Chapter 3

Microwave Pretreatment and Finishing

3.1 Analytical Solutions to the Drying of Textile Materials with Microwave Heating

An analytical model of internal transport characteristics of a textile material during drying using microwave heating was developed. The model is simplified for each period of drying (initial adjustment, liquid movement, constant rate, and falling rate) using existing experimental data and certain known characteristics of microwave heating. Solutions to these reduced modeling equations are obtained for the initial adjustment period and the constant rate period, which are the drying periods comprising the majority of the drying processes of most textile materials of interest. The analytical results are compared to the available experimental data, and a correlation is obtained in the prediction of drying rates, internal temperature profiles, and internal pressure distribution [127, 128].

3.2 Degradation of Pentachlorophenol with Zero-Valence Iron Coupled with Microwave Energy

The objective of this research was to study the degradation of pentachlorophenol with zero-valence iron (Fe^0) coupled with the use of microwave energy. The sample containing 1000 mg/L PCP solution was dosed with 0.5 g Fe^0 and then subjected to 700 W microwave energy for 10 s 85% pentachlorophenol was noted to be removed. If the microwave treatment time was increased to 30 s, the pentachlorophenol removal efficiency exceeded 99% with end products including H_2O, CO_2, HCl, etc. Using Fe^0 as a medium, the microwave treatment is made an efficient method for degrading pentachlorophenol. The time needed to achieve a satisfactory treatment is also reduced leading to significant savings of energy consumption to make this method cost-effective. Since this technology applies Fe^0, which is amenable to natural environment, to speed up the decomposition of an industrial solvent, it is not only cost-effective but also environmentally friendly for the industry to pursuit sustainable development [129].

3.3 Degumming of Silk Using Microwave-Assisted Treatments

A comparative study was carried out between degumming of raw silk yarns by the conventional methods of degumming and those assisted by microwave radiation. Different reagents are used for this study; *viz.*, mineral acid, alkaline substances, domestic soap, and commercial protease. The proteolytic enzyme savinase 16L type EX was found to be effective in degumming of silk either by conventional method or in combination with microwave. The microwave irradiation reduces, to a great extent, the time needed to reach the same degree of degumming by the conventional method. The effect of the aforementioned treatments on some of the inherent properties of silk was monitored. Scanning electron microscopic investigation was carried out to clarify the effect of these treatments on the morphological structure of silk yarns [130].

3.4 Development of Catalyst Materials being Effective for Microwave Sterilization

Recently, airborne virus infections have emerged as some of the most challenging medical problems. To prevent the threat of infection, the processes of sterilization have been studied widely. Microwave sterilization has many advantages in comparison with conventional methods. It is able to raise the temperature of a material in a short time and selectively heat the material. This results in the reduction of usage and the rapid completion of sterilization. We developed a novel microwave sterilization system that can raise the temperature in quite a short time using a lower microwave power (100 W). Filters made with Kao wool (Al_2O_3) were coated with TiO_2 (anatase) by sol–gel method and used to trap microorganisms. In addition, these filters were coated with Pt or Ag by impregnated method. We also prepared a Tyranno-fiber textile filter and a honeycomb SiC filter. Two microorganisms, *Bacillus subtilis* ATCC 9372 and *Bacillus stearothermophilus* ATCC 7953, were used in this experiment, where either microorganism was loaded onto a filter. After irradiation, filters loaded with *B. subtilis* and *B. stearothermophilus* were incubated for 48 h in a TSB medium (BactoeTryptic Soy Broth, Becton-Dickinson, MD) at 37 and 56 ℃, respectively. *B. subtilis* and *B. stearothermophilus* loaded on to Ag-impregnated filters were sterilized in 30 and 15 s, respectively. The Tyranno-fiber textile filter and the honeycomb SiC filter also showed effective microwave sterilization. These results showed that this system could sterilize *B. subtilis* and *B. stearothermophilus* in quite a short time and that microwave-absorbable materials are effective as microwave sterilization filters [131, 132].

3.5 Dissolution of Cellulose with NMMO by Microwave Heating

Environmentally-friendly microwave heating process was applied to the dissolution of cellulose in N-methylmorpholine- N-oxide (NMMO) with 105–490 W and 2450 MHz microwave energy until the dissolution completed. Microwave heating caused a decrease in the dissolution time and energy consumption. Cellulose/NMMO/water solutions with different cellulose concentrations were converted to the membrane to measure the crystallinity and degree of polymerization. It was shown that microwave heating with the power of 210 W is an alternative heating system for dissolution of cellulose in NMMO. The membranes obtained with two different heating methods showed the same crystallinity and degree of polymerization. As a result, microwave heating has an advantage in shortening reaction times, compared to conventional heating [133].

3.6 Effect of Microwave Irradiation on the Physical Properties and Morphological Structures of Cotton Cellulose

Microwave heating has been proved to be more rapid, uniform and efficient, and easily penetrate to particle inside. To investigate the effect of microwave irradiation on the physical property and morphological structure of cotton cellulose, cellulose fabric was treated with microwave irradiation at different conditions. The physical properties of the treated cellulose fabric were investigated. The morphological structures and thermal stabilities of the untreated and treated cellulose were investigated with differential scanning calorimetry (DSC) and X-ray diffraction. The results show that the physical properties of the treated cellulose fabrics were improved and the recoverability had not significant changed. The thermal stability of the treated cellulose was changed. The crystallinity and preferred orientation of the treated cotton cellulose increased [134].

