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INTERDISCIPLINARY INSIGHTS INTO ARGON PLASMA TREATMENT ON KNITTED MODAL FABRICS FOR SUSTAINABLE FABRIC PROCESSING

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ABSTRACT

In recent years, argon plasma treatment has emerged as a promising technique for enhancing the surface properties of materials, especially textiles, through the use of low-pressure glow discharge plasma. This method offers advantages in terms of performance and sustainability, making it a focus of interdisciplinary research in fields such as physics, chemistry, environmental science, resource management, and sustainable development. Physics plays a critical role in elucidating the intricate mechanisms of plasma treatment, including ion bombardment and chemical reactions, while chemistry is essential for introducing functional groups onto fabric surfaces, improving adhesion and dyeability. Environmental science underscores the importance of sustainable practices in textile processing, with argon plasma treatment offering a cleaner alternative that requires minimal water and chemicals. Resource management and water conservation are key priorities, and argon plasma treatment contributes to more efficient resource utilization and reduced water consumption. It also helps mitigate pollution hazards associated with traditional textile wet processing by minimizing chemical usage and environmental impact. Energy conservation is another significant benefit, as argon plasma treatment requires less energy compared to conventional methods, leading to reduced greenhouse gas emissions and aligning with sustainable development principles. Overall, argon plasma treatment represents a versatile and sustainable approach to surface modification in the textile industry, with potential for further advancements through multidisciplinary research and innovation.

Key words; argon, Environmental science, plasma treatment, Resource management

Sustainable development, textiles.

INTRODUCTION

In recent years, argon plasma treatment has emerged as a promising technique for modifying the surface properties of materials, including textiles. This treatment involves the use of low-pressure glow discharge plasma to alter the surface characteristics of fabrics, offering advantages in terms of performance and sustainability, (Chen et al. 2017) of research related to argon plasma treatment, highlighting its interdisciplinary nature and emphasizing its significance in various fields. Physics plays a crucial role in understanding the mechanisms behind plasma treatment. The interaction between the plasma and the fabric surface involves complex physical processes, including ion bombardment, surface activation, and chemical reactions (Hashmi et al. 2017) Understanding these processes is essential for optimizing treatment parameters and achieving desired surface modifications. Chemistry is another key aspect of argon plasma treatment research. The plasma can introduce functional groups onto the fabric surface, changing its chemical properties. This can lead to improvements in adhesion, dyeability, and other functional aspects of the fabric. Environmental science is increasingly important in the context of textile wet processing (Zhou et al. 2014). Traditional wet processing methods can have significant environmental impacts due to water consumption and chemical pollution. Argon plasma treatment offers a more sustainable alternative, as it requires minimal water and chemical inputs while providing effective surface modification. Resource management is closely linked to sustainability (Sriyanti et al. 2015). By reducing water and chemical usage, argon plasma treatment contributes to more efficient resource management in the textile industry (Vignesh et al. (2017). Water is a critical resource and a social concern, particularly in regions facing water scarcity. The use of argon plasma treatment can help reduce water consumption in textile processing, contributing to water conservation efforts, since plasma treatment is a waterless treatment. Textile wet processing pollution hazards are a significant issue in the textile industry. The chemicals used in traditional wet processing can pollute water sources and harm the environment. Argon plasma treatment offers a cleaner alternative, reducing the environmental impact of textile processing. Energy conservation is another important aspect of sustainability. Argon plasma treatment facilitates the consumption of less energy compared to traditional wet processing methods, contributing to energy conservation and reducing greenhouse gas emissions. Sustainable development is a key goal for many industries, including textiles. Argon plasma treatment aligns with the principles of sustainable development by offering a more environmentally friendly and resource-efficient approach to surface modification. Argon plasma treatment is a versatile technique with wide-ranging applications and benefits. Its interdisciplinary nature makes it a subject of interest for researchers in physics, chemistry, environmental science, and other fields. By promoting multidisciplinary research, we can further explore the potential of argon plasma treatment and its role in advancing sustainable practices in the textile industry.

