THERMAL STABILITY, ULTRAVIOLET AND ANTI-BACTERIAL EFFECT OF MODAL FABRIC USING PLASMA MODIFICATION

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Abstract

Nano composites are used in a wide range of applications in various fields, such as medicine, textiles, and cosmetics. This work is aimed to understand the textile properties of ZnO-*Aloe vera* deposited SM Modal fabric after treating with low temperature oxygen plasma treatment. The paper presents the experimental results of plasma treatment can significantly improve the tribological performance of the prepared SM Modal fabric/ZnO-*Aloe vera* composites, the best performance was the plasma treatment for 10 mins. The changes in surface topography, structure and chemical composition of the modal fabric surface was by effectively modified the wettability, antibacterial property of the fabric.

Key words: ZnO-*Aloe vera* deposited SM Modal fabric, TG/DTA, UV, Antimicrobial.

1. INTRODUCTION

Textiles that contain natural fabric, viscose, Modal, linen and cotton fabrics, find application both as finishing and insulation materials in automotive and construction industries and for medical, shoe lining and packaging products [1-4]. Many different compounds are used to impart antimicrobial functionality to textiles, ranging from synthetic inorganic compounds such as Zinc oxide nanoparticles and naturally derived antimicrobials such as Aloe vera. In recent years nanotechnology has become one of the most important and exciting forefront fields in physics, chemistry, textile, engineering and biology. Antimicrobials for textiles need to fulfill many different criteria including efficacy against microorganisms, suitability for textile processing, durability, and a favorable safety and environmental profile [5]. Antimicrobials are typically applied to give textiles improved resilience against microorganisms. Zinc oxide is a metallo-organic broad spectrum of antimicrobial that acts against the growth of bacteria, fungi.

The aim of this work was to quantify the release of ZnO nano particle and *Aloe vera* from commercially available spandex mixed model fabric and to characterize the particles with to size and chemical form. In order to investigate a realistic exposure scenario reflecting the use of textiles in households and medical, we used a washing cycle with detergent followed by two cycle with deionized water. The released particles were size fractionated and also characterized using SEM and XRD. In addition we tested the antimicrobial activity of the textiles before and after oxygen plasma treatment with the functionality of the textiles. The improved antimicrobial activity of modal fabric was analyzed by Agar diffusion test and test fabric' activity against bacteria *Staphylococcus aureus*, *Escherichia coli* and fungus *Candida albicans*, as well as washing durability of antimicrobial treatment.

2. EXPERIMENTAL TECHNIQUES

2.1 Material

Spandex mixed modal plain weave fabric (100%) of 165 g/m^2 (supplied by PKPN Company., India) was treated with a water and ethanol solution containing at temperature 45^{o}C for 1h, and then thoroughly rinsed and dried at room temperature. Zinc acetate, HCL material was purchased from Merck and used without any further purification. The fresh *Aloe vera* leaf was collected in Erode district, Tamilnadu, India.

2.2 SOLUTION PREPARATION

2.2.1 Aloe Vera Gel Extract

In this study the fresh leaves of the plant were used. *Aloe vera* leaves (5 leaves) are washed aero water and carefully remove the inner gel while avoiding the yellow sap (latex).the colorless gel was separated and collected in a clean beaker.

2.2.2 Zinc Oxide Nanoparticles

Zinc acetate material was purchased from Merck in India and used without any further purification. Zinc acetate salt was thoroughly mixed with deionized water and then few drops of high concentration of hydrochloric acid was added. After this process the insoluble salts in solution also get dissolved.

2.2.3 Extract Solution Finished Fabric Surface

The *Aloe vera* desired solution was added in the SM Modal fabric, extraction was done for 1-2 h at temperatures of 35^o C. The mixture was constantly stirred and samples of decoction were taken out at regular intervals and check the concentration of the active material in the extract. When the concentration level becomes almost constant, the mixture was drained at room temperature. The finished fabric was washed with water at room temperature. Similar method was adopted for Zinc oxide nano particle solution. The sample was dried in air oven at 40^{o}C for 25 mins. Now ZnO nano particles were coated on the SM Modal fabric. Then the fabric was safely kept in an air lock cover.

2.4 Plasma treatment

Oxygen plasma treatment of SM Modal surfaces was carried out in a plasma processor (Hydro Pneo Vac Technology, India). The apparatus was equipped with a 2.4 GHz DC source (maximum output power 600 W), which was connected by a quartz window to a vacuum chamber with dimensions of 350mm × 350mm (base pressure 0.03 mbar). The processed gas was introduced into the chamber via a gas-flow control system. After switching on the DC source, homogenous plasma was formed in the chamber [6-7]. The SM Modal fabric samples were treated with the following parameters: Expose time-10 mins, 400V and 0.03mbar pressure respectively.

