# Direct Inkjet Single Sided Hydrophobic Finishing of Textiles

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## Abstract

*Recent advances in the study of digital printhead-ink-substrate interaction, coupled with developments in printhead technology, have widened the tolerance for inkjet printing non-ideal fluids. A broader range of rheological profiles can now be jetted reliably, offering new commercial opportunities, particularly for digitally printing textiles. This advancement goes beyond just decoration, scope now exists to deposit a wide range of functional materials, including those already used in conventional processes, offering the prospect of new concepts and possibilities. As such, there is now greater emphasis on the development of inks that can functionalise textile substrates by inkjet deposition.*

*In this work, we have formulated inks incorporating fluorocarbon, based on C8 and C6 chemistry, to demonstrate that by combining the right chemistry with suitable components, many commercially available materials can be formulated into a reliable inkjet fluid. We have also studied the effect of digital hydrophobic finish on both sides of the printed fabric, and quantified this hydrophobic effect by measuring the contact angle and spray rating test. Wash durability and comfort relevant properties were also assessed. This data has improved our understanding of digital textile finishing and its unique benefits.*

## Introduction

Water repellent property for textiles remains an interesting functionality since it was first introduced. Although there have been many advances over the years in order to improve the effect of hydrophobic functionality, these advances have been remarkably slower then other areas of textile finishing. “Hydrophobic finish”, also sometime referred to as “self cleaning finish”, is one of the most desirable finishes for high-end textile products. This is commonly achieved by application of material that reduces the surface energy of the fabric, resulting in water/oil repellency in combination with other finishing materials.

Fluorocarbon, Polysiloxane and hydrocarbon wax treatment is applied on to fabric for the required level of functionality. Typically, the textile is treated with finishing materials in a bath followed by heat treatment. A limited number of fluorine-silane based hydrophobic finishing materials have also enjoyed limited success in some applications, but suffers from low oil repellency. Use of nano silica particles independently and in combination with silane hydrophobes, have also been reported to produce durable water repellent finish on textiles[1].

Traditional methods for industrial application of these treatments, involves applying a chemical/solvent solution onto the surface of the fabric, using either a spray process or a dipping process. Textile articles produced by a conventional foulard / pad mangle process, renders hydrophobic functionality throughout the structure of the fabric (front and back), which often adversely effects not only the handle properties of the fabric, but also the tactile and moisture related properties of the products, where skin contact is inevitable. This can cause a feeling of uneasiness and sensual discomfort to the people wearing apparel next to the skin with a hydrophobic finish. The overall cause of discomfort is largely identified as the inability of fabric to absorb sweat and transport it through to the fabric, primarily due to the water repellent finish on the inside of the fabric that is in direct contact with the skin.

During the last decade, the textile industry has become increasingly aware of the importance of digital technology. Many new inks for digital textile printing have reached market as a result of a rapidly advancing printhead technology. The concept of digitally functionalized textiles has been around for a while and appeared in patents[2]. This paper reports an experimental investigation into inkjet as a potential alternative and preferable means to deliver finishing material onto the fabric, to achieve a single sided hydrophobic/hydrophilic finish. This could provide the benefit of a breathable hydrophobic finish on the outside surface, and the comfort of cotton and cotton blend on the inside, which is characterized by the hydrophilic nature of cellulosic fibre.

An inkjet process, providing a single-sided hydrophobic finish, could offer four key benefits:

**1. Oil and water repellency on one side**

Repel water or water and oil both, while maintaining breathability of the fabric, depending on the selection of suitable finishing material.

**2. Hydrophilicity on opposite side**

Maintains “breathability” of the fabric, where moisture can be absorbed over large areas and transported from the hydrophilic side of the fabric to the hydrophobic side. This provides additional comfort by regulating moisture, whilst keeping the dry effect on the outer surface of the fabric.

**3. Dirt repellency**

Hydrophobic effect is caused by lowering the surface energy on the fabric, which effectively repels dirt and may substantially increase time between laundry cycles.

**4. Soil Release properties**

Unprinted side of single sided hydrophobic treated fabric can substantially improve the soil release properties of coated side during the washing process. Hydrophilic properties can considerably improve the wetting of fabric, creating the possibility to transport washing liquor to the hydrophobic side.

The concept of digitally finished single-sided hydrophobic/hydrophilic (SSH/H) fabric can be described as a surface modification process, using commercially available finishing materials, but applying them only on the outer surface of the fabric. This can be achieved using digital material deposition processes, employing either continuous or drop-on-demand printhead technology. In this way, the functional material can be deposited in a precise and controlled manner, providing a finish on the printed side, which is technically equivalent to conventionally produced samples at lower or equivalent concentration by weight of fabric. The penetration depth and active concentration of functional material on the surface by weight of fabric, is possible to achieve by controlling the quantity of fluid deposited. This is function of drop size, print resolution and concentration of the active material in the ink. The digitally finished surface may also be subjected to a further post treatment, according to the application conditions recommended for given product.

