RESEARCH ARTICLE

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# Study of Application of Fluro Nano Fibres for Filtration

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## Abstract

Air filtration performance is notably affected by the application fluro nano fibre produce by electro spinning. The high costs of ceramic and Teflon filter media for hot gas cleaning has limited their industrial applications. This study presents application of fluro nano fibres for filtration that can be used to produce an efficient filter material for industrial applications. Fluro nano fibre applied on the glass fabrics and fixed on the surface of glass fabric by sintering process. Glass fabric with nano fluro fibres were tested for the air permeability and compare with normal glass fabric sample. Air filtration fabric performance improved with the application of fluro nano fibres on the surface of glass fabric.

**Keywords:** Fluro nano fibre, Eelectro spinning, Glass fabric, Air filter, Air permeability.

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## Introduction

Filtration is the process in which solid particles in a liquid or gaseous fluid are removed by using filter medium that permits the fluid to pass through but retains the solid particles. Due to industrialization and urbanization air pollution has increased tremendously. The size of partials in air are in micro and nano, that's why filtering them become complex. Template synthesis, phase separation, melt-blown method, and plasma treatment have developed, they still suffer for nano filtration and for hot gas filter.

The conventional filtration media, including melt-blown fibres, and spun-bonded fibres, are known to exhibit relatively low filtration efficiency and high energy consumption, as well as being unsuitable for the filtration of fine particles due to the micro-sized fibre diameter. Template synthesis, melt-blown methods, phase separation, and plasma treatment have been developed to fabricate nanofibre-based membranes for separation of fine particles. But most of the filters still suffer from low filtration efficiency and high energy consumption, as well as being unsuitable for the fine particles filtration. Xu and Huan[1] and the film has been characterized by SEM, TG, XRD, FT-IR, and EDS, and the mechanical and hydrophobic properties of the membranes were also investigated. The PTFE nanofiber membranes after sintering had nanofiber and nanowire structures. Moreover, the membranes were tested in air filtration. The filtration efficiency and pressure drop were tested to evaluate the membrane permeability and separation properties. The results showed a high filtration efficiency 98% mentioned that for melting PTFE lots of solvent used as water soluble, which released in environment during sintering process and are very harmful for human health.

Electrospinning is a green technology for produce nanofibre.[2] Electric power is used to make polymer fibres with diameters ranging from nm to several micrometres from polymer solutions or melts. This process is a major focus of attention because of its versatility and ability to continuously produce fibres on a scale of nanometres, which is difficult to produce using other standard technologies.[3] In electrospinning voltages range for solution was from 5 to 30 kv, sufficient to overcome the surface tension forces of the polymer. The free surface of the charged polymer produces very fine jets of liquid that are rapidly sprayed to the grounded collector. The effect causes rapidly solidifying fibres as they approach the grounded collector.[4]

PTFE and glass fibre have high melting point so it can use in hot gas filter. PTFE is a synthetic fluoropolymer of tetra fluoro ethylene, and is a fluorocarbon solid. It has a high-molecular-weight, and consists only of carbon and fluorine. PTFE is hydrophobic, meaning that liquids do not adhere to or absorb into it, and it has one of the lowest coefficients of friction of any solid.[5]

The PTFE micro/nanofibre composite filter was prepared by coating a very thin electro spun PTFE nanofibre membrane on the surface of PTFE microfibre membrane. The purpose of this nanofibre layer is to increase hydrophobic properties and the filtration efficiency of the composite fibre membrane, thereby improving the performance of the composite

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membrane. Compared to the traditional PTFE microfibre filter membrane, it has good hydrophobicity, gas permeability and gives significant improvement in filtration effect.[6] PTFE/glass fibre filter is appropriate for use in industrial fields with operating temperatures between 200 and 250 °C. The de-dusting efficiencies of the laminated membrane types (teflon filters) were approximately 80% and the de-dusting efficiency of the PTFE/glass fibre filter was 85%. On the basis of the de-dusting efficiency, the PTFE/glass fibre filter is a competitive option for hot gas filtration.[7]

# Material and Methodology

## Material

DuPont Teflon PTFE, marketed as INOFLON® AD9300 by Gujrat Fluoro Chemicals (GFL) in Bharuch, Gujarat, was the source of a material used. This material was an aqueous milky dispersion containing small particles of PTFE resin (<230 nm) dispersed in water with a 60% solid PTFE content and 40% water content. The purpose of this material was to provide water, oil, and alcohol repellent effects when applied to a glass fabric. The glass fabric used in the trials had a specification of 730 grams per square meter (GSM) weight, 1.1 millimetres in thickness, a weave of 40 ends per inch (EPI), and 12 picks per inch (PPI).

