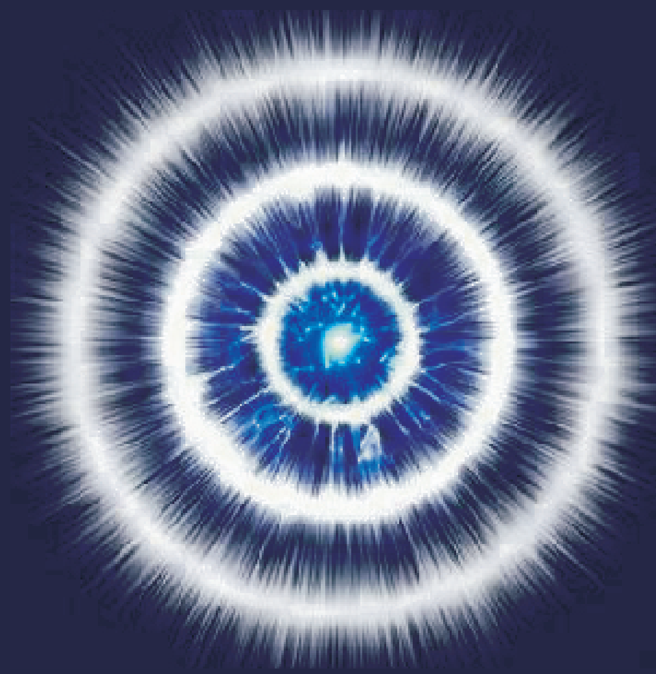

Microwave Irradiation and its Application in Textile Industries

Karima Haggag

National Research Center, Dokki, Cairo, Egypt

A. Ragheb, S. H. Nassar, M. Hashem, H. El Sayed, I. Abd El - Thalouth

Science Publishing Group

Microwave Irradiation and its Application in Textile Industries

National Research Center, Dokki, Cairo, Egypt

Karima Haggag,

A. Ragheb,

S. H. Nassar,

M. Hashem,

H. El Sayed,

I. Abd El-Thalouth

SciencePG
Science Publishing Group

Science Publishing Group
548 Fashion Avenue
New York, NY 10018
http://www.sciencepublishinggroup.com

Published by Science Publishing Group 2014

First Edition

ISBN: 978-1-940366-04-3

To order additional copies of this book, please contact:
Science Publishing Group
service@sciencepublishinggroup.com
http://www.sciencepublishinggroup.com

Printed and bound in India

Introduction

Textile processing consumes huge amount of energy as in dye fixation and heat setting. Heat can be transferred to material by radiation, conduction and convection. These three ways of heat transfer can be used either separately or in combination. Saving time and energy is of immediate interest to textile industry. The introduction of new techniques which will allow less energy to be used is a highly important area of activity to consider. A relatively short section of properly designed microwave heating can increase production speeds.

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 save energy. The microwave field and the dielectric response of a material govern its ability to heat with microwave energy. Knowledge of electromagnetic theory and dielectric response is essential to optimize the processing of materials through microwave heating.

This review addresses major basic and practical aspects of microwave irradiation as means of heat generation. Emphasis is placed on electromagnetic field dielectric response as well as application of microwave heating to textile coloration, processing equipment, and microwave/materials interactions. A future outlook is also reported within the increasing importance of microwave irradiation in textile coloration and other domains of application.