On the other hand, the non-printed side is expected to exhibit hydrophilicity depending on the penetration depth of the functional material through the thickness of the fabric. The fabric therefore repels water away on its outer surface, while taking up sweat and moisture generated from the body from the inside. This gives water repellence properties with increased comfort to the fabric compared with a conventional hydrophobic finish. This profound effect makes inkjet a preferred method to functionalize textiles, where such properties are desirable. During the course of our investigation, we successfully produced proof of concept samples with an inkjet printing process, where it is possible to have single-sided functionality on various substrates such as cotton, polyester, blends and other textile substrate. Secondly, having fabric with such a functionality opens up the possibility of successful applications in day to day apparel/garments and not just for performance clothing or out door applications.

## Material

### *Selection of Functional Material*

Fluorocarbons today represent an indispensable part of the technology of oil, water and soil-repellant finishing. These are the most used finishing materials for hydrophobic finish and remain the most successful approach for achieving high degree of water/oil repellency. The conventional paraffin or silicone based water repellent finishing agents are not adequate to protect the textiles from grease and oil stains and hence fluorocarbon based products are used. Large numbers of different products are available from finishing material suppliers. Fluorocarbon polymers family, commonly known as fluorocarbons consists of molecules having a carbon backbone, fully surrounded by fluorine. Most successful fluorocarbon polymer based commercial products for textiles are related to C8 chemistry (represents the length of carbon chain), which has been identified as risk to health and industry has been forced to focused on producing product with shorter chain C6 based fluorocarbon products. Large numbers of commercial products are still based on C8 chemistry, while some C6 based commercial products are still in industrial testing phase. We, therefore, selected one product from each class, which were then formulated into inks from their dispersions, suitable for inkjet printing.

### *Textile Substrate*

The fabric sample TenCate Tecastyle® -Denim-Look, KG 308 (245g/m$^2$) which compose of 65/35% of Polyester/Cotton of 2/1 Twill construction, suitable for casual and work wear, was supplied by TenCate, Technical Fabrics BV, Netherlands. The substrate KG 308 used, was industrially singed, desized, scoured, bleached and prepared for further finishing process.

## Results and discussions

### *Ink development and sample Preparation*

Each of the functional dispersion was formulated into inkjet inks together with suitable humectants and other additives to achieve rheology suitable for inkjet printing. Ink formulations “ESP101” incorporating a commercially available C8 based fluorocarbon dispersion and “ESP 201” based on C6 fluorocarbon dispersion were prepared and physical parameters of inks were adjusted that is suitable for Xaar Omnidot 760 printhead. Physical parameters of inks are given below in **Table 1.** Inks demonstrated good print reliability and jetting performance during the print trails. In order to achieve optimal fixation, it was also necessary to adjust pH of ink in the range of 5.5 -6.5.

**1. Functional Inkjet ink characterisation**

| Formulation | Viscosity | Surface Tension (dyns/cm) | Filtration (1μ) | pH |
|---|---|---|---|---|
| ESP101 | 9.1 | 34 | Good | 6.5 |
| ESP201 | 9.8 | 33.5 | Good | 6.5 |

Sample fabrics were printed with ESP101 and ESP201 formulations using a XenJet 4000 Print platform mounted with a Xaar omnidot 760 GS6 print head, from Xennia Technology Ltd, suitable for high accuracy material deposition. Samples were produced at fluid deposition of 24 g/m$^2$ providing a concentration of 4% active material by weight of fabric and cured at 170ºC for 3 minutes for optimal fixation and water repellent properties.

Analogue samples ESP001 and ESP002 of ESP101 and ESP201 respectively, were also prepared from a conventional recipe by conventional process and were used to assess the wash durability by spry rating test before and after 5 and 10 washing cycle. Samples were prepared by padding process with formulations ESP001 and ESP002 at 70% wet pickup giving 5% of active material on fabric by weight of the fabric, samples were then dried at 120ºC for 2 minutes and further cured at 170ºC for 3 minutes.