MATERIALS AND METHOD

Fabrics

In the present study, knitted fabrics using 100% modal yarns in single jersey construction were used.

Experiment

Plasma treatment

Based on the review of literature and standard procedures, the research methodology was formulated. The modal knitted fabrics were treated using low pressure glow discharge plasma. The glow discharge was generated using an apparatus made by an industry. The DC glow discharge was operated at 0.5 mbar. Argon was used as the feeder gas. Cathode was located in the centre of the chamber and the chamber walls acted as anode. Samples were placed hanging at a distance of about 18 cm from the cathode. The gas flow was maintained at a constant rate. The duration of plasma treatment was 5, 10 and 20 minutes for the plasma treatments.. The treated fabric samples were removed from the chamber and then conditioned under 65% RH and 25^0C standard conditions for 24 hours before testing.

Testing

Geometrical properties of plasma treated bamboo fabrics.

The weight per square metre of the fabrics was determined using GSM cutter as per IS 1962-197. The number of wales and course per centimetre was recorded as per ASTM standard D 3775. Thickness was measured at different places in the pieces on different samples as per BS 2544-1954. The loop length measured at different places in the fabric samples as per BS 5441.

SEM topography: SEM studies were carried out on the samples after mounting them on specimen stubs and coating with AU-PD in a vacuum fine coat ion sputter. For each sample, two specimens were taken. The thickness of the coating and time were optimized before the samples were examined in JOELSEM model 84 OA.

RESULT AND DISCUSSION

Table 1: Geometrical properties of untreated and argon plasma treated modal fabrics

Sample Code Description	Course/ Cm	Wale/ cm	Stitch density (cm^2)	Loop length (mm)	Tightness factor ($tex^{0.5}$ mm^{-1})	Loop shape factor	Thickness (mm)	Mass per unit area (g/m^2)
Untreated – control	21.0	16.0	336	2.20	2.02	1.31	0.45	158.67
5 min. Argon	26.0	20.0	520	1.37	3.24	1.30	0.32	153.00
10 min. Argon	17.6	15.5	273	2.46	1.80	1.14	0.34	144.00
20 min. Argon	17.6	15.0	264	2.54	1.75	1.17	0.34	144.00

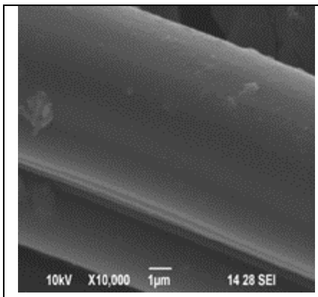	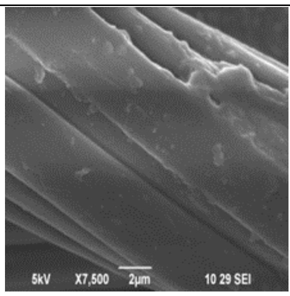	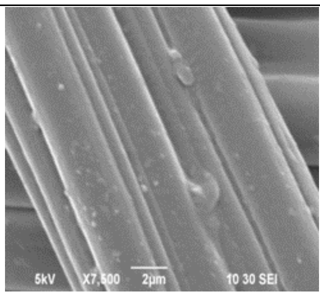	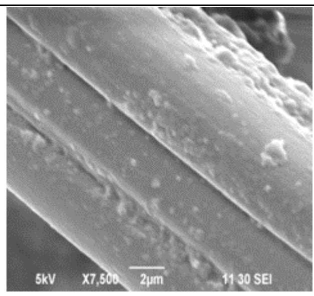
UNTREATED	5 Minutes	10 Minutes	20 Minutes

Figure 1: Scanning Electron Micrographs of untreated and argon plasma treated – modal fabric

Area of wetting (cm²): It seems that the area of wetting varies across different treatments. For instance, for the face surface, the area of wetting decreases initially at 5 minutes of treatment, then increases slightly at 10 minutes, and remains somewhat consistent at 20 minutes. On the back surface, there's an increase in the area of wetting at 5 minutes of treatment compared to the untreated fabric, then a decrease at 10 minutes, and a slight increase again at 20 minutes.