To enhance the fabric's properties, a white dispersion chemical called Nuva was utilized to synthesize the base fibres. For achieving water, oil, and alcohol repellence, this chemical treatment was applied. The leading fabric, created for this study, was formed by stitching the same glass fabric together with aramid yarn. Aramid yarn is produced using aramid fibres known for their attributes such as heat resistance, high strength, high tenacity, resistance to abrasion, and maintaining fabric integrity at elevated temperatures. Specifically, Kevlar para-aramid yarn, a type of aramid yarn, was chosen for this study.

## Process methodology

In this study, a composite woven fabric was created by electrospinning PTFE nanofibers onto glass fabric. The aqueous PTFE material contained very fine PTFE resin particles with sizes smaller than 230 nanometres. This PTFE material naturally possesses hydrophobic properties, which align with the hydrophobic nature of glass fabric.

**Table 1:** Fabric sample details

| *Sr. no* | *Sample details* |
|---|---|
| 1 | PTFE coated + sintered |
| 2 | (PTFE coated + sintered + PTFE coated + sintered) |
| 3 | Nuva coated on (PTFE coated + sintered + PTFE coated + sintered) fabric sample |
| 4 | Nuva coated + sintered on (PTFE coated + sintered + PTFE coated + sintered) fabric sample |
| 5 | Uncoated glass fabric |
| 6 | Sintered glass fabric |

As depicted in table 1 Composite textiles were manufactured through various procedures: first sample, by electrospinning PTFE nanofibers onto glass fabric and subsequently sintering it once; then, second sample by repeating the electrospinning and sintering process on the glass fabric twice; Third sample by additionally applying a Nuva coating onto the glass fabric that had undergone two rounds of electrospinning and two sintering stages; and Fourth by applying a Nuva coating onto the glass fabric that had experienced two rounds of electrospinning, two sintering processes, and an additional sintering step. The impact of introducing nanofibers to the glass fabric was assessed by measuring the air permeability of the resulting composite fabric. This parameter was used to evaluate the changes in fabric characteristics due to the incorporation of nanofibers. For making PTFE/Glass composite involves two major stage steps: 1) Generate nanofibre on glass fabric. 2) Sinter the above fabric in sintering machine.

Flurонano fibre applied on the surface of the glass fabric using advanced NS LINE electrospinning for continuous layer production. The machine used an electro-spinning method/technology of spinning fibres from a polymer solution in a high voltage electrostatic field. The high voltage field was generated between two electrodes. The spinning and collecting electrodes were connected to the high voltage power supply during operation, the machine becomes an enclosed system, secured by protective components to prevent unauthorized access to the spinning area during operation. Unlike traditional nozzle electrospinning the NS technology uses a wire electrode partially immersed in a polymer solution. A thin layer of polymer solution covers the rotating electrode. After the HV field was applied and overcomes the surface tension of the solution, the liquid was forced to move to the area with lower potential and starts to erupt towards the collector. While travelling to the collector, solvents evaporate and fibres were stretched, split and deposited onto a substrate material that runs adjacent to the collector.