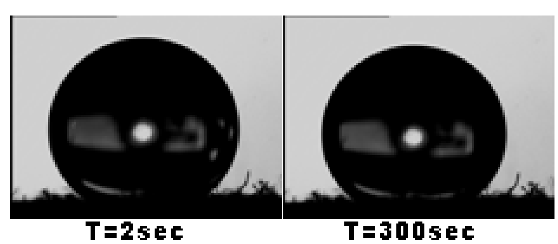


*Figure 1. ESP 101 - Hydrophobic Printed Side*

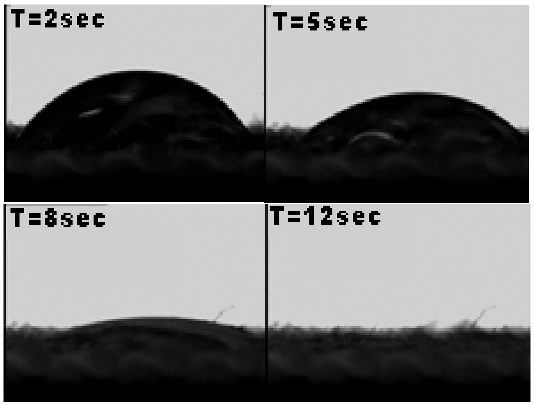


*Figure 2. ESP 101 - Hydrophilic Back Side*

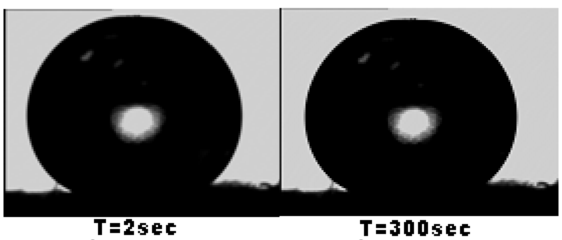


*Figure 3. ESP 102 - Hydrophobic Printed Side*

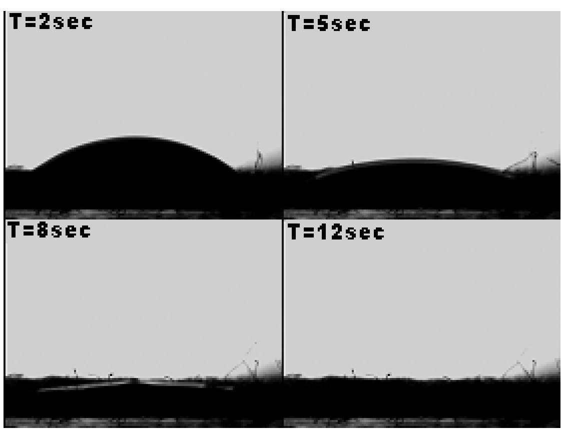


*Figure 4. ESP 102 - Hydrophilic Back Side*

## Contact angle

Contact angles, θ, were measured at room temperature (22ºC±1) using a high resolution camera, for samples ESP101, ESP201 and their analogues. 15 µl drop of deionized water was place on fabric surface. High resolution pictures were taken immediate after drop was placed on the surface and after 5 minute for printed side. On hydrophilic side of the fabric water droplet absorb by surface within 10 seconds. Therefore, pictures were taken at delay of 2, 5, 8 and 12 seconds.

When Contact angle of digitally prepared samples were compared to their analogue samples (Table 2), the results were comparable for both unwashed and washed samples (ISO6330). This provides compellingly evidence that material deposition in a control manner can produced effective results that are comparable to conventionally applied finish.

**2. Comparison of contact angle**

| Sample reference | contact angle | | |
|---|---|---|---|
| | Unwashed | 5x washed | 10x Washed |
| ESP101 | 130 | 129.2 | 123.5 |
| ESP201 | 128 | 122.5 | 117.5 |
| ESP001 | 132 | 132.5 | 126.5 |
| ESP002 | 130 | 125.2 | 121 |
| Blank | - | - | - |

**Figure 2** and **Figure 4** shows that surface of unprinted side exhibit strong hydrophilic properties and water droplet quickly absorbed by the surface of the fabric. In another observation, as shown in **Figure 5**, it was found that on hydrophilic side of digitally finished fabric, a water droplet spreads over the larger surface area when compared to unfinished fabric, this property can further enhance the drying rate of absorbed sweat and adding another dimension of comfort to the textile apparel products.

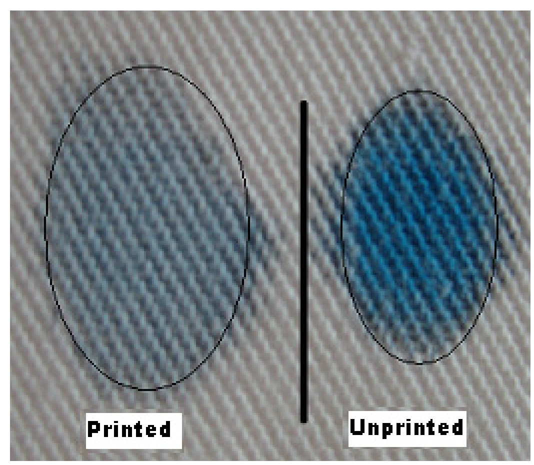


*Figure5, Drop spread behavior on hydrophilic side (with Trace colorant)*

## Spry rating Test

The repellent properties of inkjet printed side of samples and their analogues were measured in accordance with the ISO 4920* and AATCC118** spray test method for water and oil respectively.

