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Microwave Irradiation as A New Novel Dyeing of Polyamide 6 Fabrics by Reactive Dyes

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POLYAMIDE fabric was dyed with Reactive dyes using microwave irradiation at different temperatures, different duration of time, different dye concentration and different pH. The color strength K/S, tensile strength and elongation of the obtained dyeing fabrics were measured. Scanning electron microscope results showed that dyeing samples by using microwave irradiation is better than that dyeing with conventional method on polyamide fabrics surface. Fastness properties to light, rubbing, washing and perspiration for the dyed samples were measured and the Fastness properties of the fabrics by using microwave irradiation were found to be the same as conventional dyed fabrics with observed short time. The results showed that the microwave technique used for dyeing polyamide 6, fabrics had many advantages from save time, energy and money. In addition, the dyeing of polyamide 6 with reactive dye by using microwave irradiation introduced as new method.

Keywords: Polyamide 6, Reactive dyeing, Microwave irradiation, Novel dyeing .

Introduction

Microwaves are high frequency radio waves which are capable of penetrating many materials and causing heat to be generated in the process. The most important advantages of microwave irradiations are that it is a non-contact, localized, rapid, uniform, energy saving and pollution free heating process. The textile industry has extensively investigated uses of microwave energy for heating, drying, dye fixing, and finishing [1-6]. The difference between microwave heating and conventional heating is the way which heat is generated [7, 8]. Microwave energy is derived om materials through molecular interactions with the electromagnetic waves. Conversely, in conventional processing heat is transfer to materials through conduction and radiation of heat from the surface of the material. Polyamide can be dyed with a variety of dye classes; due to the affinity of disperse dyes to nylon, they can be used to dye polyamides, while the presence of polar groups on the fiber allows the use of acid dyes [9-12]. Acid dyes are likely to be adsorbed through interaction with terminal amine (NH_2) groups in the polyamide chains and also through nonionic interactions with groups along the chains [13-15]. However, the number of these amine groups in polyamide fiber is limited, thus polyamide fibers can be saturated with acid dyes at only moderate depths of shade [8, 16, 17]. Since some of the acid dyes are relatively susceptive to chemical affinity variations therefore it can cause stripes on nylon fibers [1, 18, 19]. As a result, the disperse dyes which are nonionic can be utilized on the polyamide fibers to achieve good leveling properties. relatively few reactive dyes have been introduced specifically for polyamide fibers [20, 21]. It is known that some reactive dyes, which were developed for cellulosic fibers, can be covalently fixed at the boil, to nylon at acidic pH Under these conditions, covalent bonds form between the dye and the amino groups of nylon, without the need for an alkaline fixation step [3, 4, 22-24]. Therefore, the present study was undertaken to investigate the use of microwave irradiation for dyeing the polyamide-6 fabric with reactive dye and the effect of it on the dye ability characteristics, Fastness properties and surface morphological of polyamide 6 [25-27].

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Experimental

Materials

Mill-scoured and bleached plain weave polyamide- 6 fabric (EL-Baraka group, 10th of Ramadan) of 40.88 g /m^2 was used in this study. commercial reactive dye was obtained from dye star company. All other used chemicals namely Sodium chloride and Acetic acid was used to adjust the pH of the dye bath were laboratory reagent grade.

Methods

Polyamide 6 fabric sample was dyed using reactive dye by conventional method at optimum condition 3% owf in dyeing machine at a 1:20 LR. The dye bath was prepared at pH 3 using acetic acid. Dyeing was started at 40°C and then put sodium chloride at three portions then the temperature raised to 80°C then certain amount of acetic acid was added over 45 min, followed by after washing, soaping, rinsing and air drying. Also, I dyed nylon 6 by the same dye in microwave followed by after washing and I compared between two methods in color strength, tensile strength, elongation and surface morphology. Dyeing in microwave 900 w was carried at a 20:1 LR, different concentration of dye (2,3,4,5% owf), different pH (1-4) different temperature (30,50,80,100) over (5,10,15,20 minutes).