Time to Vanish (sec): The time taken for the specular reflection to vanish also varies across different treatments. For both face and back surfaces, it's somewhat inconsistent. For instance, on the face surface, it increases at 10 minutes compared to 5 minutes, but decreases again at 20 minutes. On the back surface, it increases at 10 minutes compared to 5 minutes, but decreases again at 20 minutes.

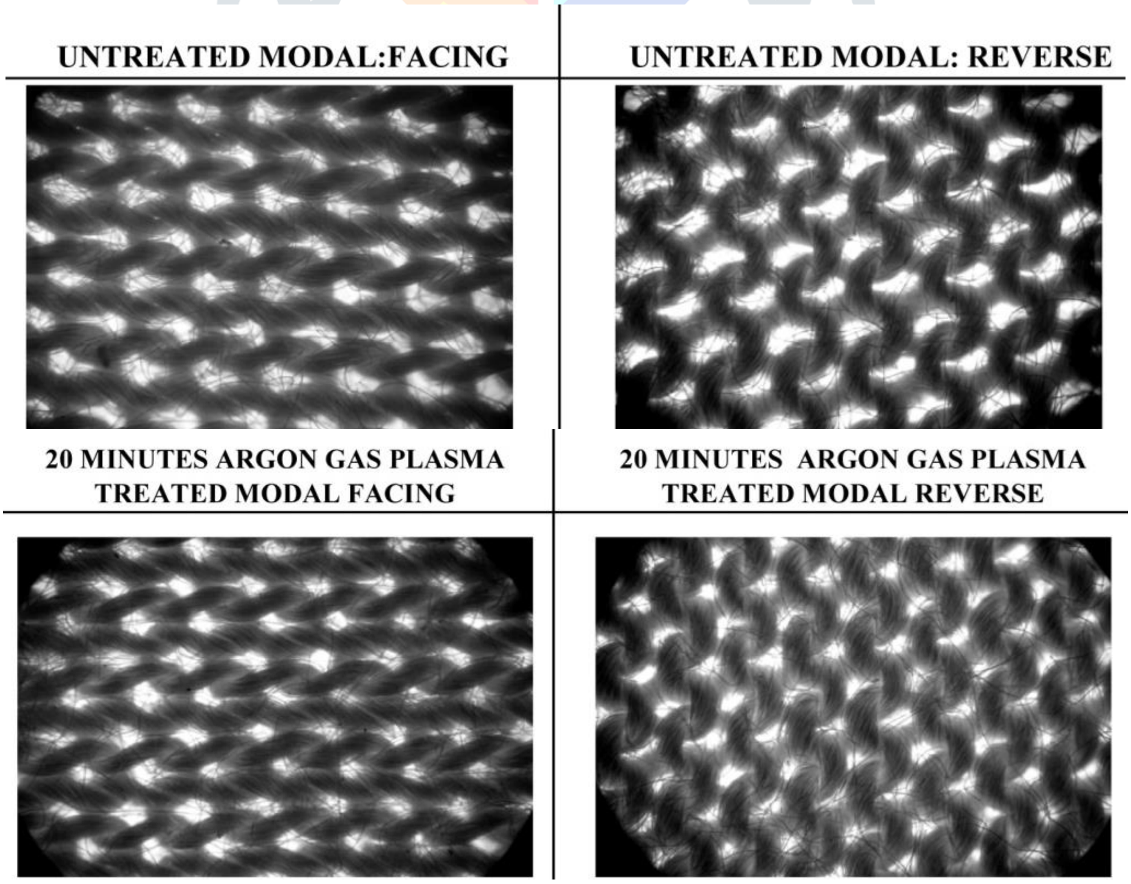

Figure 2 : Macropore structure of untreated and argon plasma treated modal fabrics

Table 2: Wettability of plasma treated modal fabric

Description	Area of wetting (cm^2)		Time taken for the specular reflection to vanish(sec)	
100% modal	**Face**	**Back**	**Face**	**Reverse**
Untreated	0.83	0.67	5.00	4.00
5 min.argon	0.76	1.32	8.00	4.00
10 min.argon	0.69	0.58	10.00	12.00
20 min.argon	0.83	0.66	7.00	10.00

Treatment Duration: Longer treatment durations (10 and 20 minutes) seem to have different effects compared to shorter durations (5 minutes). For example, at 10 minutes, the area of wetting decreases for both face and back surfaces compared to 5 minutes, but then slightly increases again at 20 minutes. Similarly, the time to vanish increases at 10 minutes compared to 5 minutes, but decreases again at 20 minutes.

