Research Journal of Chemical Sciences ____ ISSN 2231-606X
Vol. **5(4),** 20-25, April **(2015)** *Res. J. Chem. Sci.*

Pigment Printing of Cotton Fabrics using Microwave Irradiation

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Available online at: www.isca.in, www.isca.me
Received 6th March 2015, revised 30th April 2015, accepted 15th April 2015

Abstract

Microwave irradiation was successfully used in fixation of pigment prints on cotton fabrics with a K/S values comparable with those obtained in case of conventional thermo-fixation technique. The printing pastes were applied to the fabric via screen printing technique. Afterwards, the printed fabrics were subjected to microwave irradiation for different periods of time at different microwave power. 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. The K/S values of the printed cotton fabrics fixed via microwave irradiation was found to be time and microwave power dependent. Results of this investigation clarified also that, regardless of the time of microwave exposure, covering the pigment printed cotton fabric samples with either permeable cellulosic paper sheet or impermeable plastic sheets led to a significant increase in K/S. In all cases the K/S follows the order uncovered sample < paper sheet covered sample < plastic sheet covered sample. Furthermore, the influence of minimization of the particle size of pigment green colour to the nano-scale on the K/S and overall fastness properties of cotton fabrics printed and fixed using microwave irradiation was also investigated.

Keywords: Pigment, printing, cotton, microwave and irradiation.

Introduction

Cellulosic fibres are natural polymers of vegetable origin, like cotton, linen, jute, ramie, hessian and sisal[1]. So, it would be useful to study and improve the printing technique of these natural polymers.

Recently, all of us searching for another source of energy to be clean, energy saving, fast and attractive when it comes to extraction of secondary metabolites from plants, and the world looks have been traveled towards microwave radiation as a heating source to be an alternative energy[2-7].

In pigment printing, insoluble pigments, which have no affinity for the fibre and fixed on to the textile with binding agents in the pattern required. This description is perhaps oversimplified, but it does obviously set pigments apart from dyes that are absorbed into the fibre and fixed there as a result of reactions specific to the dye[8,9].

The economic importance of pigments in printing is substantial since 1960 these have become the largest colorant group for textile prints. More than 50% of all textile prints are printed by this method, mainly because it is the cheapest and simplest printing method. After drying and fixation, these prints meet the requirement of the market. The washing process, carried out on chemical prints to remove unfixed dye, thickening agents and auxiliaries, is not normally when using the pigment printing technique[10,11].

For more the 3000 years, mineral pigments have been ground with natural binding agents (drying and boiled oils, or viscous, aqueous solutions of albumen products and vegetable gums) and applied to the textile to form a pattern[11]. The basic products for modern pigment printing were available quite early, but the technique required development. In 1920 dispersions of useful organic pigments liquid there found in pigment printing today were available on the market[11]. In 1930 emulsion copolymerization of olefinic substances (such as butadiene, vinyl esters, acrylonitrile and acrylic acid esters was discovered at the former I G Forben in Leverkusen and Ludwigshafen. In 1937 the first pigment printing pastes based on water-in-oil emulsions were developed in the USA by Inter-chemical Corporation[11].

In Europe aqueous pigment systems, for use oil-in-water emulsions were developed. The oil-in-water emulsions ultimately drove out the water-in-oil emulsion-based system[12], even in the USA. Eventually, synthetic thickeners became available[13].

A good-quality pigment printing is characterized by: i. brilliance and high colour value relative to the pigment concentration in the paste, ii. minimum stiffening in the handle of the textile, and iii. generally acceptable fastness properties.

In spite of, there are a lot of publication[14-31] deals with utilization of microwave irradiation in the field of textile dyeing; its utilization in the field of textile printing is not yet fulfilled. Hence the present work was undertaken in view of evaluation of microwave irradiation to fix pigment printed fabrics in comparison with the conventional thermo-fixation technique.

Material and Methods

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

Thickening agent: Commercial synthetic thickener Daicothick 1600, manufactured by Daico Company, Egypt was used.

Pigment: Pigment used is commercial Pigment green under the name M. O. Green B supplied by Daico company, Egypt.