Measurements and Testing

Color measurements

The color strength, K/S of the obtained dyeing were measured using an Ultra Scan PRO spectrophotometer (Hunter Lab) with a D65 illuminant and 10° standard observers.

Fastness properties

Fastness properties tested by standard methods (society of Dyers and colourists,1990). wash fastness [ISO AQ:105-C02(1989)] and fastness to perspiration [ISO 105-E04(1989)]. light fastness (Xenon arc) [ISO105-B02], crock fastness (ISO 105-X12(1987).

Scanning electron microscopy

Surface morphology of the dyed and undyed polyamide fabric was examined by scanning electron micrographs (SEM).

Result and Discussion

Dyeing of Nylon 6 using Conventional heating technique

Polyamide 6 contains terminal amide groups ,terminal carboxylic groups and amine groups, dye penetration of the fiber is difficult because swelling is little [9, 21] .Dyed polyamide fabrics with 2% reactive dye at Liquor ratio 1:20 ,dyeing time 60 , temperature 90 °C, at pH= 4 . Table1 shows the color strength is 10.20 the fastness properties to light ranged from fair to fairly good. fastness properties to wash, rubbing (wet or dry) and perspiration (acidic or alkaline) for dyed sample ranged from good to excellent. Tensile strength 51kg/5cm and elongation is 190%. Dyeing by using microwave irradiation accompanied with increase in both tensile strength and elongation at break as shown in Table 1. So that the effect of microwave irradiation cause and enhancement of both tensile strength and elongation at break of the dyed samples.

Dyeing of Nylon 6 using microwave irradiation

Effect of salt amount on the color strength, tensile strength and elongation

Effect of salt amount on the color strength, tensile strength and elongation the dyed polyamide 6 fabrics using reactive dye in fig.1 it was observed that increase in salt amount from zero to 15g/L led to decrease in color strength under microwave irradiation. this may be due to hydrolyses in the reactive dye by adding the salt under microwave irradiation. This mean that there is no necessity for adding salt when using microwave irradiation in dyeing polyamide 6. which mean reducing in chemical. From advantages of these method using microwave irradiation in dyeing is ecofriendly. There are increase in both in the tensile strength and elongation as shown in table 2.

TABLE 1. Color strength and fastness properties of dyed polyamide 6 fabric using conventional method vs. microwave irradiation

Dyeing technique	K/S	Light fastness	Rubbing fastness		Washing fastness			Perspiration Fastness					
			Wet	Dry	Alt	St	Sb	Acid			Alkali		
								Alt	St	Sb	Alt	St	Sb
Conventional method	9.60	2 - 3	3 -4	4	4	4	4	4-5	4-5	4-5	4	4-5	4
Microwave irradiation	10.20	2 - 3	3 -4	4	4	4	4	4-5	4-5	4-5	4	4-5	4

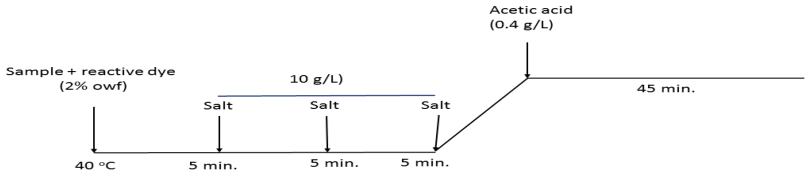


Fig. 1. Dyeing of polyamide with conventional method

TABLE 2. Effect of salt amount on the color strength, tensile strength and elongation at break

Salt amount g/L	k/s	Tensile strength Kg/cm	Elongation at break %
Blank	0.00	50	100
0	9.60	68	198
5	6.77	68	198
10	6.17	68	198
15	5.99	68	198