3. Result and discussion

3.1 FTIR Spectroscopy

The ATR-FTIR spectra of the untreated and (O_2, Air) plasma treated samples were taken to determine the chemical changes that may have occurred due to the plasma treatment. Plasma treatment is known to break the covalent bonds present on the surface of organic substrates and generate radicals. Since the samples were exposed to air and oxygen plasma treatment, it is expected that hydrophilic groups would be generated by reaction of surrounding oxygen molecules. Figure 1 shows that *Aloe vera* coated spandex mixed modal fabric. The presence or absence of hydrogen bonding is well delineated in the region. The characteristic vibration that is observed in the region C-O, C-H Stretching, and OH plan bending. In the absorbed bond is commonly for untreated, air plasma and O_2 plasma is also present in the region of 1026.13, 1550.77, 2900.94, and 3317.56 [9].

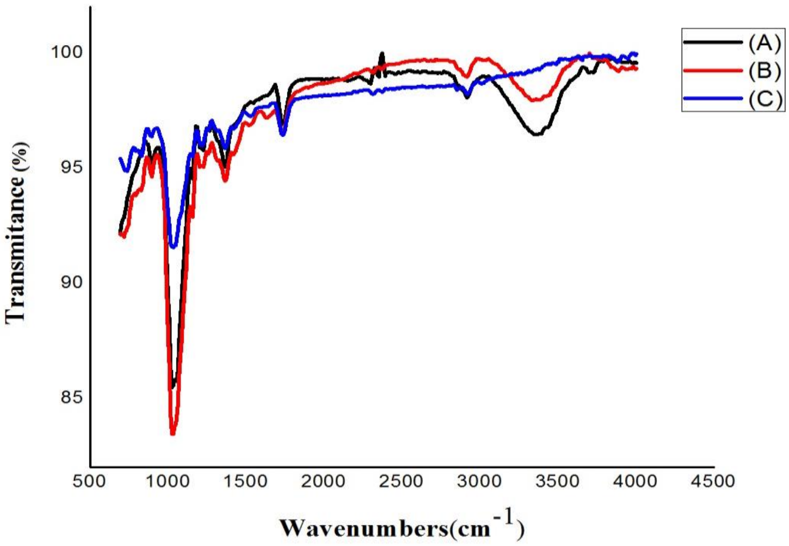


Figure 1. (a) Untreated *Aloe vera* coated SM Modal fabric, (b) Air plasma treated SM Modal fabric, (c) Oxygen plasma treated SM Modal fabric

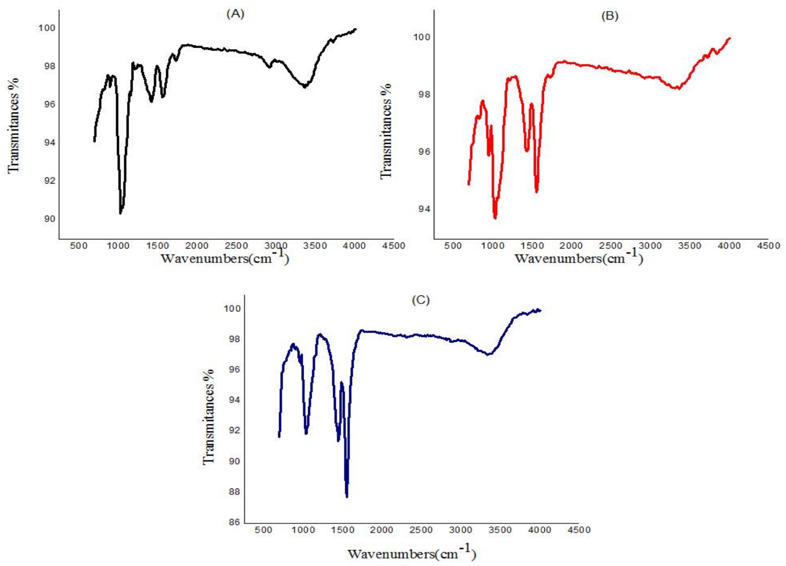


Figure 2 (a) Untreated ZnO coated SM Modal fabric, (b) Air plasma treated SM Modal fabric, (c) Oxygen plasma treated SM Modal fabric

Figure 2 shows the ZnO coated spandex mixed modal fabric. Some inorganics may exhibit a combination of both broad and very narrow bands, even for certain hydrated species. The crystalline structure of the compound symmetry of certain aspects of the molecular structure. The lowering of this frequency, accompanied by intensification of the band is characteristic of conjugation with double bond structure such as C=O, NO_2 at 2924.09 for untreated and air plasma treatment. OH Stretching and Plane bending are present in region 3383.86 and 1550.77 for ZnO coated modal fabric surface.