Overall, the relationship between the area of wetting, time to vanish, and treatment duration is not straightforward and might involve complex interactions influenced by various factors such as plasma intensity, fabric properties, and treatment conditions. Further experimentation and analysis may be needed to fully understand these relationships.

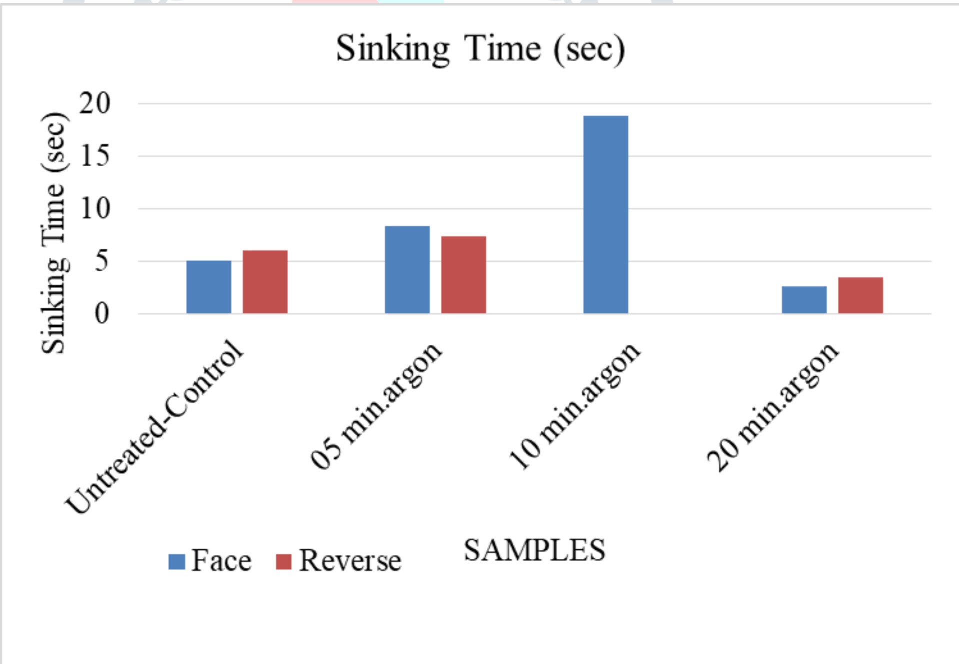

Figure 3 : Sinking time of argon plasma treated 100% Modal fabric

To analyse the data regarding the surface absorption of water of argon plasma-treated samples, the focus is on the sinking times of the samples. Lower sinking times indicate higher absorption rates, while floating indicates no absorption. Figure 3 gives the sinking times for the face and reverse sides of the samples and from this data, the following trend is observed:

The untreated control sample has relatively low sinking times, indicating moderate absorption. The 05 min. argon-treated samples show slightly higher sinking times compared to the control, suggesting a slight decrease in absorption. The 10 min. argon-treated sample on the face side shows a significant increase in sinking time, indicating reduced absorption. However, the reverse side of this sample is floating, indicating either no absorption or very low absorption. The 20 min. argon-treated samples show low sinking times, especially the face side, indicating higher absorption compared to the other treated samples.Overall, the 20 min. argon-treated samples have the highest surface absorption of water, while the 10 min. argon-treated sample on the face side shows a significant decrease in absorption. The reverse side of the 10 min. argon-treated sample does not absorb water, at least not to the extent of sinking and continues to float.

To analyse the data regarding the water gain after static immersion of argon plasma-treated modal samples, the percentage increase in weight for each sample is compared. Figure 4 gives the summary of the water gain after static immersion for each sample.

