# Development of multifunctional non- woven fabrics by electro spinning for medical protection

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**Abstract -** *As today's world is demanding multipurpose product which can protect from attack of bacteria and simultaneously release their stress and anxiety. The electrospun films can be produced by adding herbal material in the polymer solution. The electrospinning process becomes quite a vital for producing of nanofibres. The PVA and starch polymer solutions were used, in which emulsion of citronella essential oil was added in a small quantity and electrospinning was carried out at optimum parameters. The films were collected on non-woven fabrics of viscose and polypropylene fibres of GSM 90. These qualities type of polypropylene fabric are used for making face masks which can protect bacterial entry into the nose and mouth during medical treatments. The value addition in terms of making them antibacterial and also with stress relieving aroma was done by electrospinning on these fabrics. The fabrics with electrospun layer containing PVA and starch with citronella oil showed antibacterial and mosquito repellent properties with good fragrance. Such base material can be used to make face masks, napkins, head masks, etc.*

***Key Words:*** *antibacterial, fragrance, mosquito repellent, electrospinning, electrospraying.*

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## 1. INTRODUCTION

The combined use of two techniques namely electrospray and spinning is made use in a highly versatile technique called electrospinning (electro + spinning). A high electric field is applied to the droplet of a fluid which may be a melt or solution coming out from the tip of a die, which acts as one of the electrodes. This leads to the droplet deformation and finally to the ejection of a charged jet from the tip of the cone accelerating towards the counter electrode leading to the formation of continuous fibres [1]. Electrospinning is a bottom up process that has been applied in the preparation of submicrometer (micro–nano) diameter fibers and fibrous structures. Electrospinning works on the principle of electrostatic charge to produce non-woven fibre mats/films from several micrometers to nanoscale diameters. Proper selection of solvents, optimization of voltage, feed rate, distance from tip to collector are decisive factors for the quality of nanofibres. Recently, electrospinning technology is gaining a lot of attention in various fields including biomedical, food, nutraceutical and pharmaceutical formulations [2]. The effects of concentration and elongation on the morphology and optical properties of the electrospun composite nanofibres were also reported [3]. The scale up of nanofibres through single jet is not very feasible and for various applications there is a requirement of large quantities of fibers. Various research groups have used porous hollow tube in order to get multiple jets and in this case the production rate can be enhanced by increasing the tube length and number of holes. Apart from the huge success, advantages of electrospinning method and spun nanofibres have still a lot of limitations that need proper consideration. A major challenge encountered in using electrospun mats and scaffolds for tissue engineering is the nonuniform cellular distribution and lack of cellular migration in the scaffold with increasing depth under normal passive seeding conditions [4].

Electrospun materials organised in two and three dimensions are particularly interesting for enhancing the performance of various applications in healthcare (regenerative medicine, reprogramming of cells, drug delivery, stem cells and implants), wellbeing (nutrition, food & health supplements), recreation (light weight structures, fouling & bacteria resistant coatings & surfaces), energy (harvesting, storage, & efficiency), environment (air pollution control and water treatment). Hence the last ten years saw worldwide growth of R&D on various uses of electropsun materials [5].Currently electrospinning research is as vibrant as ever, as demonstrated by the constantly increasing rate of published scientific contributions.

More than 2500 articles have been published about polymer electrospun nanofibres in the last decade. The number of publications in 2011 was approximately ten times more than that in 2003 [6]. Prior to this, the electrospinning process has been known to consistently produce fibers in the order of 1 μm, with some excursions into the upper nanometer range [7]. Electrospinning has gained much attention in the last decade not only due to its versatility in spinning a wide variety of polymeric fibres, but also due to its consistency in producing fibres in the submicron range [8]. Electrospun nano fibres have attracted considerable attention because of their unique properties, ease of fabrication and functionalization, and versatility in controlling the fiber diameter and morphology. The extremely fine electrospun nano fibres make them very useful in a wide range of advanced applications [9].

Various collector designs have been explored for generating a variety of fibrous forms (fluffy mass and yarns) which includes rotating collector drums, patterned and dual conductive electrodes separated by an air gap, funnel targets, liquid targets, knife-edged collectors, dual ring electrodes, hemispherical collector with concentric needular arrays, etc [10].

As we know the open wounds surface is often infected with microbes, including bacteria, fungi, and viruses. An infection of a wound is initiated by the adherences of bacteria to the surface of wounds and thus antibiotics, antimicrobial agents, and metallic particles are incorporated with the surgical dressings. Therefore, antibacterial agents, such as chitosan, silver nanoparticles or zinc oxide (ZnO) have been added to electrospun nano fibres, thus increasing their potential in biomedical engineering applications [11]. Many synthetic and natural polymers and their blends have been successfully electrospun to make nano fibres. Although there exist other methods such as melt blowing, drawing, bicomponent spinning, flash spinning, force spinning, template synthesis, phase separation, self- assembly, they are not convenient for producing nanoscaled fibres [12].