3.2 X-Ray Diffraction

X-ray diffraction (XRD) is also used to measure the nature of inorganic and nature of material extent of crystalline present in the fabric sample. The results of XRD analysis are reported in Figure 3 using air and oxygen plasma treated for 10 min respectively. It is evident that there is no change in shape and position of the diffraction peak, except the peak is more intense in case of air and oxygen treated sample. The particles size was calculated in the *Aloe vera* coated sample as 4.14 and 4.12.

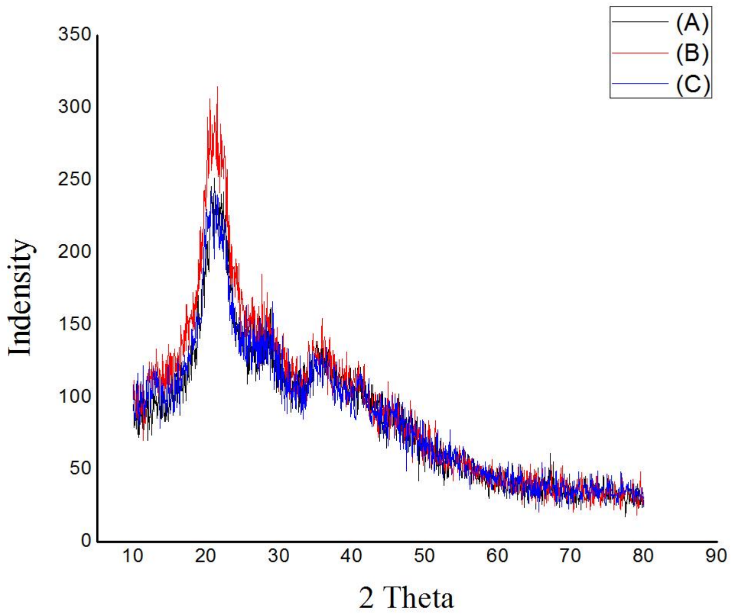


Figure 3. (a) Untreated *Aloe vera* coated SM Modal fabric, (b) Air plasma treated SM Modal fabric, (c) Oxygen plasma treated SM Modal fabric

The Broadening of the peak indicates that the particles are in nanometer scale. The particle size can be estimated from the XRD pattern using Scherrer's formula.

$$D=\frac{k\lambda}{\beta\cos\theta}$$

Where **D** is the crystalline size, ***k*** is a geometrical factor taken to be 0.89, λ=1.5406 Å is the X-ray wavelength, θ is the diffraction angle and β the peak width at half maximum of the most prominent peaks [8].

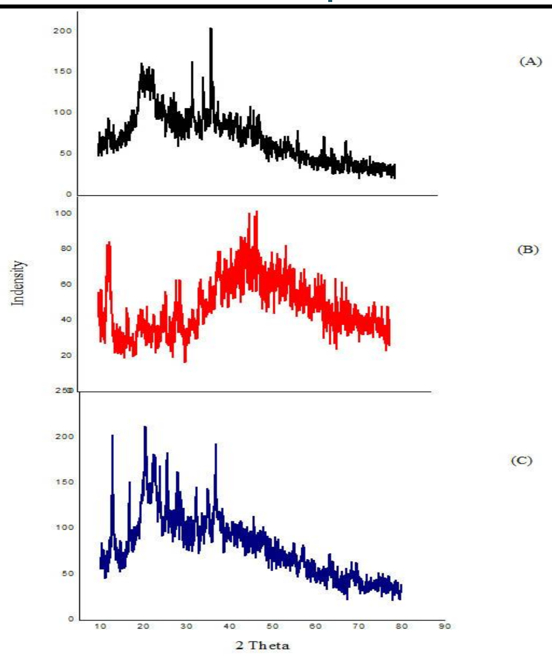
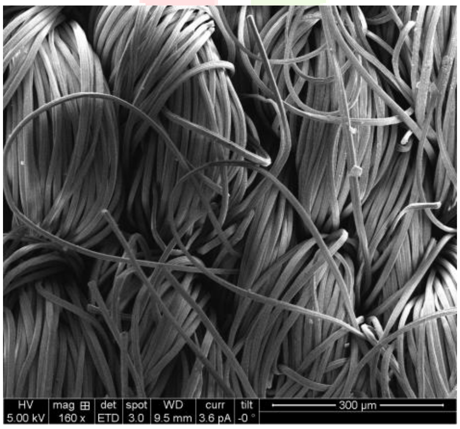