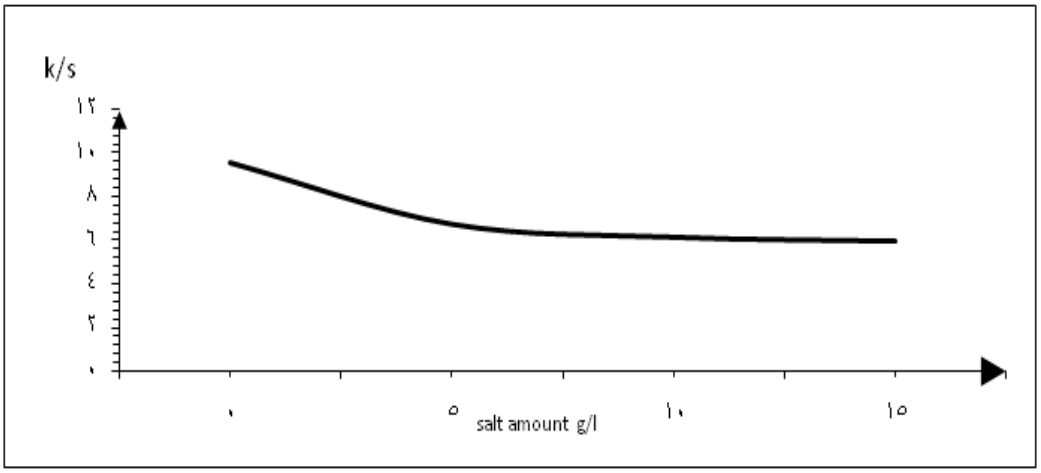


Fig.1. Effect of salt amount on the color strength of dyed polyamide 6 fabric with reactive dye using microwave irradiation

Effect of microwave power on the color strength, tensile strength and elongation

The effect of microwave power on the color strength, tensile strength and elongation of the dyed polyamide 6 fabrics using reactive dye it can be seen from table 3 that the increase in the power from 30 to 100 at pH3

Led to increase in the color strength as shown in fig.2, tensile strength and elongation increase due to the increase in the uptake of the reactive dye.

Effect of microwave heating time on the color strength, tensile strength and elongation

The effect of microwave heating time on the color strength, tensile strength and elongation of the dyed polyamide 6 fabrics using reactive dye it can be seen from fig.3 that the increase in the dyeing time from 5 minutes to 20 minutes led to increase in the color depth of the dyed sample. Exposure to microwave irradiation from 5min to 10min caused no change in the tensile strength and elongation but when increasing heating time to 15 and 20 min cause slightly decrease in tensile strength and elongation as shown in table 4. It is found that the microwave heating saves 40 min. which mean reducing in time and energy used for dyeing.

TABLE 3. Effect of microwave power on the color strength, tensile strength and elongation at break

Microwave power	K/S	Tensile strength Kg/ cm	Elongation at break %
Blank	0.00	50	100
30	2.70	53	190
50	5.25	56	195
80	8.87	65	196
100	9.60	68	198

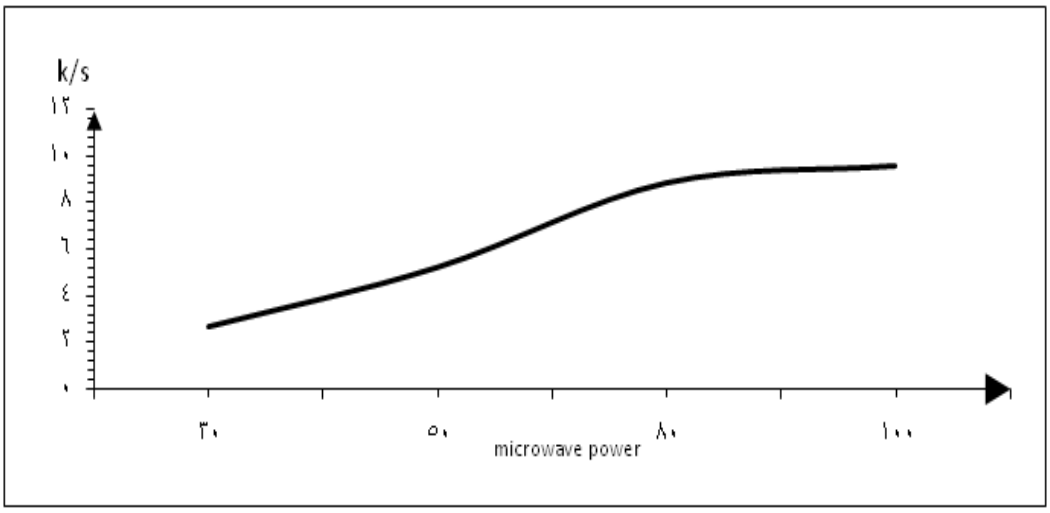


Fig. 2. Effect of microwave power on the color strength of dyed polyamide 6 fabric with reactive dye using microwave irradiation