D-PTFE taken in beaker having capacity of 3 litres. In the PTFE around 5 ml anti forming agent (Polydimethylsiloxane-PDMS) mix. Three spinning tubs was present there. All tubs having capacity of 3 litres, so total 9 litres PTFE was used. Filled with PTFE, tubs insert into the groove at the bottom of spinning chamber plates. Slide the cover on tubs so liquid don't evaporate. Glass fabric roll lay down on NS LINE machine length wise. Before starting the machine remove the cover from the tub. HV plate insert at front and rear side of spinning tub. 1x1 meter of fabric taken and passed through electrospinning zone. According to the requirement of width plate can placed on spinning tub, close the door, and then main switch of the machine was on to starts the process. Fabric run on machine with 0.2 mpm at slow speed so that nanofibre deposited on glass fabric surface in required amount. After electrospinning fabric dry in drying zone and final fabric wrap on take-up roller.

The PTFE sintering machine was used for fixing the nanofiber layer on fabric surface. This was the process of forming a solid mass of material or loose material into a solid piece through pressure and heat without melting to the point of liquefaction. Fabric run on machine with 0.4 mpm speed above 300$^{0}$c temperature of machine. Processing section were: A) Unwinding and baking, B) Sintering, C) Cooling and Plaiter D) Winding section. Initially the switches on the panel board, all must be in off position, after verifying the same switch on the main switch. Place the fabric roll in unwinding section in such a way that it was in centre, clamped it on the unwinding shaft. Open the dryer doors on one side and pass fabric above the support rolls through baking, sintering, cooling chambers followed by plaiter roll and winding tube. Once fabric was set through over dryer close all door properly. Position the manual break on unwinding section to minimum friction position. Switch on the web guide and let the winding assembly position itself accordingly and web guide. After that switch on the winding motor and plaiter motor. Adjust the plaiter speed as per the required line speed, simultaneously adjust winding speed to manage the tension on the fabric. The mechanical system was set, switch off the plaiter and winding motor don't switch off the web guiding motor. Fit adapter and electric heating pad plugs on 6 no. L.P.G. cylinder. Set the supply pressure setting high pressure P.R.V and low pressure P.R.V to maintain gas supply pressure between 600 to 700 mm water columns. Checked for any gas leakage. Opened ball valves to allow gas supply and put on air blower of baking/sintering/exhaust/cooling. Once fabric was wound completely first switch off web guide/plaiter/winding motor. Switched off burner first then switched off all blowers after cooling up to 100c inside dryer oven.

### Testing

Air permeability of composite fabric was measured with TEXTTEST FX 3300 air permeability tester. This test measures a composite fabric resistance to air flow rate in litre per cubic meter per second. Sample clamping is fast and simple. The test samples were free from tension, was placed across the test head. The clamping arm was pressed down to start the test and appropriate measuring range was selected on range switch. The Air permeability test results of composite fabrics were digitally displayed and recorded as shown in table 2.

**Figure 1:** simple glass fabric sample

**Figure 2:** PTFE & sintered glass fabric sample

## Results and Discussion

In the present study, an attempt has been made to develop self - cleaning hydrophobic glass fabric filter coated with PTFE nanofibre using PTFE electrospinning technique. Figure 1 and 2 depict the simple glass fabric without treatment and with PTFE & sintered treatment respectively. The thickness of the PTFE nanofibre on glass fabric was very less compare to thickness of glass fabric. It was observed that changes in thickness of PTFE nanofibre fabric was negligible. After electrospinning and sintering GSM of composite material didn't change, or change in GSM was negligible. Table 2 indicate the air permeability results of composite fabric for different treatment and air pressure.

On PTFE/glass composite fabric different type of treatment was given for reducing pore size of fabric. As shown in Table 2 uncoated fabric has been testing under 50 pascal then air pass through glass fabric was 617.67 liter/m2 per second, 948.5 liter/m2/sec under 100 pascal and 1386.67 liter/m2/sec under 200 pascal. As air pressure increased air transfer increased in simple glass fabric.