Binder: Binder used is commercial binder named Minex Binder BD supplied by Daico Company, Egypt.

Chemicals: Urea and sodium dihydrogen phosphate dihydrate were of laboratory grade chemicals.

Methods: Preparation of nano-scale pigment: The particles of pigment were subjected to minimization using Ultrasonic homogenizer (Sonics and Materials, INC), Model: VCX750, Volts: 230VAC 50/60 HZNOM, U.S.A).

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

Pigment	**40 g**
Urea	25 g
Thickener	25 g
Binder	50 g
Sodium dihydrogen phosphate	50 g
Water	X g
	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 different microwave power (300,400, 500, 600, 700 and 800W). For the sake of comparison anther samples of cotton fabrics were printed with the same paste, dried and subjected to fixation according to the conventional technique, i.e. thermo fixation for 3 min at 160°C.

Washing: After printing and fixation via microwave irradiation, steaming or thermo fixation the printed good were subjected to washing through 5 stages as follows. Rinsing thoroughly with cold wate, Treatment with hot water, Treatment nears boiling temperate with a solution containing 2g/l aspkon 1030, Washing with hot water, 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[12,32-38].

Results and Discussion

When a piece of material is exposed to microwave irradiation, microwave can be: Reflected from the surface if it is on electric conductor (e.g. metals, graphite, etc), penetrate the material without absorption in the case of good insulators with good dielectric properties (e.g. quartz glass, porcelain, and ceramics). Absorbed by the material if it is a lossy dielectric (i.e. material that exhibits so-called dielectric larses which in turn results in heat generation in a quickly oscillating electromagnetic field such as water.

In fact the electric field component of microwave radiation is responsible for electric heating mechanisms because it can cause molecular motion by either migration of ionic species (conduction mechanism).

In spite of, there are a lot of researches 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 main aim of the present work is to evaluate the efficiency of microwave irradiation in fixation of pigment printing film. To achieve this goal a printing paste containing a green pigment colour was prepared according to the recipe indicated in the experimental section. The printed cotton fabric samples were subjected to microwave irradiation immediately after printing, i.e. before drying under a variety of conditions.

Effect of different irradiation time and different magnitudes of power: The latter comprise different irradiation time at a constant microwave power at 500 W (table-1), or for 5 min. at different magnitudes of power (300, 400, 500, 600, 700 and 800 W (table-2).

It is clear from the date of table-1 that the K/S of the printed cotton fabrics fixed via microwave irradiation depends on the time of exposure, whereas the time of exposure increases from 1to 3 to 5 to 7 and to 9 the K/S increases regularly from 0.78 to 2.75 to 6.78 to 7.5 to 8.01 respectively.

It is also clear from table-1 that covering the pigment printed cotton fabric samples with either permeable cellulosic paper sheet or impermeable plastic sheets is accompanied by a significant increase in K/S. this phenomenon holds true regardless of the time of microwave exposure, for example the sample which have been exposed for microwave irradiation at 500W for 9 min. increases from 8.01 to 9.11 to 11.22 by covering printed cotton fabric by a paper sheet or a plastic sheet respectively.

Table-1
Effect of time of microwave irradiation on printed cotton fabrics with green pigment at power 500 W

Time (min.)	K/S for the sample subjected to microwave irradiation		
	Uncovered samples	Samples covered with	
		Paper sheet	Plastic sheet
1	0.78	3.25	4.26
3	2.75	4.53	5.86
5	6.78	8.20	10.11
7	7.50	8.78	10.59
9	8.01	9.11	11.22

K/S of the sample fixed via conventional method thermo-fixation= 10.09

Table-2
Effect of power of microwave irradiation on printed cotton fabrics with green pigment for 5 min

Power (W)	K/S for the sample subjected to microwave irradiation		
	Uncovered samples	Samples covered with	
		Paper sheet	Plastic sheet
300	4.23	6.48	7.64
400	6.05	7.84	9.48
500	6.78	8.20	10.11
600	8.78	9.04	11.59
700	9.53	9.79	13.77
800	13.47	14.19	17.73

K/S of the sample fixed via conventional method thermo-fixation= 10.09

Increasing the K/S by covering the printed goods is expected, since microwave heating depends on the polar solvent i.e. water in this study, which is able to absorb the electrical energy and convert it into heat energy.