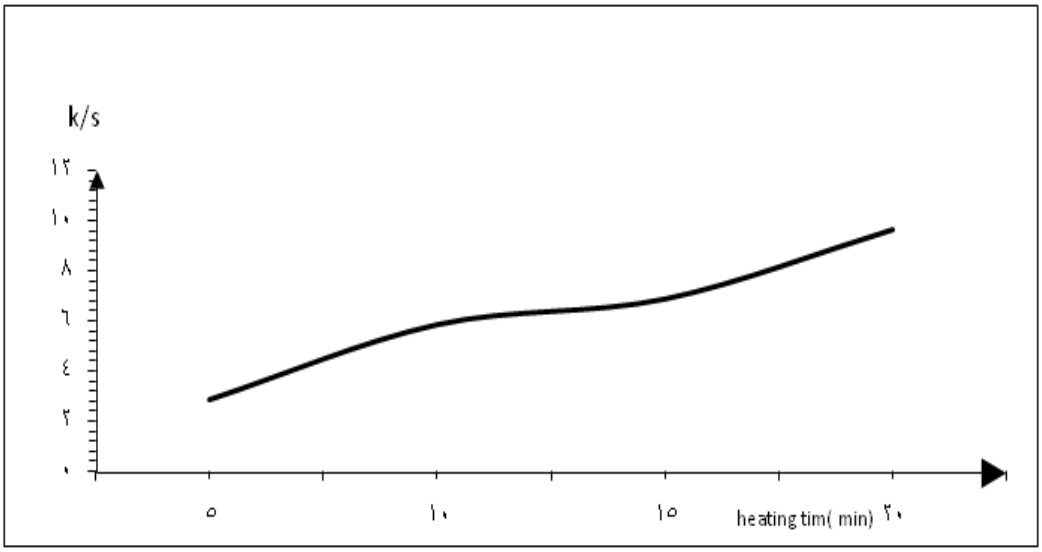


Fig.3. Effect of microwave heating time on the color strength of dyed polyamide 6 fabric with reactive dye using microwave irradiation

TABLE 4. Effect of microwave heating time on the color strength, tensile strength and elongation at break

Irradiation time	K/S	Tensile strength Kg/ cm	Elongation at break %
Blank	0.00	50	100
5	2.90	61	170
10	5.86	62	172
15	6.87	64	178
20	9.60	68	198

Effect of dye concentration on the color strength, tensile strength and elongation

Effect of dye concentration on the color strength, tensile strength and elongation of the dyed polyamide 6 were studied. As shown in fig.4 it is observed that the increase in the dye concentration from 2 ,3, 4 and 5% led to increase in color strength and there are increase in tensile strength and elongation as shown in table 5.

Effect of dye bath pH on the color strength , tensile strength and elongation

Polyamide 6 fiber produce cationic sites in acidic medium this mean that more acidity of the solution led to more cationic sites and the reactive dye can combine with polyamide. dyeing with 3% owf dye concentration using acetic acid medium pH (1, 2, 3, 4) as shown in fig.5. It is observed that the best K/S in pH3 ,in pH2 , pH3 and pH4 the affinity of dye is getting down .these may be because in pH1, pH2 the increase in the acidity of the solution decrease the affinity of the reactive dye to polyamide 6 and increase the acidity of solution increase H^+ ion which associated with NH in all chain not on terminal NH_2 only and that cause decrease in the tensile strength as shown in table 6 .the best result of k/S at pH 3 .The tensile strength and elongation of polyamide 6 fibers decrease by increasing the acidity of the dyeing solution under the microwave irradiation as shown in table 6.