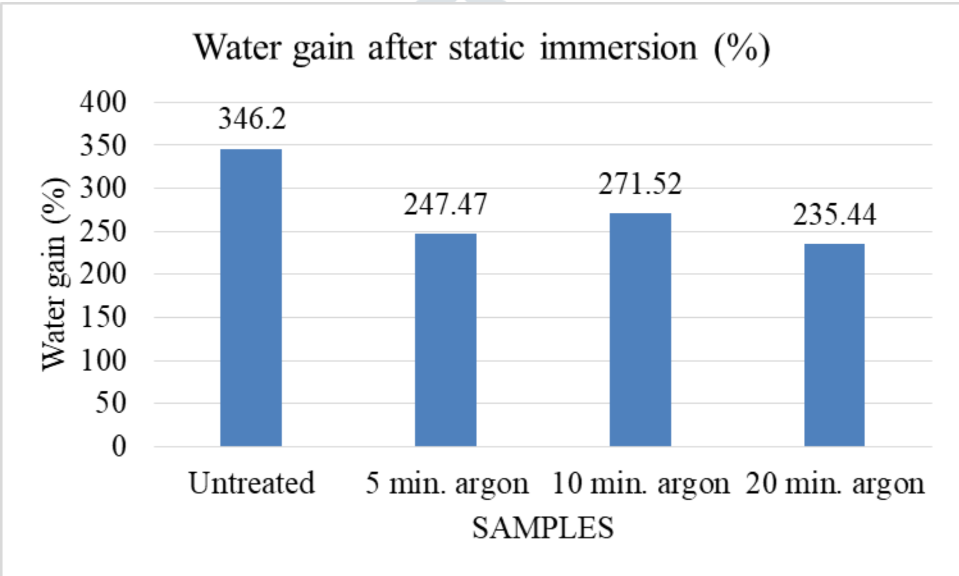

Figure 4: Percentage water gain by argon plasma treated 100% modal fabrics after static immersion

From these calculations, all three argon plasma treatments resulted in a decrease in water absorption compared to the untreated sample, with the 20 min. treatment showing the highest reduction in water gain. This indicates that the argon plasma treatment effectively reduces the water absorption of modal samples, with longer treatment times generally resulting in greater reductions. It indicates that the argon plasma treatment has facilitated in the process of completely wetting the samples. This is an advantage since it will reduce water consumption at the same time not compromising on the wetting process essential for the wet processing of textiles.

To analyse the data regarding the static immersion and drying of untreated and argon plasma-treated modal fabric the percentage weight retention at different time intervals is depicted in figure 5 .The result indicate that the untreated sample takes longer to dry completely (150 min.) while the argon plasma treated samples dry faster.

