following: 85.13% and 86.09% for *Escherichia coli* and *Staphylococcus aureus* respectively. In addition, *Pseudomonas aeruginosa* were 84.44 and pathogenic fungal strains *Candida albicans* has a weak effect on it, which indicated that these fabrics have an excellent potential antibacterial effect. Overall, plasma technique leads to improve the antibacterial of non- woven fabric (SMS) coated with ($CaSiO_3$/CuO) nano particles.

3.3- Air Permeability

Air permeability for blank sample and coatednon- woven fabric samples at different time intervals (5 min-10 min-15 min -20 min) are shown in Figure 6. It was shown from the results of air permeability that the blank sample recorded the highest results, while treated sample with time exposure 20 min recorded the lowest result. This can be interpreted that the nano particle coating reducing the pore size of sample which lead to reduce the air permeability property of the sample.

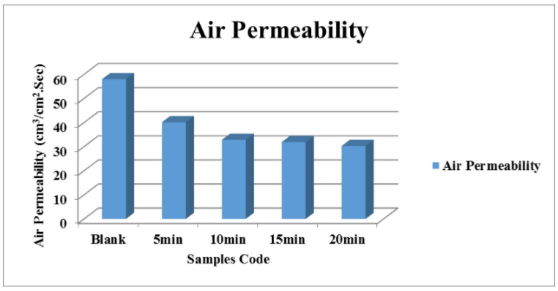

Figure 6: Air permeability of blank sampleand coatednon- woven fabric samples at different time intervals

3.4 Bursting Strength

The results of bursting strength of blank sample and coatednon- woven fabric samples at different time intervals (5 min-10 min-15 min -20 min) are represented in Figure 7. It was clear from the results of bursting strength that the blank sample recorded the highest results, while treated sample with time exposure 20 min recorded the lowest result. This can be interpreted by increasing the time interval during coating process it lead to decrease the bursting strength.

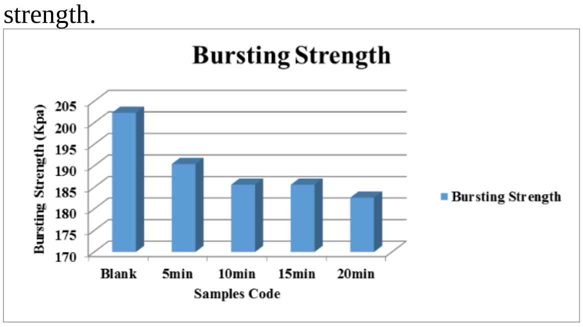

Figure 7:Bursting strength of blank sampleand coatednon- woven fabric samples at different time intervals

Table (2): Relative reduction [OD reduction (%)] of the pathogenic strain after 24 hours incubation applying the shake flask method

Test bacteria Samples		*Staphylococcusaurous*		*Escherichia coli*		*Pseudomonas aeruginosa*		*Candida albicans*	
o.	**Code**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**
1-	**Blank**	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
2-	**5.0 min.**	73.28	70.05	25.97	21.28	32.37	27.77	Nil	Nil
3-	**10.0 min.**	76.71	71.64	37.01	36.22	51.85	47.41	Nil	Nil
4-	**15.0 min.**	78.65	79.75	45.14	46.13	68.66	66.74	6.53	7.7
5-	**20.0 min.**	86.09	84.15	85.13	80.63	84.44	80.44	10.6	16.93

* Nil: No reduction activity recorded

3.4 Tensile strength

The results of the tensile strength in term of machine direction and cross-wise direction of blank sample and samples treated with ($CaSiO_3$/CuO)-NPSare shown in Figures 8 and 9.

It was demonstrated from the results of tensile strength that the blank sample recorded the highest results, while treated sample with time exposure 20 min recorded the lowest result. This can be interpreted by increasing the time interval during coating process it lead to decrease the tensile strength.

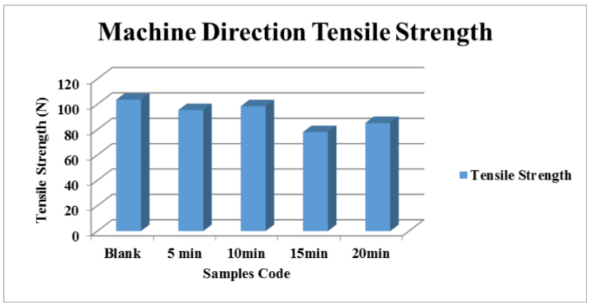

Figure 8:Tensile strength (machine direction) of blank sample and coated non- woven fabric samples at different time intervals

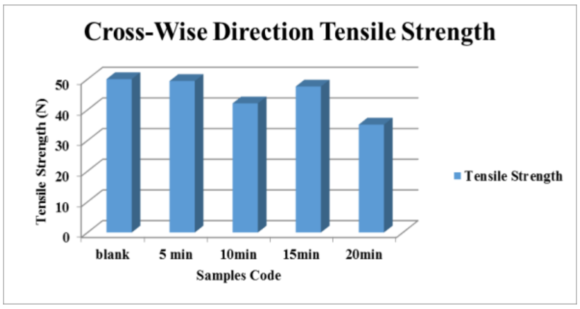

Figure 9:Tensile strength (cross -wise direction) of blank sample and coated non- woven fabric samples at different time intervals

3.6 Breaking Elongation

Figures 10 and 11 represent the breaking elongation(machine direction and cross -wisedirection) of blank sample and coatednon- woven fabric samples at different time intervals (5 min-10 min-15 min -20 min) are represented in Figure 10-11. It was shown from Figure 10 that the breaking elongation(machine direction)
a blank for machine direction and cross-wise direction respectivily sample recorded the highest values (44.22%), (49.19%) followed by sample coated with ($CaSiO_3$/CuO)-NPS for 5 minutes (38.29 %),(40.45%)

Conclusion

The results revealed that non- woven fabric (SMS) coated by ($CaSiO_3$/CuO) nano particles showed an antimicrobial effect on *E. coli* and *S. aureus* were 85.13% and 86.09% in (20min) and *Pseudomonas aeruginosa* were 84.44% in (20 min). In general, plasma technique leads to improve the antibacterial activity of non- woven fabric (SMS) by coating with ($CaSiO_3$/CuO) nano particles. This type of treatment improves the function performance of surgical gowns. The development of antibacterial fabrics is an important purpose for their application in many fields.

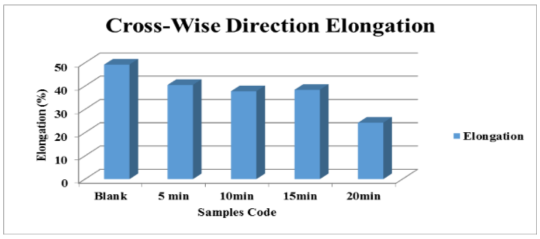

Figure 10 : Breaking elongation (cross-wisedirection) of blank sample and coated non- woven fabric samples at different time intervals

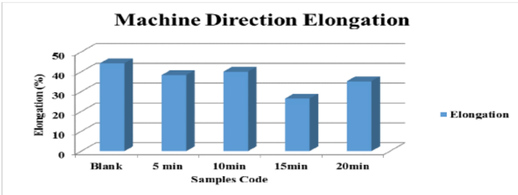

Figure 11 : Breaking elongation (machine direction) of blank sample and coated non- woven fabric samples at different time intervals

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