Research Journal of Chemical Sciences ISSN 2231-606X
Vol. **4(9),** 41-46, September **(2014)** *Res. J. Chem. Sci.*

Application of Microwave in Textile Printing of Cellulosic Fabrics

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Available online at: www.isca.in, www.isca.me
Received 27th August 2014, revised 7th September 2014, accepted 16th September 2014

Abstract

Two different commercial reactive dyes; namely Cibacrox Brown P6R and Livafix Brilliant Red P-B were used in printing of cotton fabrics via screen printing technique. The printed fabrics were subjected to microwave irradiation for different periods of time at a power ranging between400– 800 W. Another series of samples were subjected to microwave irradiation at different temperatures 50 – 150oC. The colour strength of the microwave-assisted printed fabrics was compared with that of cotton fabric printed with the same paste, dried and subjected to fixation according to the conventional technique (steaming at 102oC for 15min or thermo fixation for 5 min at 150oC). The obtained results clarified that, the colour strength of the printed fabrics increases as a function of the same microwave power and the exposure time. It was also found that the most effective factor in fixation of the colour from the microwave-assisted printed fabric is the heat energy. Generally speaking, microwave-assisted printed samples acquired K/S similar or higher than that obtained by the conventional thermo fixation technique.

Keywords: Cellulose, cotton, reactive, dye, printing, microwave.

Introduction

Reactive dyes are extensively used in the textile industry because of their wide variety of colour shades, high wet fastness profiles, simplicity of application, brilliant colours, and minimal energy consumption. Reactive dye is the only class of dyes amongst all the classes of dyes which makes covalent bond with the fibre and becomes a part of it. Fibre reactive dyes are indisputably the best choice for dyeing any cellulose fibre including cotton, rayon, hemp and flax[1-4].

In spite of, there are a lot of researches[5-23] in the field of utilization of microwave in textile dyeing, its utilization in textile printing is not yet fulfilled. This may be due to the lake of water component in the printed film. The aim of the present work is to evaluate microwave irradiation as a source of heat to fix reactive dyes in comparative with the conventional methods, i.e. steaming and thermo-fixation.

Material and Methods

Substrate: Mill desized, bleached and mercerized cotton fabrics produced by El-Mahalla for Spinning and Weaving, El-Mahalla, Egypt.

Thickening agent: High viscosity sodium alginate extracted from brown algae, manufactured by Fulka Chemical Company, was used.

Reactive dyes: Two different commercial reactive dyes namely Cibacrox brown P6R and Levafix brilliant red P-B their reactive centre is monochlorotiazine and methylsulphonyl chloromethyl pyramidine respectively.

Chemicals: Urea and Sodium bicarbonate were of laboratory grade chemicals.

Preparation of the printing paste: The printing paste was prepared according to the following recipe

Reactive dyes	40 g
Urea	100 g
Sodium alginate	40 g
Sodium bicarbonate	30 g
Water	X g
Total	1000 g

The printing pastes were applied to the fabric via screen printing technique. After printing the printed fabric samples were subjected directly, i.e. before drying to microwave irradiation for different periods of time ranging between 1 to 9 min at a power of either 500 or 700 W for 5 min.. Another series of samples were subjected to microwave irradiation at different degrees of temperature (50, 75, 80, 100, 115, 150, 130 and 150°C. For the sake of comparison another samples of cotton fabrics were printed with the same paste, dried and subjected to fixation according to the conventional technique, i.e.either for steaming at 102°C for 15min. or thermo-fixation for 5 min and 1min. at 150°C for the samples printed using Cibacrown brown and Levafix brilliant red relatively.

Washing: After printing and fixation via microwave irradiation, steaming or thermo fixation the printed good were subjected to washing through 5 stages as follows: i. Rinsing thoroughly with cold water, ii. Treatment with hot water, iii. Treatment nears boiling temperate with a solution containing

2g/lAspkon 1030, iv. Washing with hot water, v. Rinsing with cold water. Finally the samples were dried and assessed for colour strength (K/S)

Colour, Fastness properties measurements and testing: The colour strength of the printed samples was evaluated by Hunter lab Ultra scan PRO. The colour strength, expressed as K/S and the overall fastness properties (washing, perspiration and crocking) were assessed according to the standard methods[24-32].

Results and Discussion

Microwaves, like other radio waves, are a form of electromagnetic waves. Electromagnetic waves are wavelike oscillations of electric and magnetic fields. Electric fields are what makes electric charges attract or repel. Positive or negative electric charges produce electric fields which in turn act on other charges. In a similar way, magnetic fields cause magnetic forces[33]. These fields are perpendicular to each other and continually oscillate between maximum positive and maximum negative (pointing in the opposite direction).