In the last three decades, the microwave oven has become an essential appliance in most kitchens. Faster cooking times and energy savings over conventional cooking methods are the primary benefits. Although the use of microwaves for cooking food is widespread, the application of this technology to the processing of materials is a relatively new development. The use of microwave energy for processing materials has the potential to offer similar advantages in reduced processing times and energy savings. In conventional thermal processing, energy is transferred to the material through convection, conduction, and radiation of heat from the surfaces of the material. In contrast, microwave energy is delivered directly to materials through molecular interaction with the electromagnetic field. In heat transfer, energy is transferred due to thermal gradients, but microwave heating is the transfer of electromagnetic energy to thermal energy and is energy conversion, rather than heat transfer. This difference in the way energy is delivered can result in many potential advantages to using microwaves for processing of materials. Because microwaves can penetrate materials and deposit energy, heat can be generated throughout the volume of the material. The transfer of energy does not rely on diffusion of heat from the surfaces, and it is possible to achieve rapid and uniform heating of thick materials. In traditional heating, the cycle time is often dominated by slow heating rates that are chosen to minimize steep thermal gradients that result in process-induced stresses. For polymers and ceramics, which are materials with low thermal conductivities, this can result in significantly reduced processing times. Thus, there often is a balance between processing time and product quality in conventional processing. As microwaves can transfer energy throughout the volume of the material, the potential exists to reduce processing time and enhance overall quality.

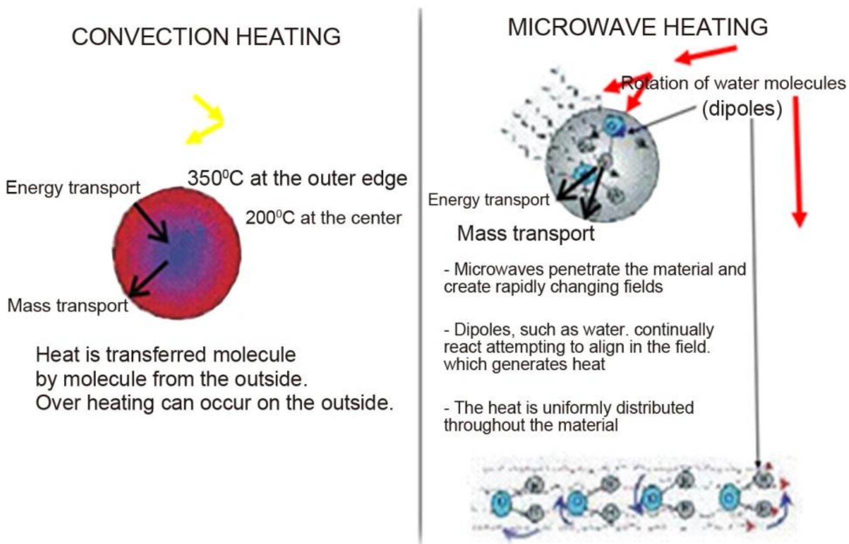

Fig. 1. *Energy transfer comparison.*

In addition to volumetric heating, energy transfer at a molecular level can have some additional advantages. Microwaves can be utilized for selective heating of materials. The molecular structure affects the ability of the microwaves to interact with materials and transfer energy. When materials in contact have different dielectric properties, microwaves will selectively couple with the higher loss material. This phenomenon of selective heating can be used for a number of purposes. In conventional joining of ceramics or polymers, considerable time and energy is wasted in heating up the interface by conduction through the substrates. With microwaves, the joint interface can be heated in-situ by incorporating a higher loss material at the interface [1]. In multiple phase materials, some phases may couple more readily with microwaves. Thus, it may be possible to process materials with new or unique microstructures by selectively heating distinct phases. Microwaves may also be able to initiate chemical reactions not possible in conventional processing through selective heating of reactants. Thus, new materials may be created.