As the amount of water molecules on the printed surface of cotton fabric increases the expected heat on the fabric surface increases. Table-2 represent the values of K/S obtained when pigment printed cotton fabrics subjected to microwave fixation for 5 min. at various magnitude of microwave power (300, 400, 500, 600, 700, and 800 W. it is clear from the data of table-2 that as the microwave power increases from 300 to 800 W the K/S increases regularly from 4.23 to 13.47 in case of the uncover samples, from 6.48 to 14.19 and from 7.64 to 17.73 for the uncovered, covered with paper sheet and covered with a plastic sheet respectively. Here, too covering the printed goods is a companied by an increase in the K/S. In all cases the K/S follows the order uncover sample < paper sheet covered sample < plastic sheet covered sample.

From the results of table-1 and table-2, it is clear that microwave could be used successfully in fixation of pigment prints on cotton fabric samples. The K/S depends on both the power and time of microwave irradiation. A K/S of 8.01 and 13.47 could be achieved for the uncovered samples subjected to microwave irradiation for 9 min. at 500 W or 5 min. at 800 W respectively while the K/S of the sample printed by the same pigment colour and fixed via conventional technique, i.e. thermo-fixation at 160^{o}C for 3 min. acquire a K/S of 10.09.

Table-3 represents the overall colour fastness properties of the printed cotton fabric fixed either by microwave irradiation or conventional method. The data of table-3 reveal that the overall colour fastness properties are nearly equal for both the samples either fixed via microwave irradiation or conventional method.

Table-3
Fastness properties of the cotton fabric printed with green pigment fixed either by optimum conditions for microwave irradiation or conventional method

Sample	Fastness Properties							
	Washing		Rubbing		Perspiration			
					Acidic		Alkaline	
	St.	Alt.	Wet	Dry	St.	Alt.	St.	Alt.
Pigment printed fixed by microwave at 800 W for 5 min.	4-5	4	4-5	4-5	4-5	4	4-5	4
Pigment printed fixed by conventional method	4-5	4	4	4-5	4-5	4	4-5	4

St.: staining, Alt.: alteration

Effect of molecular size of pigment on the K/S and on the overall fastness properties: Ultrafine pigments with excellent properties have widely been used in inkjet inks, dyeing of textile fibres and other fields. It was interested to investigate the effect of minimization of pigment particle to the nano-size on the quality of printing goods. To achieve this goal the nano-scale pigment was prepared by mixing 4g of commercial pigment with 100ml water and set to motion in the ultrasonic stirrer (the Probe is turned to resonate at a specific frequency 20 khz ± 100 hz). The ultrasonic stirrer was operated for 40 min at 80°C, then, two different printing pastes were prepared according to the recipe mentioned in the experimental section. The first containing the untreated commercial pigment green (305.16 nm), while the second containing the treated pigment green (27.33 nm). Samples of cotton fabrics were printed using the two pastes and subjected to microwave fixation at various powers (700 and 800W) for different intervals of time (5 and 7min). For the sake of comparison another samples were printed and fixed via the conventional method, i.e. thermo-fixation at 106°C for 3 minutes. Finally, all the printed fabrics were washed and subjected to measure the K/S and overall fastness properties. The results obtained are shown in table-4. Figure-1 and figure-2 represent the SEM of the aforementioned pigment colour before and after minimization. It's clear from these figures that the molecular particle size had decrease from about 305.16 nm to about 27.33 nm.