Figure 4. (a) Untreated ZnO coated SM Modal fabric, (b) Air plasma treated SM Modal fabric, (c) Oxygen plasma treated SM Modal fabric

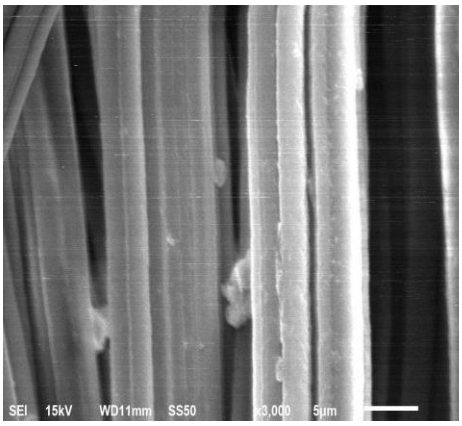
The XRD pattern of ZnO coated Modal fabric was shown in Figure 4. The intensity peaks located at 2θ =35. The pattern reveals the formation of ZnO coated SMM fabric and its well resembles with the standard JCPDS files (89-0510) [8]. The plasma treated sample was not changed but intensity was changed. The particle size of ZnO present in Modal fabric was 6.74 and 7.62.

3.3 Scanning Electron Microscopy

The plasma treatment was changed the morphology of the modal fabric/ ZnO-*Aloe vera* due to chemical interactions. The surface of the original SM Modal fabric observed was covered with smooth cuticles as shown in Figure 5. After exposure to the non-polymerizing O_2 plasma, the surface etching was observed. The modified SM Modal fabric was roughened and nano-crystalline structures were found in different stages of the treatment as illustrated in Figures 5(c).



(a)



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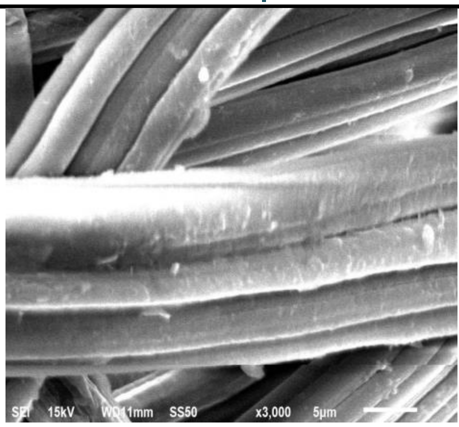
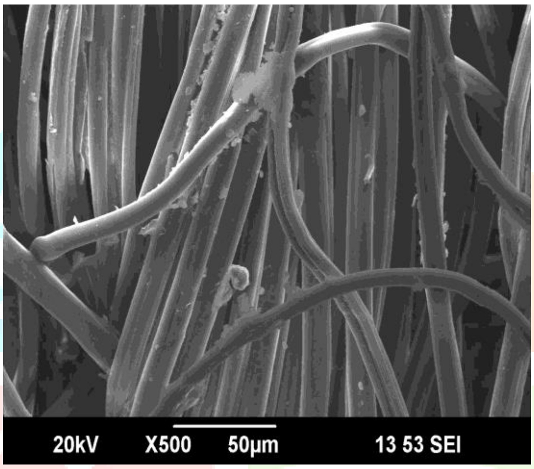
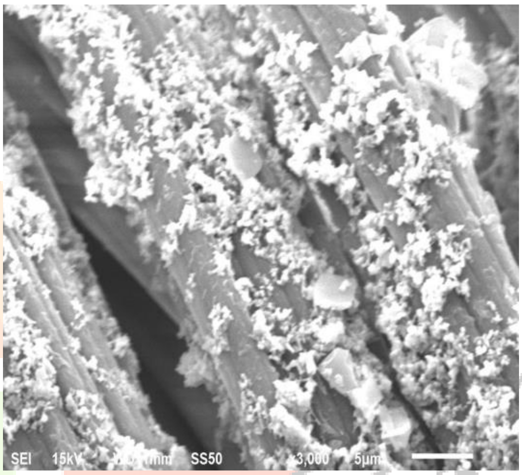


(c)