Results convincingly demonstrated that samples produced by inkjet method were comparable to conventionally produced samples for both oil and water repellent properties. Single sided hydrophobic inkjet printed samples were as effective as their respective analogues. To evaluate durability and compare the effect of washing on inkjet printed samples to their respective analogues, all samples were washed for up to 5 and 10 times according to ISO 6330***, procedure 5A and tumble dried (only after final wash).

**3. Spray Rating Test**

| Sample | Spray Rating Test water*/Oil** | | | | | |
|---|---|---|---|---|---|---|
| | Unwashed | | Washing Cycle*** | | | |
| | | | 5 | | 10 | |
| | water | Oil | water | Oil | water | Oil |
| ESP101 | 5 | 7 | 4-5 | 5 | 3 | 4 |
| ESP201 | 5 | 6 | 3 | 3 | 1-2 | 2 |
| ESP001 | 5 | 7 | 4-5 | 6 | 3 | 4 |
| ESP002 | 5 | 6 | 3-4 | 4 | 2 | 2 |
| Blank | - | - | - | - | - | - |

It can be seen from **Table 3** that after five washes Oil and water repellent properties remain very good. Inkjet sample ESP101 showed similar results to its analogue sample, but in case of ESP201, its analogue samples showed slightly better fastness to washing but two samples reaming were very comparable. After 10 washing cycles, repellent properties were reduced for both inkjet and their analogue sample, again showing that durability of inkjet printed samples were very similar to their conventionally produce analogue samples.

### *Water vapor transmission measurements (in climate chamber)*

Water Vapor transmission (WVT) tests were done on inkjet printed samples according to the standard UNI 4818-26 after conditioning them on standard conditions in the desiccators for 24 hours at 20º C and 65% relative humidity. Three aluminium pots were filled with 25 ml of distilled water and the fabric samples were placed on the pot, a rubber gasket was placed on the pots and closed. The fabric was placed on the pot in such a way as to have the hydrophilic side facing the inside of the pot. The pot opening has an area of 1000 $mm^2$ for the water vapor transmission. The pots were kept in a climate chamber and the difference in weights is noted before and after 24 hours. The conditions in the climate chamber were also 20º C and 65 % relative humidity (RH) and in second case, 20º C and 80 % relative humidity.

$$WVT\ (gm^{-2}day^{-1}) = \frac{\Delta m \times 24}{S \times t}$$

Where Δm is change of weight (g), S is the testing area of the sample (1000 $m^2$), t is testing time (h).

**4. Comparison of WVT rate**

| | WVT rate gm/m2/day | | | |
|---|---|---|---|---|
| | Unwashed | | 5x Washed | |
| RH* | 65% | 80% | 65% | 80% |
| ESP101 | 1043 | 646 | 916.6 | 630 |
| ESP201 | 1066.6 | 570 | 1046 | 590 |
| Blank | 1153 | 610 | 1110 | 556 8 |

*RH – Relative humidity

It can be seen from Table 4, that water vapor transmission rates were very slightly affected by single sided hydrophobic finish when compared to unfinished non treated fabric.

## Conclusions

Finishing of textile materials by mean of digital material deposition process showed good water repellent properties with out any obvious alteration to fabric handle properties. Its effectiveness and performance was evident by high spray rating and contact angle. We tested the durability of inkjet printed sample up to 10 laundry cycle and it maintained very high degree of water repellency and spray rating similar that their respective analogues. It was illustrated that, when functional material was only present on the single side of the fabric, its effectiveness and durability was comparable to their conventionally produced analogue samples.

On the other hand digital finishing process proved to be very successful in order to produce hydrophobic effect on only printed side of the fabric. Unprinted side showed substantial hydrophilic properties which was evident by rapid absorption of water droplet. Samples also showed very small drop on water vapor transmission rate when compared to untreated blank substrate.

## References


[1] Craamer, Johannes A. WO/2006/100280 (2005)

[2] Xiangwu Zhang, Durable Hydrophobic Textile Fabric Finishing Using Silica Nanoparticles and Mixed Silanes, Textile Research Journal, Vol. 79, No. 12, 1115-1122 (2009)


## Author Biography

*Dr. Karim Ali has a B.E Honors degree in Textile Chemistry and a PhD in Color Chemistry from the University of Manchester, UK. Karim joined Xennia in 2006. Prior to this, Karim worked in the area of Textile printing and gained experience in process and chemical technology of textile. Since working for Xennia, Karim developed number of novel inkjet inks for Continuous and DOD printhead technologies and also responsible for developing various inkjet inks for textile materials.*