Table-4
Effect of power and time of exposure of microwave irradiation on K/S of printed cotton fabrics with commercial and nano-scale green pigment

Power (W)	Time (min)	The particle size of Pigment Used	K/S for the sample subjected to microwave irradiation		
			Uncovered samples	Samples covered with	
				Paper sheet	Plastic sheet
700	5	Mini-sized	6.52	7.73	10.17
		Original	5.42	5.67	7.76
	7	Mini-sized	16.90	18.01	18.40
		Original	16.13	17.32	17.90
800	5	Mini-sized	17.21	18.25	18.73
		original	17.00	17.56	18.02
	7	Mini-sized	17.60	18.33	18.90
		original	17.23	17.50	18.33

K/S of the sample fixed via conventional method thermo-fixation commercial pigment= 14.68& nano-scale pigment =17.30

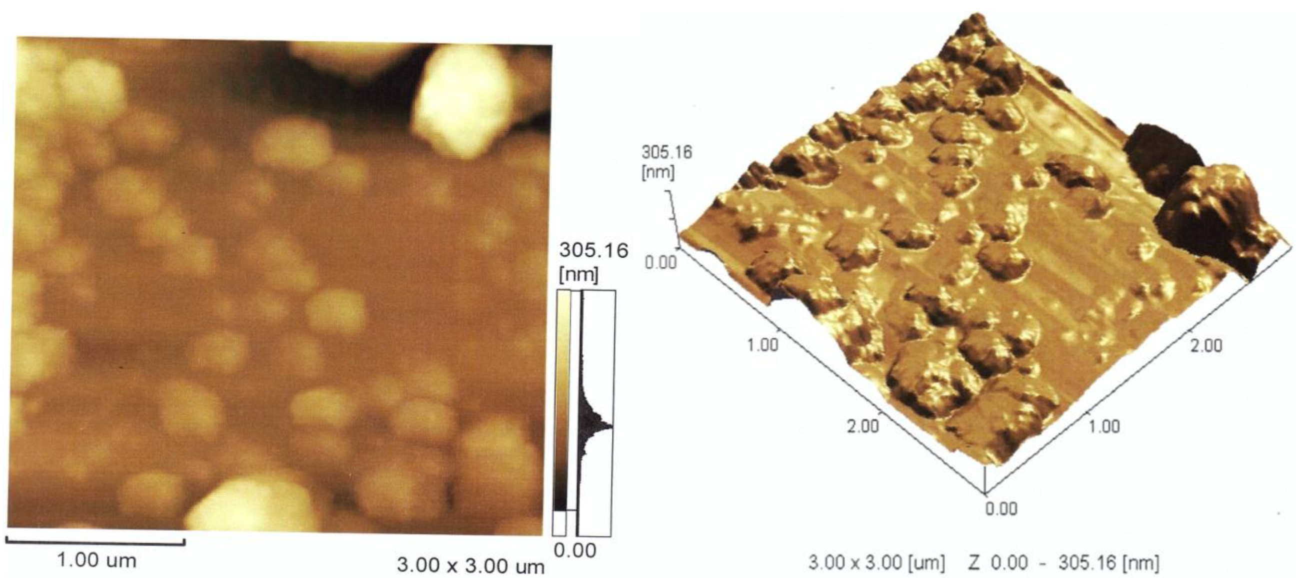

Figure-1
SEM micrograph of commercial green pigment before treatment

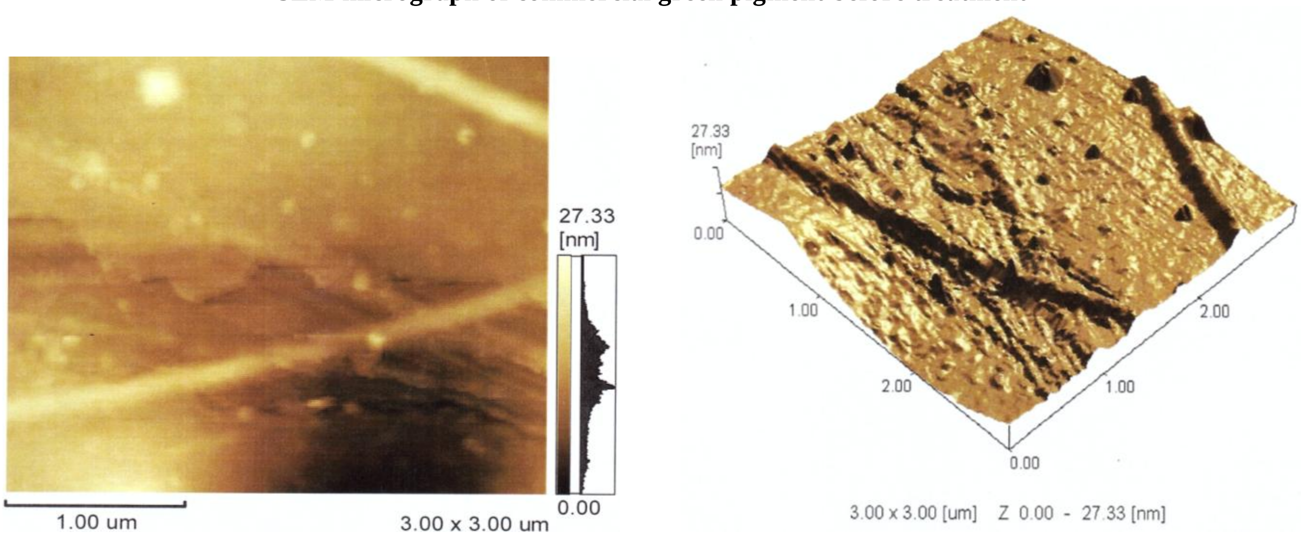

Figure-2
SEM micrograph of commercial green pigment after treatment

Generally speaking the particle size plays a remarkable influence on the K/S of the printed goods. Where, in all cases the K/S of the nano-scale pigment is higher than their corresponding samples printed using the untreated commercial pigment. This phenomenon holds true in all cases i.e. for the samples printed and fixed either by conventional or microwave technique regardless of the magnitude of the microwave power or the time of microwave irradiation exposure.

The increase in the K/S by decreasing the particle size of the pigment to the nano-scale is expected since as the size of the pigment decreases both distribution of the colour and its penetration increases hence the K/S increases. The data of table-4 clarify that the K/S of the samples printed using nano-size pigment depends on both the power and time of microwave irradiation exposure. The same phenomenon holds true for the samples printed using untreated commercial pigment. However, in all cases the K/S increases as the particle size decreases. Furthermore the data of table-4 reveals that covering the samples printed with nano-size pigment improves too the K/S. the latter follows the order uncovered sample < paper sheet covered sample < plastic sheet covered sample. From the data of table-4 it is clear that the optimum conditions to achieve the higher K/S on using nano-scale green pigment colour or commercial green pigment colour was at power of 800W for 7 minutes.