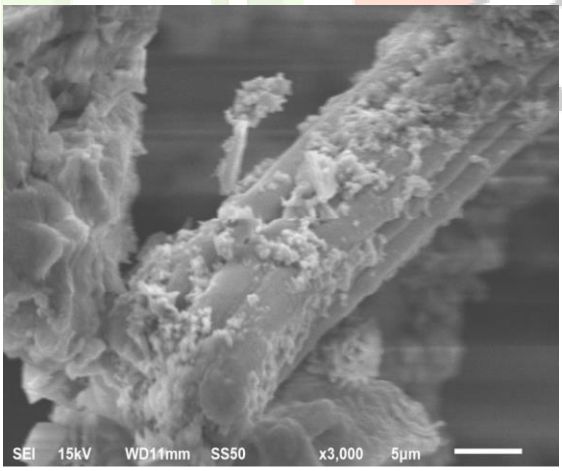
Figure 5. (a) Untreated *Aloe vera* coated SM Modal fabric, (b) Air plasma treated SM Modal fabric, (c) Oxygen plasma treated SM Modal fabric



(a)



(b)



(c)

Figure 6. (a) Untreated ZnO coated SM Modal fabric, (b) Air plasma treated SM Modal fabric, (c) Oxygen plasma treated SM Modal fabric

A progressive topographical alternation is shown in Figure 6. In general, plasma induced furrows parallel to the SM Modal fabric axis of cuticles at 10mins of exposure. After exposure, some observable nano-cones were developed on the surface. The diameter of nano-cones formed on the modified SM Modal fabric was in nano-scale range. The plasma gas flow after an ablation, which resulting in the fabric weight loss and the brokering of the size coverings. The elemental present in an *Aloe vera* and ZnO coated fabric shown in Table 3 and 4.

Table 3. Energy dispersive spectrum of *Aloe vera* coated SM Modal fabric

Elements	Untreated and plasma-treated *Aloe vera* coated SM Modal fabric					
	Untreated fabric		Air plasma-treated fabric		Oxygen plasma-treated fabric	
	Mass	Atom	Mass	Atom	Mass	Atom
C	48.03	55.36	71.97	80.34	44.23	51.38
O	51.31	44.40	20.05	16.8	55.77	48.62
Si	-	-	1.1	1.43	-	-
K	0.66	0.23	4.18	1.43	-	-
Ca	-	-	2.69	0.9	-	-

Table 4. Energy dispersive spectrum of Zno coated SM Modal fabric

Elements	Untreated and plasma-treated Zno coated SM Modal fabric					
	Untreated fabric		Air plasma treated fabric		Oxygen plasma-treated fabric	
	Mass	Atom	Mass	Atom	Mass	Atom
C	14.56	29.22	64.32	73.48	27.50	45.32
O	34.52	52.00	33.84	25.01	35.03	43.34
K	50.93	18.78	-	-	-	-
Zn	1.36	1.45	1.83	1.49	37.46	11.34

3.4 Ultra Violate Absorption:

Figure 7 and 8 shows that the mean ultra-violate absorption of *Aloe vera* and ZnO coated fabric that was increased after the application of plasma treatment. This study is an attempt to determine whether *Aloe vera* as natural occurring and ZnO inorganic compound can satisfy the UV-absorbance property or not. This Figure 7 and 8 indicates that the *Aloe vera*-ZnO coated SM Modal fabrics can provide an excellent protection of ultraviolet radiation. Therefore, the ultraviolet blocking performance is significant for the effect of plasma treatment.

This reflection will reduce the absorption of ultra-violet radiation. Hence, the ultra-violet radiation protection can be achieved. Since the oxygen plasma treatment can improve the hydrophilicity of the hydrophobic *Aloe vera* and ZnO coated SM Modal fabric, more *Aloe vera* and ZnO particles has deposited on the SM Modal fabric and give more coverage on the fabric with better ultra-violet radiation protection.

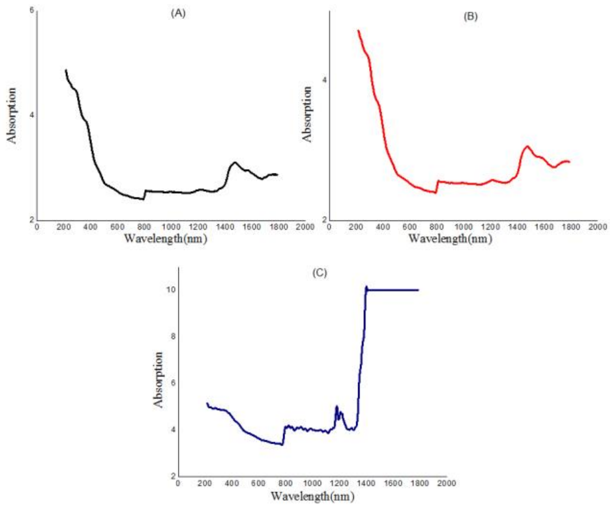


Figure 7. *Aloe vera* coated spandex mixed modal fabric (a) untreated (b) air plasma-treated (c) oxygen plasma-treated