Scanning electron microscopy

The surface morphology of the undyed polyamide 6 fabric , fabric dyed with conventional method and the fabric dyed using microwaves were examined by SEM as shown in Fig 6 .the undyed polyamide 6 fabric (a) exhibits a smooth surface texture and organized chain .The SEM photograph Fig 6(b) (c) shows that the surface morphology of dyed polyamide 6 with reactive dyes using microwave irradiation is more organized and smooth than polyamide 6 fabric dyed using the conventional method .This may be due to that the microwave irradiation didn't make a big move in the chains like conventional heating which made move in the molecular chains and break down amount of hydrogen bonds more than microwave irradiation [28, 29].

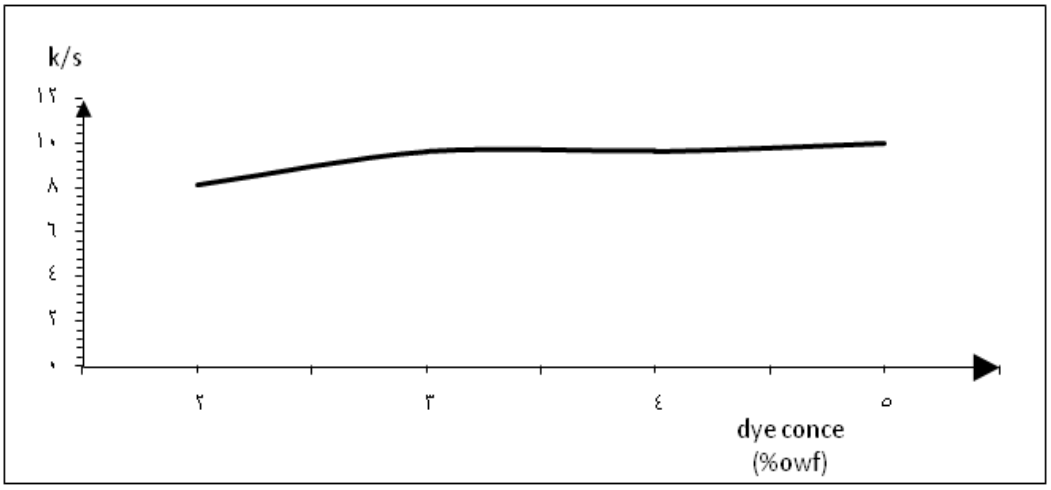


Fig.4. Effect of dye concentration on the color strength of dyed polyamide 6 fabric with reactive dye using microwave irradiation