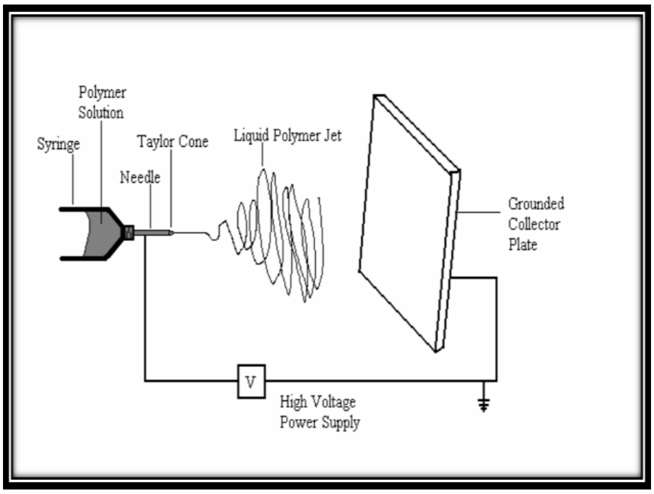


Figure 1. Basic components of electrospinning [13].

## 2. MATERIALS AND METHODS

PVA (hot) is used as a polymer supplied by laboratory reagent of molecular weight 14,000 whose viscosity at 4% aq solution at 20°C was 4 -6 cP. The solvent used for this polymer is water. Another polymer is potato starch which was supplied by S.D. Fine chemicals limited.

Both polymers are water soluble. Their 5% w/v concentration was prepared. They were stirred at melting temperature till clear and bubble less solution was made. The syringe of 10 ml was used for electrospinning. The polymer solution was filled upto 5 ml and set at parameters required for the electrospinning. The voltage was set at 25kV and the cylinder speed was kept at 400 rpm. The flow rate for injecting the solution from the syringes was 0.6 ml/min and the elestrospinning was done on non-woven viscose and polypropylene fabrics of 90 GSM. The fabrics were rolled over the cylinder.

### 2.1 Preparation of emulsion

The specific ratio of alcohol and distilled water was used for making emulsion of citronella essential oil. This oil was added along with binder for the crosslinking effect. After adding all, it was stirred at 4000 rpm for 2 hrs at 90-80°C.

### 2.2 Mixing of emulsion, PVA and potato starch

The mixture of citronella emulsion, PVA and potato starch was used for the preparation of electrospun films. Keeping the same concentration of citronella oil, the different ratios of PVA and potato starch were varied.

**Table 1. Ratio of polymers used for electrospinning**

| Non - Woven GSM | Ratio (PVA:Starch) | PVA (5% w/v) | Starch (5% w/v) | Emulsion (ml) |
|---|---|---|---|---|
| Viscose 90 | 2:1 | 10ml | 5ml | 5ml |
| Viscose 90 | 1:1 | 10ml | 10ml | 5ml |
| PP 90 | 2:1 | 10ml | 5ml | 5ml |
| PP 90 | 1:1 | 10ml | 10ml | 5ml |

## 2.3. Antibacterial activity

The quantitative assessment of antibacterial activity exhibited on the finished cotton fabric was carried out by AATCC Test 100. The percentage of antibacterial activity was determined by the reduction in number of colonies formed with resoect to the untreated control sample using following equation:

$$R(\%) = \frac{(B - A)}{B} X\ 100$$

Where, R, (%) = reduction in bacterial count

A = the number of bacterial colonies recovered from the inoculated treated test specimen petri dish incubated for 24 hours

B = the number of bacterial colonies recovered from the inoculated untreated test specimen petri dish incubated for 24 hours

## 2.4. Mosquito repellency

To evaluate the mosquito repellent efficacy of the treated fabric, the samples were tested with the standard cage test method. . The person keeps arm wrapped with treated fabric in the cage for 30minutes. During that time the sample was exposed to mosquitoes, the biting occurrence was reported by the test subjects as per time interval of 2 min, 5min, 10min, 20min and 30min. The number of bites at the end of exposure was counted and recorded. The percentage of repellency was defined as the percentage reduction in the number of bites on the treated sample, as compared to that of control sample. The results were analysed according to the following equation:

Mosquito Repellency, (%) = (C-T)/C X 100

Where,

C = the number of mosquitoes collected from the control area

T = the number of mosquitoes collected from the treated area of a subject

## 2.5. Fragrance finish

The measurement of aroma was done qualitatively by giving ratings out of 10. For this subjective evaluation was done by panel of 10 judges.The samples are rated as 0-Repulsive, 1-Very Poor, 2-Poor, 3-Poorly Fair, 4-Fair, 5-Acceptable, 6-Fairly Good, 7-Good, 8-Very Good, 9-Excellent, 10-Ideal.