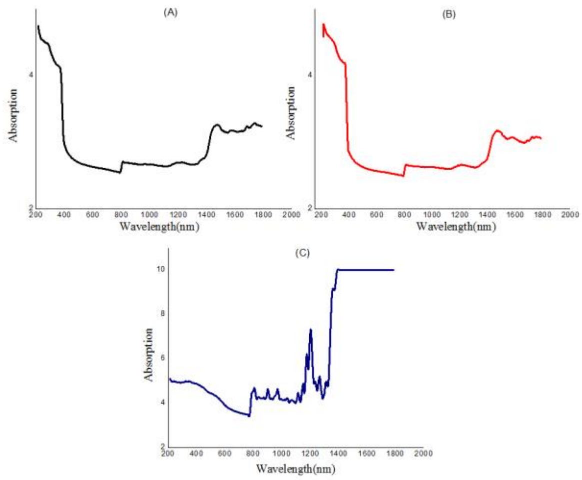


Figure 8. ZnO coated spandex mixed modal fabric (a) untreated (b) air plasma-treated (c) oxygen plasma-treated

3.5 Thermo gravimetric analysis

The crystallization behavior of *Aloe vera*/nano-ZnO multifilament of SM Modal fabric was examined using the Thermo gravimetric analysis (TGA) method. TGA was made between 40^{o} c to 750^{o}c at 10^{o}c/min in a static atmosphere of nitrogen. Microbalance has been devised for measuring smaller samples is the order of a microgram. Figure 10 and 11, displays TGA thermo gram curves of the modal fabric and oxygen treated with containing different amounts of *Aloe vera* and ZnO. The heating scans were used to determine the melting behavior of the fabric such as the melting temperature (Tm) and the heat of fusion (ΔHf).

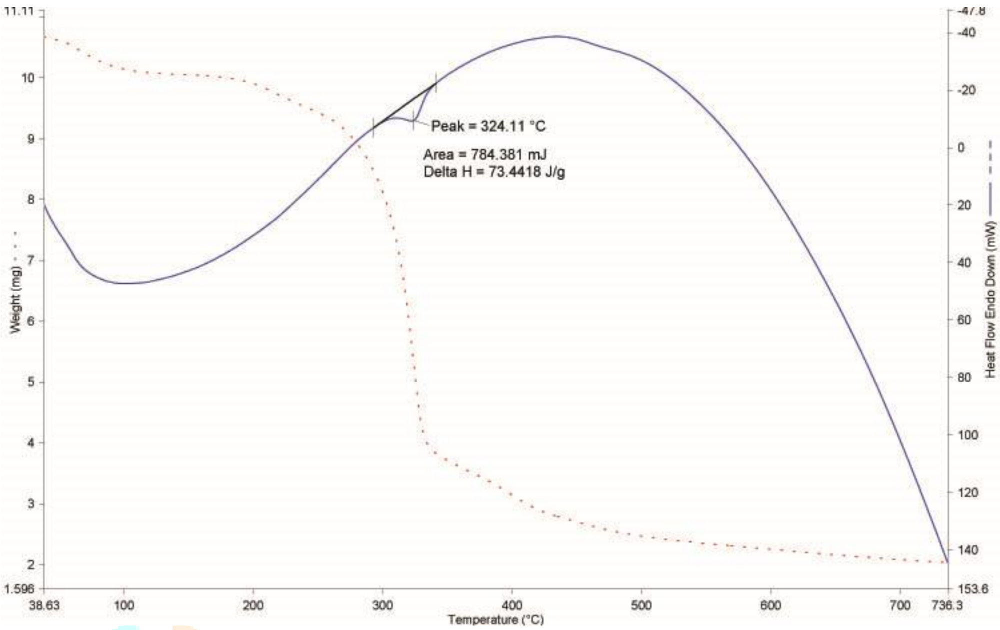


Figure 9. Endo and exothermic peak of *Aloe vera* coated SM Modal fabric

This melting indicates that the material is more stable up to the melting. There is an endothermic peak observed in the DTA curve below the melting temperature and similarly there is minimum weight loss observed in TG curve up to the melting temperature. This confirms that the material decomposes. Results of this study confirm that ZnO coated SM Modal fabric have more thermal stability than that of *Aloe vera* coated oxygen plasma treated fabric is in Figure 10 and 11.