Finally, table-5 represent the overall colour fastness properties for cotton samples printed with either untreated or nano-scale green pigment and fixed at the optimum condition, i.e. using microwave irradiation at 800W for 7 minutes. It is clear from the data that decreasing the particle size of pigment green colour from 305.16 nm to 27.33 nm practically has no influence on the overall colour fastness properties.

Table-5
Fastness properties of the cotton fabric printed with either untreated or nano-scale green pigment fixed using microwave irradiation at optimum conditions

Sample	Fastness Properties							
	Washing		Rubbing		Perspiration			
					Acidic		Alkaline	
	St.	Alt.	Wet	Dry	St.	Alt.	St.	Alt.
Commercial Pigment printed	4-5	4	4-5	4-5	4-5	4	4-5	4
Nano-sized Pigment printed fixed by conventional method	4-5	4	4-5	4-5	4-5	4	4-5	4

Conclusion

It can be concluded that the microwave irradiation could be used successfully in pigment printing fixation on cotton fabric surface .It is also clear from the data that the K/S depends on: i. the size of particles, ii. the method of fixation, iii. The power and time of microwave fixation and iv. On the technique applied during microwave fixation, i.e. presence or absence of cover and also the nature of the cover. Furthermore the data reveals that covering of the samples printed with nano-size pigment improves too the K/S. The K/S values of the pigment printing cotton fabric fixed by microwave irradiation follows the order uncovered sample < paper sheet covered sample < plastic sheet covered sample. It is clear that the optimum conditions to achieve the higher K/S on using nano-scale green pigment colour or commercial green pigment colour was at power of 800W for 7 minutes.

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