## 2.6. Characterizations

The scanning electron microscopic analysis was done using JEOL JSM-6380LA. Images were taken at different voltages and magnifications and the surface topography was analysed.

## 3. RESULTS AND DISCUSSIONS

## 3.1. Antibacterial activity

The antibacterial activity against S.Aureus and E.Coli bacteria was tested quantitatively for both viscose and polypropylene fabrics. The percentage of bacterial colonial reduction was almost more than 90% in all cases for both non-woven viscose and polypropylene fabrics with 2:1 and 1:1 PVA: Starch ratios. This was due to presence of citronella oil emulsion present in the solution used for electrospinning. That 5 ml of emulsion was contributing resistance to the growth of bacteria colonies on the samples.

It was observed that polypropylene samples have more resistance to the bacterial growth than viscose. The polypropylene fibre is inert in nature and has no reactive sites for bacterial growth in the fibre, nor it is hydrophilic and hence, it itself is not conducive to bacterial growth. Whereas viscose being polysaccharide based fibre with very high hydrophilicity, offers very good atmosphere for bacterial growth.

**Table 2. Non- woven fabrics used for electrospinning**

| Non - Woven GSM | Bacterial Colonial Reduction, (%) | |
|---|---|---|
| | *S.Aureus* | *E.Coli* |
| Viscose 90 | 91.64 | 89.54 |
| Viscose 90 | 94.24 | 91.26 |
| PP 90 | 92.47 | 93.35 |
| PP 90 | 91.69 | 88.81 |

## 3.2. Mosquito repellency

The repellency percent of mosquitoes was observed for various samples. The viscose 90 GSM with 1:1 PVA: starch ratio, had more repellency due to equal composition of both PVA and starch in the film. Both the polymers are having ability to adhere the electrospun product on their surface. The citronella oil emulsion containing binder had also ability to crosslink with the viscose fibre. So, it has more mosquito repellency than that of 2:1 PVA: starch polymers. The polypropylene has also good repellency, but it showed less mosquito repellency than viscose. This may be due to absence of any reacting group in polypropylene fibre with binder. Hence, the electrospun material cannot crosslink with the fibre structure. It was showing mosquito repellency only due to surface deposition of electrospun material, and its adhesion due to nanoform.

**Table 3. Effect of mosquito repellency on non- woven viscose and polypropylene (PP) fabric**

| Sample | Mosquito Repellency, (%) | | | | |
|---|---|---|---|---|---|
| | 2 min | 5 min | 10 min | 20 min | 30 min |
| Viscose 90 (2:1)* | 83.35 | 83.06 | 82.81 | 80.43 | 78.91 |
| Viscose 90 (1:1)* | 88.56 | 86.89 | 84.97 | 83.64 | 81.20 |
| PP 90 (2:1)* | 78.43 | 72.14 | 69.61 | 69.53 | 68.74 |
| PP 90 (1:1)* | 76.54 | 75.48 | 74.51 | 72.81 | 70.93 |

()*- PVA: starch ratio of polymer mixture.

### 3.3 Fragrance finish

The aroma ratings were been given to the non – woven viscose and polypropylene (PP) fabrics of GSM 90 by the panel of judges. For non- woven viscose and polypropylene, the mixture PVA: starch polymer was taken in 2:1 and 1:1each.The aroma of non-woven viscose samples was more than non-woven polypropylene. The reason was due to more absorbency of viscose fibre for aqueous emulsion of citronella oil. It also has more moisture regain, and it can also absorb more aroma due to high degree of amorphous content. In polypropylene fibre there are no reacting group or functional groups and its moisture regain is very negligible and thus pick up of aroma will be poor. The electrospun material is on the surface of the polypropylene fibre while in viscose it may have had bonding with hydroxyl groups of cellulosic viscose.

**Table 4. Effect of aroma on non – woven viscose and polypropylene (PP) fabric**

| Sample | Ratings out of 10 |
|---|---|
| Viscose 90 (2:1)* | 8 |
| Viscose 90 (1:1)* | 9 |
| PP 90 (2:1)* | 6 |
| PP 90 (1:1)* | 6 |

()*- PVA: starch ratio of polymer mixture.

### 3.4 Characterization

The scanning electron microscope analysis was done and images were taken at 10kVand 20kV voltages for 5000 and 10,000 magnifications each. It is observed from Figure 2 that there is a closed matrix formation between the two polymers. The pores are visible in the image confirming that the film is porous in nature.