In recent literature, many researchers report non-thermal phenomena that have been broadly termed "microwave effects". Examples of the microwave effect include enhanced reaction rates of thermosetting resins during microwave curing [2] and faster densification rates in ceramics sintering [3]. Although there is considerable debate over the existence of microwave effects, many papers present unexpected results that do not seem to be a consequence of reduced thermal gradients possible within microwave processed materials. Critics of the microwave effect often claim that differences can be attributed to poor temperature measurement and control of experimental conditions that result in systematic error. Although direct heating by microwaves can offer advantages over conventional heat transfer, the different mechanism of energy transfer in microwave heating has also resulted in several new processing challenges. Because energy is transferred by the electromagnetic field, non uniformity within the electromagnetic field will result in non-uniform heating. As materials are processed, they often undergo physical and structural transformations that affect the dielectric properties. Thus, the ability of microwaves to generate heat varies during the process. Sharp transformations in the ability of microwaves to generate heat can cause difficulties with process modeling and control. Understanding the generation, propagation, and interaction of microwaves with materials is critical. Because the processing equipment determines the electromagnetic field, the design of microwave equipment is particularly important. The properties of the electromagnetic field, chemical composition of the material being processed, structural changes that occur during processing, size and shape of the object being heated, and the physics of the microwave/ materials interactions all complicate microwave process [4–12].

Contents

Introduction III

Chapter 1 Microwaves 1

1.1 Electromagnetic Spectrum 3
1.2 Fundamentals of Microwaves 5
1.3 Interaction of Microwaves with Materials[24] 6
1.4 Microwave Equipment 10
1.4.1 Microwave Generators 11
1.4.2 Transmission Lines (Waveguides) 12
1.4.3 Microwave Applicators (Cavities) 12
1.5 Methods for Performing Reactions under Microwave Irradiation 13
1.5.1 Microwave Irradiation vis-a-vis to Conventional Heating 14
1.5.2 The Advantages of Microwave 14
1.5.3 Disadvantages of Microwave 15
1.5.4 Harmful Effects of Microwave 15
1.5.5 Microwave Safety 16
1.5.6 Economical Aspects 16
1.5.7 Maintenance 18

Chapter 2 Microwave Coloration 19

2.1 Flax 20
2.2 Polyester 21
2.2.1 Dyeing of Polyester Fabric 21
2.2.2 Effect of Microwave Pretreatment on the Dyeing Behavior of Polyester Fabric 22
2.2.3 The Research Progress of the Physical Technology on the Polyester Fabric Dyeing 22
2.2.4 The Level Dyeing Technology of Polyester Fabric by Microwave . 22
2.3 Polyamide 23
2.4 Cotton 23

2.4.1 Microwave Dyeing of Cotton 23
2.4.2 Microwave Versus Conventional Dyeing of Cotton Fabrics........ 25
2.4.3 Application of Microwave Technology in Cotton Fabric Dyeing with Reactive Dyes........ 25
2.4.4 Saturated Steam-Assisted Radio Frequency Fixation of Reactive Printed Cotton Fabrics........ 25
2.4.5 The Use of Microwave Energy for the Fixating of Reactive Printed Cotton Fabrics 26
2.5 Wool 26
2.5.1 Dyeing of Wool Fabrics 26
2.5.2 Microwave Heating for Fixation of Pad-Dyeing on Wool 27
2.6 Silk........ 28
2.7 Application of Microwave Technology in Textile Modification 28
2.8 Acrylic Fiber........ 28
2.9 Polypropylene........ 29
2.9.1 Acid Dyeing of Polypropylene 29
2.9.2 Disperse Dyeability of Polypropylene Fibers Via Microwave and Ultrasonic Energy........ 30
2.10 Use of Microwave Fixation in Printing with Natural Color 30
2.11 Synthesis........ 31
2.11.1 Microwave-Assisted Synthesis of Eco-Friendly Binders from Natural Resources........ 31
2.11.2 Microwave-Assisted Synthesis of New Polyfunctionally Substituted Arylazo-Aminopyrazoles 31
2.11.3 One-Pot Synthesis of Disperse Dyes under Microwave Irradiation: Dyebath Reuse in Dyeing of Polyester Fabrics 32
2.11.4 Microwave-Assisted Synthesis of 5-Arylazo-4, 6-Disubstituted-3-Cyano-2-Pyridone Dyes 32
2.12 Colour Removal........ 33
2.12.1 Microwave-Assisted Degradation of Remazol Golden Yellow Dye Wastewater as well as Enhanced Chlorine Dioxide CLO_2 Catalytic Oxidation Process........ 33
2.12.2 Microwave-Assisted Regeneration Process of Reactive Black 5 Treatments by Combined Electro-Coagulation-Granular Activated Carbon Adsorption........ 35
2.12.3 Regeneration of Acid Orange 7-Exhausted Granular Activated