Further PTFE nanofibres were deposited on glass fabric. For fixation of PTFE sintering process done on a side of glass fabric having PTFE nanofibres. Air permeability of PTFE and

**Table 2:** Air permeability of composite fabric

| *Sr. no* | *Sample detail* | *Unit* | *Air Pressure (Pascal)* | | |
|---|---|---|---|---|---|
| | | | *50* | *100* | *200* |
| 1 | Uncoated glass fabric | liter/m2/s | 617.67 | 948.5 | 1386.67 |
| 2 | Sintered glass fabric | liter/m2/s | 618.5 | 904 | 1296.67 |
| 3 | PTFE coated + sintered | liter/m2/s | 570 | 845 | 1208.34 |
| 4 | (PTFE coated + sintered + PTFE coated + sintered) | liter/m2/s | 570.83 | 848.5 | 1255 |
| 5 | Nuva coated on (PTFE coated + sintered + PTFE coated + sintered) fabric sample | liter/m2/s | 599.11 | 890.11 | 1319.71 |
| 6 | Nuva coated + sintered on (PTFE coated + sintered + PTFE coated + sintered) fabric sample | liter/m2/s | 619.98 | 938.7 | 1336 |

sintered fabric was 570 liter/m2/sec at 50 pascal, 845 liter/m2/sec at 100 pascal, 1208.34 liter/m2/sec at 200 pascal.

After first time PTFE electrospinning and sinter were done on fabric. This process repeated again on fabric. That mean electrospinning of PTFE nanofibre on composite glass fabric with same parameter which has been used in first time process. After that sintered the fabric with same temperature means above $300^0$ c. This composite fabric having twice PTFE and twice sintering has been tested for air permeability. At 50 pascal air pressure air permeability was 570.83 liter/m2/sec, at 100 pascal air permeability was 848.5 liter/m2/sec and at 200 pascal air permeability was 1255 liter/m2/sec. The air permeability of this composite was almost same as one time PTFE and sintering composite. This shows that, second time PTFE and sintering doesn't have effect on air permeability and further reduction of pore size of fabric. Percentage reduce in air permeability in twice PTFE and twice sintering glass fabric is almost same as one time PTFE and sintering.