In microwave processing energy is supplied by an electromagnetic field directly to the material. This results in rapid heating throughout the material thickness with reduced thermal gradients. Volumetric heating can also reduce processing times and wave energy. The microwave field and the dielectric response of a material govern the ability to heat with microwave energy. Knowledge of electromagnetic theory and dielectric response is essential to optimize the processing of materials through microwave heating.

In fact the electric field component of microwave radiation is responsible for dielectric heating mechanism because it can cause molecular motion by either migration of icons species (conduction mechanism) or dipolar rotation (dipolar polarization mechanism).

It has been reported[34] that, microwave takes into account the dielectric and the thermal properties. The dielectric property refers to the intrinsic electrical properties that affect the dyeing by dipolar rotation of the dye and influences the microwave field upon the dipoles, in the high frequency microwave filed oscillating at 2450MHz. It influences the vibrational energy in the water molecules and the dye molecules.

The heating mechanism is through ionic conduction, which is a type of resistance heating. Depending on the acceleration of the ions trough the dye solution, it results in collision of dye molecules with the molecule of the fibre. The mordant helps and affects the penetration of the dye and also the depth to which the penetration takes place in the fabric. This makes microwave superior to conventional dyeing techniques. Microwave is a volumetric heating (fast) whereas conventional is a surface heating (slow) as shown in figure-1.

Dyeing and fixation of cotton fabric with reactive dyes using microwave have been researched and compared with conventional dyeing process. Based on trials the results showed that, the dye uptake and colour fastness of microwave dyed fabric were reached or higher than conventional process. The microwave heating could be shortened dyed time, and saved energy greatly. Furthermore utilization of microwave in dyeing polyester with disperse dyes[35,36] polyamide with reactive dye[37] and cotton with reactive dyes[38,39] were investigated. While utilization of microwave fixation the printed fabrics is not yet investigated. Hence, a trial was made here to investigate the possibility of using microwave fixation of cotton fabric printed with reactive dyes and comparing the results with the traditional thermo-fixation technique.

To achieve these goal two different reactive dyes were selected. Printing pastes were prepared containing these reactive dyes according to the recipe indicated in the experimental section. Samples of cotton fabrics were printed via screen printing technique and subjected directly to microwave fixation under a variety of conditions. The latter comprise the time of exposure, the microwave power and the temperature. Another, sample was printed using the same printing paste under the same technique followed by drying and fixation according to the conventional thermo-fixation techniques recommended for each reactive dye used. This was done according to the conditions indicated in the experimental section.

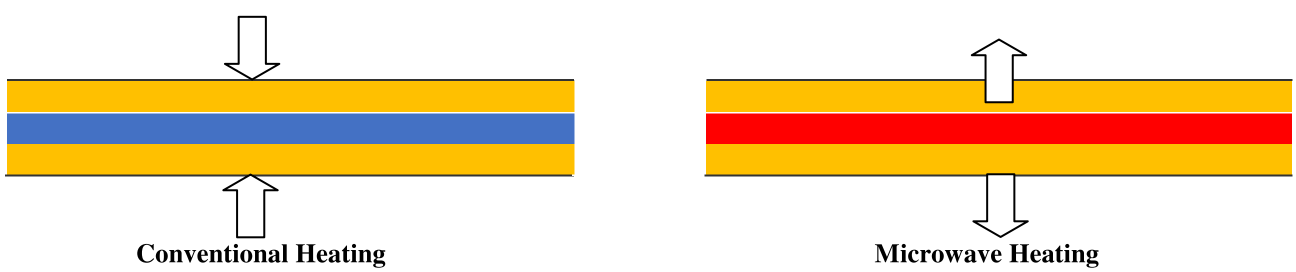

Figure-1
Microwave heating (volumetric) versus conventional heating (surface)

After fixation, the fabric samples were subjected to washing according to the aforementioned procedure in the experimental section followed by drying at ambient conditions and assessed for K/S and overall fastness properties.

Table-1 and table-2 comprise the results obtained for the samples printed with Cibacrown brown P6R and fixed via microwave irradiation at various time (1, 3, 5, 7 and 9 min.) at constant microwave power of 500W (table-1) or 700W (table-2) The K/S of the samples fixed via the conventional thermofixation technique was also measured and listed in the same tables.

It is clear from the data of table-1 that, as the time of exposure to microwave irradiation increases from 3 to 9 min. at constant power of 500W, the K/S of the printed cotton fabrics increases regularly from 0.55 to 6.89. In addition, the same trend was observed from the data of table-2.