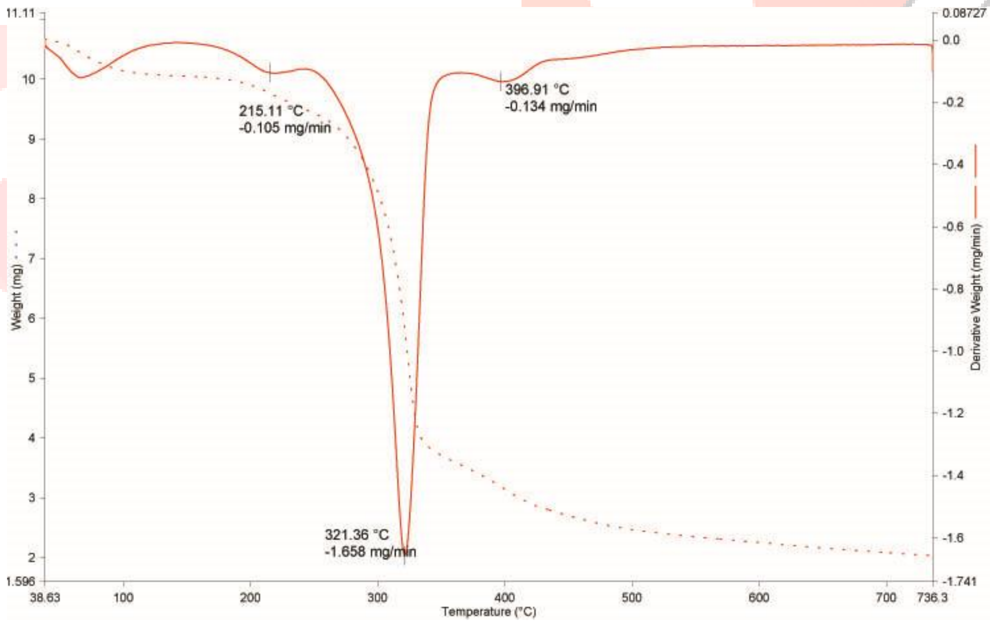


Figure 10. *Aloe vera* coated and oxygen plasma treated SM Modal fabric

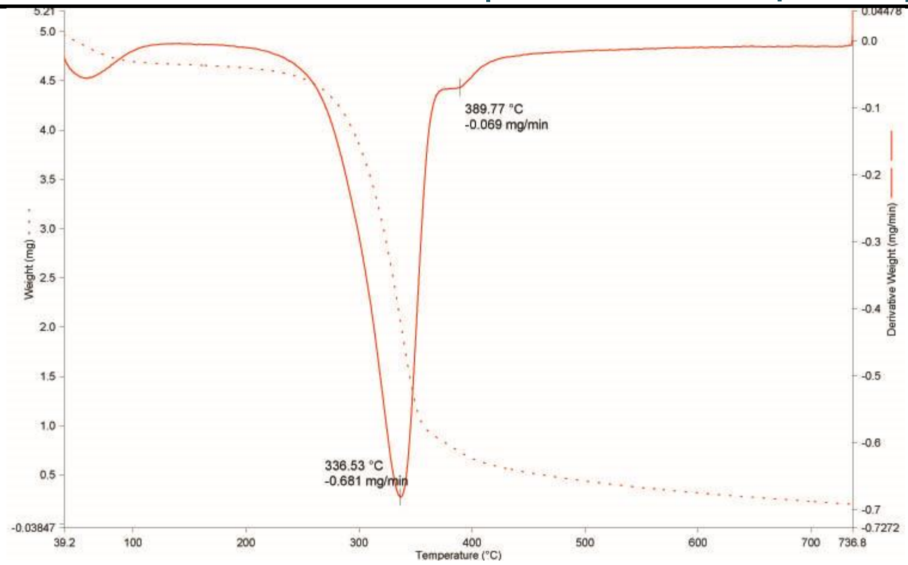


Figure 11. ZnO coated and oxygen plasma treated SM Modal fabric

3.6 Antimicrobial activity

Many antimicrobial agents are used in the textile industry known from the food stuff and cosmetics sector. The inherent properties of the textile fabric provide room for the growth of microorganisms. Besides, the structure of the substrates and the chemical processes may induce the growth of microbes. A wide palette of antimicrobial compounds is now in use but differ in their mode of action. Agar diffusion test is a preliminary test to detect the diffusive antimicrobial finish fabric. The antibacterial activity on the fabric samples was assessed qualitatively according to the AATCC test method 147-2004 by the parallel streak method [10]. The antibacterial property of *Aloe vera* and ZnO coated SM Modal fabric for *Staphylococcus aureus*, *Escherichia coli* and *Candida albicans* are given in Figure 12(a and b). The treatment was done on 100% SM Modal fabric. Figure 12, indicates that the increase in concentration of *Aloe vera* leads to increase in the antibacterial properties against S. aureus and E. coli. It is clear that the inhibition zone for *S. aureus* is smaller than the one for *E. coli* which are Gram negative bacteria and this can be attributed to the maximum resistant of the Gram-negative bacteria according to the difference in the structure between the Gram-negative bacteria and Gram-positive bacteria. It can be seen that a strong antimicrobial effect towards the Gram (–) and Gram (+) bacteria is manifested, proving that all the *Aloe vera* and ZnO compounds can be used for the antimicrobial finishing of SM Modal fabric.