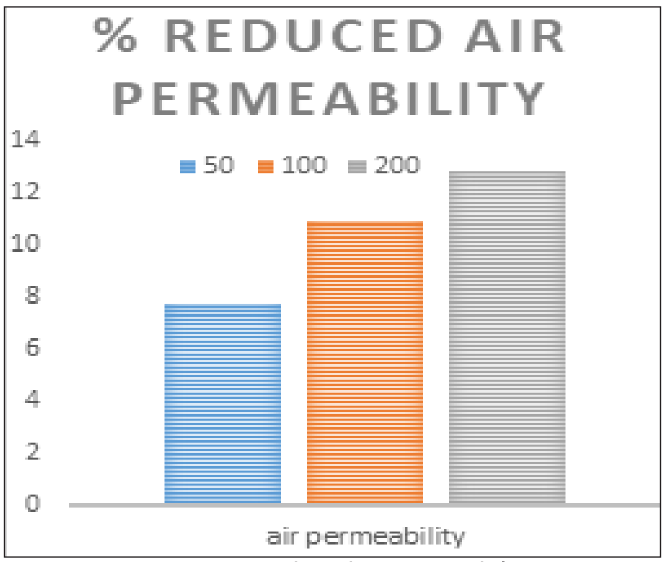


**Figure 3:** % reduced air permeability

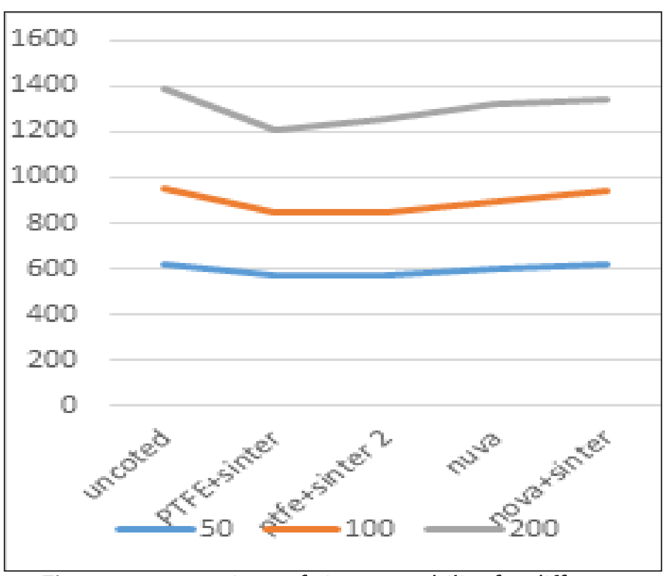


**Figure 4:** comparison of air permeability for different treatment and air pressure

**Figure 5:** Lotus effect

Further, Nuva electrospinning done on twice PTFE and twice sintering glass fabric with same parameter. Air permeability of this nuva fabric was 599.11 liter/m2/sec at 50 pascal air pressure, 890.11 liter/m2/sec at 100 pascal air pressure and 1319.71 liter/m2/sec at200 pressure. Which is more than one time PTFE and sintering and two time PTFE and sintering. Which show, percentage reduce in air permeability was less than one time PTFE and sintering of glass fabric. For fixation of nuva sintering treatment was given.

Testing of this nuva and sintering glass fabric gave air permeability 619.98 liter/m2/sec at 50 pascal air pressure, 938.7 liter/m2/sec at 100 pascal and 1336 liter/m2/sec at 200 pascal. Air permeability was almost same as air permeability of simple glass fabric. Which shows that, air permeability was not reduced in composite fabric and also pore size not reduced.

In PTFE and sinter fabric for air pressure of 50 pascal air permeability reduced by 7.71%. Similarly, at 100 pascal air permeability reduced by 10.91% and at 200 pascal air permeability reduced by 12.86%. Results indicate that, as air pressure increase percentage reduction in air permeability of fabric increase. Figure 3 shows reduce percentage in air permeability for 50, 100, 200 pascal.

Figure 4 shown that air permeability of glass composite for different treatment like one time PTFE & sintering, two time repeating PTFE & sintering, nuva coating on two time repeating PTFE & sintering , nuva coated on two time repeating PTFE & sintering and sintering, simples glass fabric were tested at different air pressure 50, 100, 200 pascal. It shows that as air pressure increase, reduction in air permeability observe with increase in PTFE & sintering composite. For 200 pascal air pressure, air permeability of glass fabric reduced up to 12 % as shown in figure 4. From this graph it can be said that, with one time PTFE & sintering treatment on glass fabric has more reduced air permeability and pore size of fabric with compare to other treated fabrics like , two time repeating PTFE & sintering, nuva coating on two time repeating PTFE & sintering , nuva coated on two time repeating PTFE & sintering and sintering.

PTFE is polymer having very less coefficient of friction and hydrophobic. Glass fabric is also hydrophobic material. When glass fabric treated with PTFE nanofibre, material behave as lotus leaf. Material surface become highly water-repellent or super hydrophobic. Figure 5 shown the hydrophobic behaviour or louts effect.

# Conclusion

PTFE and glass fabric has excellent heat resistance, so it can be used for hot gases filter in industry. In this study, for making composite fabric no solvent was used for binding purpose sintering of composite fabric has nothing to release in environment. That's why process was eco-friendly and have no any adverse effect on environment and human health. PTFE & sintered glass composite become super hydrophobic in nature so louts effect achieved on surface of material. Reduction in Air permeability of one time PTFE & Sintering of glass fabric is highest. Air permeability of one time PTFE & Sintering of glass fabric, and twice repeated PTFE & sintering of glass fabric was almost same. It can be said, there was no change for second time electrospinning of PTFE & sintering process on glass composite. Air permeability of Nuva coated glass fabric that had undergone twice repeated PTFE electrospinning & sintering was more than one time PTFE & sintering and twice repeated PTFE & sintering. Even after sintering of nuva coated glass fabric that had undergone twice repeated PTFE electrospinning & sintering air permeability increase compare to only nuva coated glass fabric that had undergone twice repeated PTFE electrospinning & sintering. It can be said, there was no use for applying nuva on composite fabric. Decreased in % air permeability in 200 pascal air pressure was highest then 50 pascal and 100 pascal air pressure. Decreased in % air permeability at 100 pascal was more than 50 pascal and less than 100 pascal air pressure. It can be said, as air pressure increase, reduction in air permeability increase.

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