By comparing the results of the second column in table-1 and table 2, it is clear from the data that increasing the power from 500W to 700W at any specific time is accompanied by an increase in the K/S. This phenomenon holds true for all the period of time under investigation except for the sample which exposed to microwave irradiation for relatively long time (9 min.).

The current data is expected since increase in the power at constant time is accompanied by an increase in the temperature. As the temperature increase, the rate of reaction between the reactive dye molecules and the hydroxyl groups of cotton increases. However, at relatively long time, i.e. 9 min. the opposite holds true where the K/S decreases from 6.86 to 6.75 by increasing the microwave power from 500W to 700W. It seems that, under these severe conditions, the produced heat affects the rate of reaction between cellulosic cotton and reactive dyes via either hydrolysis of some dye molecules or subjecting some dye molecules to thermal decomposition.

Since the conversion of microwave radiation to heat energy depends on the presence of polar water molecules, a trial was made to conserve same water molecules and decrease its evaporation and escaping from the printed film, this was done via covering the printed goods with either a sheet of paper or a plastic sheet.

It is clear from the data that irrespective of the magnitude of the microwave power or the time of exposure, covering the printed cotton fabrics is accompanied by an increase in the K/S. In all cases the K/S of the printed and microwave fixed fabrics follows the order samples covered with impermeable plastic sheet > samples covered with permeable paper sheet> uncovered samples. For example, the K/S of the samples, which subjected to microwave irradiation for 7 min. at a power of 700W, was increased from 11.69 to 13.95 to 16.56 for the uncovered, covered with paper sheet and covered with plastic sheet respectively. This was against their corresponding samples fixed at a power of 500W where their K/S was increased from 1.69 to 3.47 to 7.60 only.

Table-3 represent the K/S of cotton samples printed with Cibacrown brown P6R and subjected to microwave irradiation for 5 min. at different magnitude of power (400, 500, 600, 700 and 800W).

Table-1
Effect of time of microwave irradiation on the K/S of printed cotton fabrics with Cibacrox brown dye at power 500W

Time (min.)	K/S for the sample subjected to microwave irradiation		
	Uncovered samples	Samples covered with	
		Paper sheet	Plastic sheet
3	0.55	0.98	3.09
5	1.35	2.34	6.90
7	1.96	3.47	7.60
9	6.86	9.20	12

K/S of the sample fixed via conventional method thermo-fixation= 14.33- steaming= 14.78

Table-2
Effect of time of microwave irradiation on the K/S of printed cotton fabrics with Cibacrox brown dye at power 700W

Time (min.)	K/S for the sample subjected to microwave irradiation		
	Uncovered samples	Samples covered with	
		Paper sheet	Plastic sheet
1	1.41	1.68	6.12
3	3.52	4.58	10.61
5	7.49	11.22	15.94
7	11.69	13.95	16.65
9	6.75	15.98	17.91

K/S of the sample fixed via conventional method thermo-fixation= 14.33- steaming= 14.78

It is clear from the data that, increasing the magnitude of microwave fixation from 400 to 800W at constant time of 5 min. is accompanied by an increase in the K/S for all the samples. For the uncovered and covered samples for example, it increases from 0.80, 1.35, 4.25, 7.49 and 7.67 by increasing the power from 400, 500, 600, 700 and 800 for the uncovered samples respectively. However, the K/S for the samples fixed at a power of 700W increase from 7.49, 11.22, 15.94 or the samples fixed without cover, covered by a paper sheet or plastic sheet respectively. The current data is expected since in microwave technique, the produced heat depends on the magnitude of microwave power, the time of exposure as well as the present of heat polar solvent, which is responsible for capture of the electric filed, and converts it to heat energy. Hence, increasing the time at constant power, or increasing the power at constant time of exposure as well as increasing the amount of water molecules on the printed film via covering it causes an increase in the produced heat energy.

It is clean from the foregoing discussion that in case of using microwave irradiation the most effective factor in fixation of the colour from the printed film to the fabric surface is the heat energy. Naturally, the latter depends on[34] the magnitude of the applied power[40], the time of exposure and[41] on to presence of a polar relevant. Since the most effective factor in dye fixation is the produced heat, a trial was made to investigate the effect of the microwave-produced heat on the K/S of the printed cotton fabric in presence or absence of paper sheet cover. Table-4 represent the data of K/S obtained by varying the temperature from 50 to 150°Cforcotton fabrics printed with Cibacrown brown P6R and Levafix brilliant P-B respectively.