Carbons with Microwave Irradiation 36
2.12.4 Microwave-Assisted Synthesis of Titania Nanocubes, Nanospheres and Nanorods for Photocatalytic Dye Degradation 36
2.12.5 Microwave Enhanced-Sorption of Dyestuffs to Dual-Cation Organobentonites from Water 37

Chapter 3 Microwave Pretreatment and Finishing 39

3.1 Analytical Solutions to the Drying of Textile Materials with Microwave Heating 40
3.2 Degradation of Pentachlorophenol with Zero-Valence Iron Coupled with Microwave Energy 40
3.3 Degumming of Silk Using Microwave-Assisted Treatments 40
3.4 Development of Catalyst Materials being Effective for Microwave Sterilization 41
3.5 Dissolution of Cellulose with NMMO by Microwave Heating 42
3.6 Effect of Microwave Irradiation on the Physical Properties and Morphological Structures of Cotton Cellulose 42
3.7 Functionalization of Cotton Fabric with Vinyltrimethoxysilane 42
3.8 ICP-OES Determination of Metals Present in Textile Materials 43
3.9 Influence of Microwaves on Nonformaldehyde DP Finished Dyed Cotton Fabrics 43
3.10 Microwave Curing for Producing Cotton Fabrics with Easy Care and Antibacterial Properties 44
3.11 Microwave Properties of Conductive Polymers 44
3.12 Microwave Sanitization of Polyester and Cotton 45
3.13 Microwave Synthesized Chitosan-Graft-Poly (Methylmethacrylate): An Efficient Zn^{+2} Ion Binder 45
3.14 Modern Applications of Nanotechnology in Textiles 45
3.15 Optimization of Ultrasonic Extraction of 23 Elements from Cotton 46
3.16 Oxidative Decomposition of Azo Dye C.I. Acid Orange 7 (AO7) under Microwave Electrodeless Lamp Irradiation in the Presence of H_2O_2 46
3.17 Preparation of TiO_2-Pillared Montmorillonite as Photocatalyst Part II Photocatalytic Degradation of a Textile Azo Dye 47
3.18 Properties and Applications of Conductive Textiles 47
3.19 Single-End Sizing of Yarn using a Slot Applicator 48

3.20 Spectroscopic Characterization of Zinc Oxide Nanorods Synthesized by Solid-State Reaction 48
3.21 The Effect of Microwave Drying on Warp Sizing 48
3.22 The Effect of Microwave Radiation on the Cell Genome 49
3.23 Thermal Analysis in the Cellulose, Paper and Textile Industry 49
3.24 Technique to Reduce Water and Energy Consumption in Polyester Dyeing 50
3.25 Microwave Effect 50
3.26 Molecular Magic with Microwaves 50
3.27 Wrinkle-Resistant Advances 51
3.28 Microwave Processing of Nonwovens: An Introduction 51
3.29 Microwave Absorption by Textiles 52
3.30 Microwave Processes for the Combined Desizing, Scouring, and Bleaching of Grey Cotton Fabrics 52
3.31 Usage of Microwave Energy in Textile Production Sector 52
3.32 Microwave-Promoted Rapid Curing Reaction of Phenolic Fibers 53
3.33 Polypyrrole Coated Textiles 53
3.34 Curing of Polymers and Composites by Microwave Energy 54
3.35 Antimicrobial Properties of Cotton Medical Textiles 55
3.36 Eradication of Insects from Wool Textile 55
3.37 Microwave Radiations for Heat-Setting of Polyester Fibers 56
3.38 Microwave Irradiation Technique to Enhance Protein Fiber Properties. 57

References 58