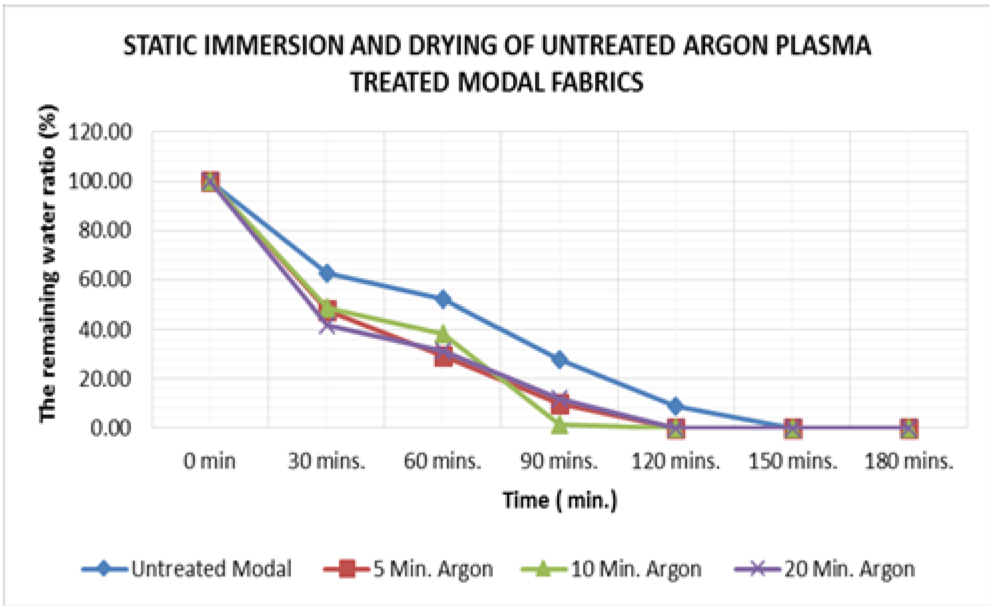

Figure 5: Static immersion and drying of untreated and argon plasma treated modal fabric

The fastest drying is happening between 60 to 90 minutes. The data regarding the total drying time of untreated and argon plasma-treated modal fabric, the drying times for each sample is given in figure 6. The data indicates that all the argon plasma-treated samples (5 min., 10 min., and 20 min.) have a total drying time of 120 minutes, which is 30 minutes less than the untreated sample. This indicates that the argon plasma treatment helps reduce the drying time of modal fabric as a result saving the energy required to dry the fabric after the wet processing procedures.

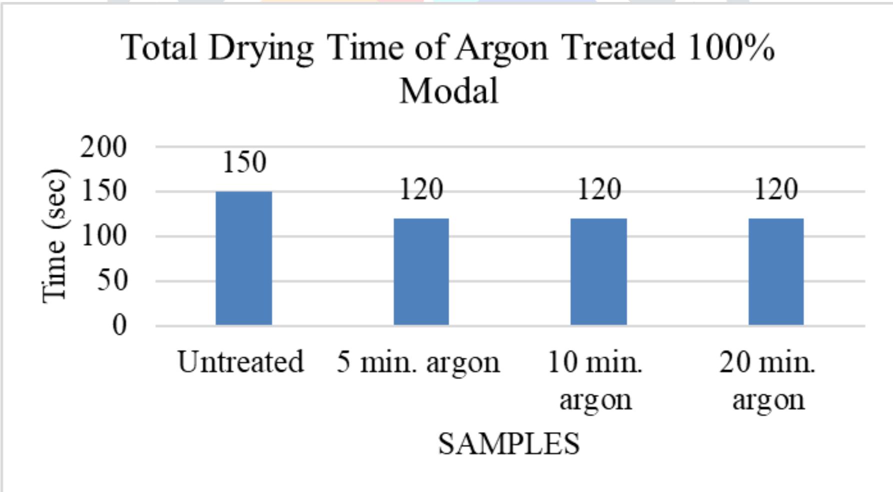

Figure 6: Total drying time of untreated and argon Plasma treated modal fabrics

CONCLUSION

Argon plasma treatment has emerged as a significant technique for modifying material surfaces, especially textiles, offering advantages in performance and sustainability. The interdisciplinary nature of research related to argon plasma treatment is evident, involving physics, chemistry, environmental science, and resource management. Physics plays a crucial role in understanding the complex mechanisms of plasma treatment, including ion bombardment and chemical reactions. Chemistry is essential for introducing functional groups onto fabric surfaces, enhancing adhesion and dyeability. Environmental science highlights the sustainability of argon plasma treatment, reducing water and chemical usage compared to traditional methods. Resource management benefits from argon plasma treatment, as it contributes to more efficient resource utilization and reduced water consumption in textile processing. Water conservation is critical, and argon plasma treatment helps reduce water consumption, aiding in sustainable textile production. Textile wet processing pollution hazards are mitigated by argon plasma treatment, which minimizes chemical usage and environmental impact. Energy conservation is another significant benefit, with argon plasma treatment requiring less energy compared to traditional methods, reducing greenhouse gas emissions. In conclusion, argon plasma treatment represents a versatile and sustainable approach to surface modification in the textile industry. Multidisciplinary research is crucial for exploring its potential fully. By advancing sustainable practices in textile processing through argon plasma treatment, we can enhance fabric properties while reducing environmental impact and energy consumption, contributing to a more sustainable and efficient textile manufacturing process.

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