It is clear from the data that, as the temperature increases from 50 to150°C. The K/S increases regularly from 0.45 to 10.98 in case of using Cibacrown brown P6R, and from 0.34 to 25.12 in case of using Levafix brilliant P-B (table-4). Covering the printed fabrics with paper sheet is always causes an increase in the K/S values irrespective of the nature of the dyestuff used or the temperature of thermo-fixation.

It is worthy to mention that during investigating the effect of temperature on the K/S of the printed cotton fabrics, both the magnitude of power and the time of exposure in neglected. Where, the sample was subjected to microwave irradiation till the desired temperature reached, after that the sample was left for 1 min. at the desired temperature and removed from the microwave device, cooled, subjected to, washing, drying and finally accessed for K/S.

Table-3
Effect of power of microwave irradiation on the K/S of printed cotton fabrics with Cibacorn brown P6R for 5 min

Power (W)	K/S for the sample subjected to microwave irradiation		
	Uncovered samples	Samples covered with	
		Paper sheet	Plastic sheet
400	0.80	1.03	1.60
500	1.35	2.34	6.90
600	4.25	7.49	10.41
700	7.49	11.22	15.94
800	7.67	12.90	17.80

K/S of the sample fixed via conventional method thermo-fixation= 14.33- steaming= 14.78

Table-4
Effect of temperature of microwave irradiation on the K/S of printed cotton fabrics with Cibacorn brown P6R and Levalex brilliant red P-B

Temperature °C	K/S for the sample subjected to microwave irradiation			
	Cibacorn brown P6R[a]		Levalex brilliant red P-B[b]	
	Uncovered samples	Samples covered with paper sheet	Uncovered samples	Samples covered with paper sheet
50	0.45	0.51	0.34	2.7
75	1.13	2.84	0.96	3.42
80	1.50	4.40	1.30	7.85
100	6.25	8.28	11.40	17.05
115	7.28	9.50	17.08	20.16
125	8.50	10.39	22	24.33
130	9.90	11.45	23.59	25.69
150	10.98	-	25.12	-

[a] K/S of the sample fixed via conventional method thermo-fixation= 14.33 - steaming= 14.78, [b] K/S of the sample fixed via conventional method thermo-fixation= 20.04 - steaming= 19.05.

Table-5
Fastness properties of reactive dyeprinted cotton fabric fixed either by microwave irradiation or conventional method

Reactive dye used	Fastness Properties							
	Washing		Rubbing		Perspiration			
					Acidic		Alkaline	
	St.	Alt.	Wet	Dry	St.	Alt.	St.	Alt.
Cibacorn brown P6R sample fixed by microwave at 150°C	4-5	4	4-5	4-5	4-5	4	4-5	4
Cibacorn brown P6R sample fixed via steaming	4-5	4	4	4-5	4-5	4	4-5	4
Cibacorn brown P6R sample fixed via thermo-fixation	4-5	4	4	4-5	4	3	4-5	4
Levalex brilliant red P-B sample fixed by microwave at 150°C	4-5	4	4-5	4-5	4	3	4-5	4
Levalex brilliant red P-B sample fixed via steaming	4-5	4	4-5	4-5	4-5	4	4-5	4
Levalex brilliant red P-B sample fixed via thermo-fixation	4-5	4	4	4-5	4-5	3	4-5	4

St.: staining, Alt.: alteration.

It is clear from the data of table-2 and table-3 that in case of using Cibacrown brown samples acquire K/S near that obtained by the conventional thermo-fixation technique (14.33) or in some cases higher (15.98, 17.91 or 17.80) cold be attained. Also on using Lavafix brilliant red the same result could be attained (table-4).

Finally table-5 represents the overall colour fastness properties of the printed cotton fabric fixed by either microwave irradiation or conventional method. The data of table-5 reveal that the overall colour fastness properties are nearly equal for both the samples either fixed via microwave irradiation or conventional method.

Conclusion

It can be concluded that microwave irradiation could be used successfully in reactive dye fixation on cotton fabric surface. The K/S depends on the magnitude of the microwave power as well as the time of exposure to microwave. Since the presence of polar solvent, i.e. – water is necessary for microwave to convert the electric field to heat energy it is preferred to subjecting the printed fabrics immediately after printing, i.e. before drying to microwave fixation. Covering the printed cotton fabric samples with a paper or plastic sheet is accompanied by an increase in the K/S. Irrespective of the magnitude of power or the time of exposure to microwave the K/S follows the order samples covered by a plastic sheet > samples covered by paper sheet > uncovered samples.

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