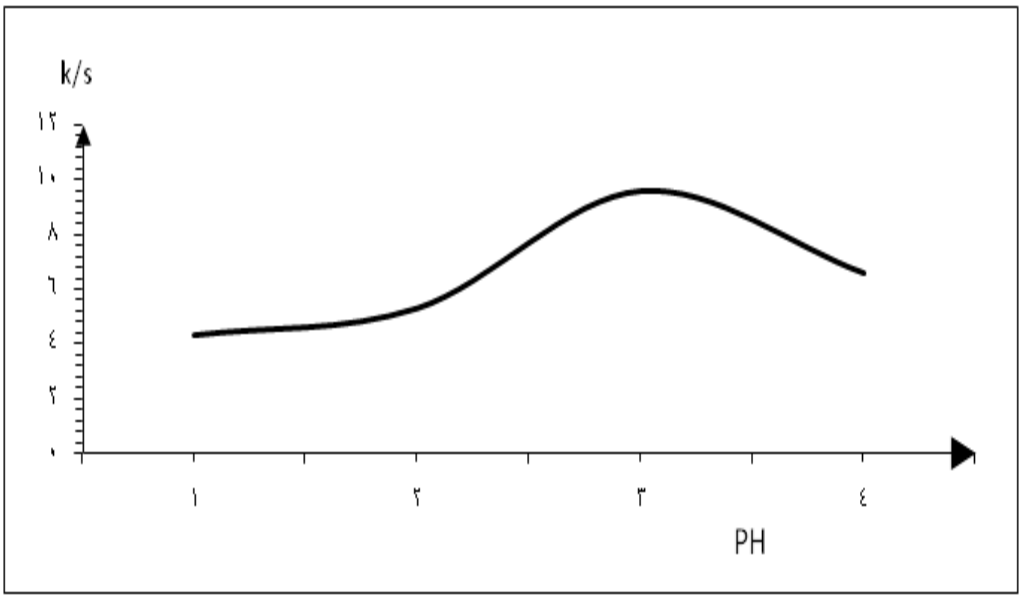


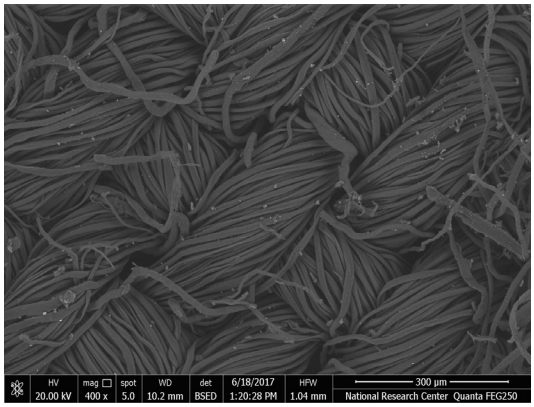
Fig.5. Effect of dye bath PH on the color strength of dyed polyamide 6 fabric with reactive dye using microwave irradiation

TABLE 5. Effect of dye concentration on the color strength, tensile strength and elongation at break

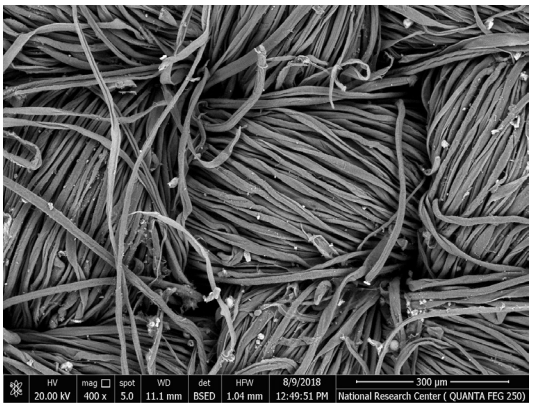
Dye concentration	K/S	Tensile strength Kg/ cm	Elongation at break %
Blank	0.00	50	100
2	8.10	66	195
3	9.60	68	198
4	9.65	69	200
5	10.01	69	200

TABLE 6. Effect of dye bath PH on the color strength tensile strength and elongation at break

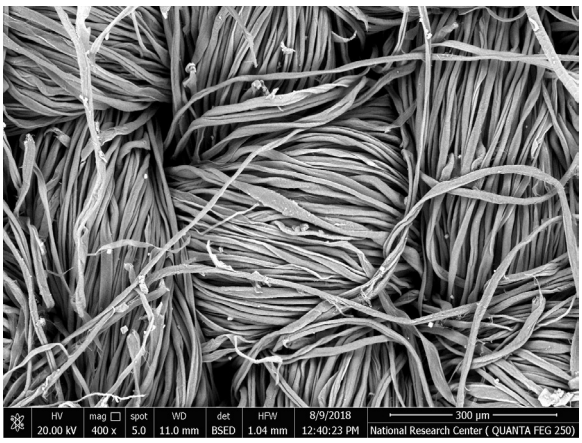
pH	K/S	Tensile strength Kg/ cm	Elongation at break %
Blank	0.00	50	100
1	4.30	50	180
2	5.29	53	190
3	9.60	70	198
4	6.68	50	200



(a) Undyed polyamide 6 fabric



(b) Dyed using microwave irradiation



(c) Dyed with conventional method

Fig.6. SEM micrographs of undyed polyamide 6 fabric (a), dyed polyamide 6 fabric using microwave irradiation(b) and dyed polyamide 6 fabric with conventional method(c)

Conclusion

The rate of dyeing polyamide 6 fabric with microwave irradiation is much faster than conventional heating that save about 40 min. The liquor ratio used 1:20 which save water. dyeing with microwave technique without use of salt and have the same result of dyeing in conventional method with salt so dyeing with microwave technique is eco-friendly method save money, time, energy, increase the tensile strength and maintains the surface morphology and the appearance of polyamide 6 after dyeing.

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