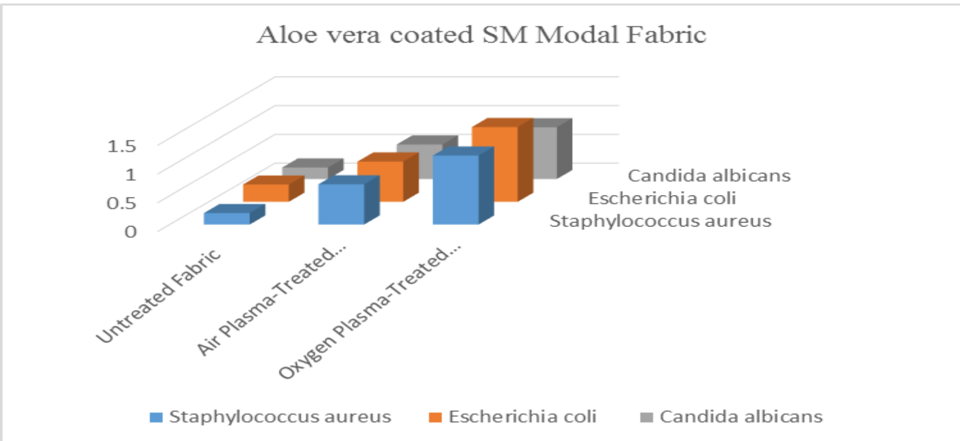


Figure 12(a) *Aloe vera* coated SM Modal fabric

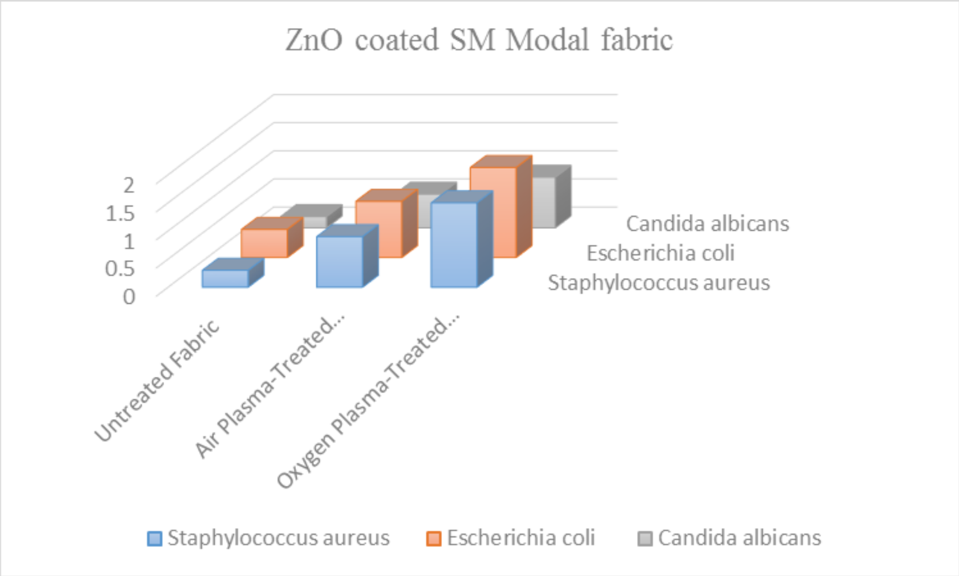


Figure 12(b) ZnO coated SM Modal fabric

4. Conclusion

During this study, spandex mixed modal fabrics were pre-treated with oxygen plasma followed by combined *Aloe vera* and ZnO. This sequence of treatment confirm the changes in the surface, physical, antimicrobial properties of the treated fabric, as a direct consequence of modifying the surface of the fabric by the plasma treatment. As a general conclusion, *Aloe vera* and ZnO coated fabrics were identified as preferable selection of air and oxygen plasma due to the higher amount of metal uptake and consequently has exhibited the prominent parameter like thermal stability, ultra-violate productive and antimicrobial activity.

Acknowledgements

All the characterization study was performed at Sophisticated Analytical Instrument facility (SAIF) at STIC, Cochin and Karunya University, Coimbatore, India. The author is thankful to Dr.Aruna dhevi and Dr.K.Mohan, Research Department of Zoology, Sri Vasavi College, Erode for their support to antibacterial analysis during study period.

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