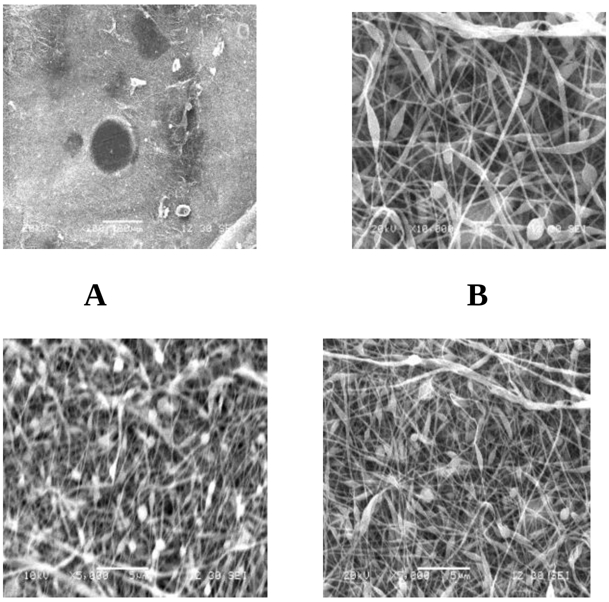


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Figure - 2: SEM images of PVA and starch electrospun film at 1:1. (A) pore structure at 200X at 20kV (B) 10.000X at 20kV (C) 5000X at 10kV (D) 5000X at 20Kv

## 4 Conclusions

The electrospinning of polymers like polyvinyl alcohol and potato starch on non-woven viscose and polypropylene fabrics was done successfully. The polymer blends contain PVA and starch used were 2:1 and 1:1. These non-woven fabrics containing electrospun PVA: starch: citronella oil film can be used specially for face masks where antibacterial activity is necessary. Further, it was found to be mosquito repellent and having anxiety removal fragrance in it too. So, the developed product is reported to be having multifunctional properties which are useful for health and hygienic purposes.

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## REFERENCES

[1] Agarwal, S., Wendorff, J.H. & Greiner, A., 2008. Use of electrospinning technique for biomedical applications. Polymer, 49(26), pp.5603–5621.

[2] Vuddanda, P.R., Mathew, A.P. & Velaga, S., 2016. Electrospun nanofiber mats for ultrafast release of ondansetron. Reactive and Functional Polymers, 99, pp.65–72.

[3] Calisir, M.D. et al., 2016. Photophysical properties of phosphorescent elastomeric composite nanofibers. Dyes and Pigments, 125, pp.95–99.

[4] Bhardwaj, N. & Kundu, S.C., 2010. Electrospinning: A fascinating fiber fabrication technique. Biotechnology Advances, 28(3), pp.325–347.

[5] Anon, Electrospinning, Principles, Possibilities and Practice (2013).

[6] Persano, L. et al., 2013. Industrial Upscaling of Electrospinning and Applications of Polymer Nanofibers: A Review. Macromolecular Materials and Engineering, 298(5), pp.504–520. Available at: http://doi.wiley.com/10.1002/mame.201200290 [Accessed January 3, 2017].

[7] Senador, A.E. et al., 2000. Electrospinning of Polymeric Nanofibers: Analysis of Jet Formation. MRS Proceedings, 661(1), p.KK5.9. Available at: http://journals.cambridge.org/abstract_S1946427400634899 [Accessed January 3, 2017].

[8] Subbiah, T. et al., 2005. Electrospinning of nanofibers. Journal of Applied Polymer Science, 96(2), pp.557–569. Available at: http://doi.wiley.com/10.1002/app.21481 [Accessed January 3, 2017].

[9] Lin, T. ed., 2011. Nanofibers - Production, Properties and Functional Applications, InTech. Available at: http://www.intechopen.com/books/nanofibers-production-properties-and-functional-applications [Accessed January 3, 2017].

[10] Joseph, J., Nair, S. V. & Menon, D., 2015. Integrating Substrateless Electrospinning with Textile Technology for Creating Biodegradable Three-Dimensional Structures. Nano Letters, 15(8), pp.5420–5426. Available at: http://pubs.acs.org/doi/abs/10.1021/acs.nanolett.5b01815 [Accessed January 3, 2017].

[11] Pan, Y.-J., Lin, J.-H. & Chiang, K.-C., 2016. Biomedical Applications of Antibacterial Nanofiber Mats Made of Electrospinning with Wire Electrodes. Applied Sciences, 6(2), p.46. Available at: http://www.mdpi.com/2076-3417/6/2/46 [Accessed January 3, 2017].

[12] Hossain, M.F., Gong, R.H. & Rigout, M., 2016. Effect of polymer concentration on electrospinning of hydroxypropyl-β-cyclodextrins/PEO nanofibres. The Journal of The Textile Institute, 107(12), pp.1511–1518. Available at: https://www.tandfonline.com/doi/full/10.1080/00405000.2015.1128714 [Accessed January 3, 2017].

[13] Queen, H., 2006. Electrospinning Chitosan-based Nanofibers for Biomedical Applications.

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