3.7 Functionalization of Cotton Fabric with Vinyltrimethoxysilane

The surface of cotton fabric was successfully functionalized with vinyltrimethoxysilane in order to impart water repellency and wrinkle recovery and to introduce surface vinyl groups (–CH=CH_2) to the fabric, which could then be initiated for copolymerization reactions with various monomers. The introduction of active groups onto the fabric surface was evidenced from the universal attenuated total reflectance Fourier transform infrared (UATR-FTIR) spectrum of the treated fabric. The spectrum shows two peaks located at 1410 and 1600 cm^{-1} (C=C stretch). An additional peak located at 756 cm^{-1} attributed to Si–O–Si symmetric stretch was also observed. Excellent water contact angle and wrinkle recovery angle values were obtained [135].

3.8 ICP-OES Determination of Metals Present in Textile Materials

The content of elements present in textile materials was assessed since it is known that textiles containing metals may represent a health hazard to consumers. Determination of metal content can be also useful to the textile industry since some metals present in textiles may contribute to problems during textile production. Extraction of metals from different textile materials was performed in an artificial acidic sweat solution according to the Öko Tex standard for materials coming into direct contact with the skin. After extraction from textile products made of cotton, flax, wool, silk, viscose, and polyester materials, all elements were determined by means of inductively coupled plasmaoptical emission spectrometry (ICP-OES). Results in the sweat extracts (minimum–maximum in μg/mL) were: Al 0.11–1.58, Cd 0.02–0.05, Cr 0.01–0.32, Cu 0.05–1.95, Mn 0.01–2.17, and Ni 0.05–0.10. Concentrations of other elements were below detection limits. The total amount of metals present was determined after microwave-assisted acidic digestion of textile materials with 7 M nitric acid. According to the results, the majority of the detected elements were below the concentration limits given by the Öko Tex, and for this reason the textile materials investigated do not represent a health hazard to consumers [136].

3.9 Influence of Microwaves on Nonformaldehyde DP Finished Dyed Cotton Fabrics

An alternative approach to formaldehyde-releasing conventional N-methylol compounds is based on the use of non-formaldehyde durable press polycarboxlic acid (PCA) finishing agents. Another alternative approach, investigated here, is using microwave energy to impart durable crease resistance to dyed cotton fabric. The bifunctional dyes C.I. Reactive Red 195, C.I.

Reactive Yellow 145, and C.I. Reactive Blue 221 were used in the study, and the isocratic HPLC method was employed to quantify the PCA reacted with the cellulosic material for two different curing procedures. Shade change evaluation revealed that microwave curing has a greater influence on the d*E* values than conventional curing. In all other aspects, primarily wrinkle recovery and deformation resistance, microwave curing offers much better results [137].

3.10 Microwave Curing for Producing Cotton Fabrics with Easy Care and Antibacterial Properties

A new microwave curing system was used to affect crosslinking of cotton fabric with non-formaldehyde finishes, namely, glyoxal, glutaraldehyde and 1,2,3,4 butanetetracarboxylic acid (BTCA). Water soluble chitosan was incorporated in the finishing bath in order to impart antibacterial activity to the fabric in addition to the ease of care characteristics. Glyoxal proved to be the best finish and, hence, it was studied along with the chitosan under a variety of conditions including chitosan concentrations, power and time of microwave curing. Besides the crease recovery and strength properties of the finished fabrics, the latter were also monitored for N%, antibacterial activity and characterized using scanning electron microscope (SEM) and FTIR spectra when compared. With conventional curing system, the microwave curing system was found advantageous in production of cotton fabrics with easy care antibacterial properties without high losses in strength properties [138].

3.11 Microwave Properties of Conductive Polymers

Conductive polymers are a new class of microwave absorbing materials which show a number of advantages over traditional granular materials. Polypyrrole, Polyaniline, and Polyalkylthiophenes can be applied in specific fields where the conductive inclusion is directly integrated in the matrix or on the substrate (honeycomb, textile) during synthesis, instead of being mechanically dispersed as in the case of extrinsic conductive materials. This method can be used to produce materials with specific properties, whose performances are equivalent to those of magnetic materials but with lower surface mass. The properties of these materials can be easily modified by chemical means and by tailoring the structural properties. We show that dielectric properties strongly depend on the microstructure of conductive polymer. For that purpose, the influence of the molecular weight, density of defects, size of the alkyl chain on the substituted monomer and nature of counter anion have been explored. Theoretical models using physicochemical properties of polymer have been developed in order to calculate the frequency dependence of (E', E'') for a chain of Polyaniline [139].

3.12 Microwave Sanitization of Polyester and Cotton

The potential of using 2450-MHz microwave radiation to dry and sterilize polyester and cotton fabrics was evaluated against *Staphylococcus aureus*, *Escherichia coli* and *Bacillus cereus*. *B. cereus* were the most tolerant microoganisms to microwave radiation, and *E. coli* were the most senstive. All *S. aureus* and *E. coli* organisms were killed within seven minutes of exposure to microwave drying, which was substantially more effective than convection oven drying. Microwave exposure had no effect on the elongation of polyester and cotton, but cottons strength decreased 10% after five minutes of microwave exposure [140].

3.13 Microwave Synthesized Chitosan-Graft-Poly (Methylmethacrylate): An Efficient Zn^{+2} Ion Binder

Microwave-promoted grafting of methyl methacrylate onto the chitosan has been optimized. Chitosan-graft-poly(methylmethacrylate) (Ch-g-PMMA) could be synthesized with 160% grafting using 80% MW power in 2 min at (MMA) 0.17 M, (Chitosan) 0.1 g/25 ml. The representative graft copolymer was characterized by Fourier transform-infrared, thermo gravimetric analysis and X-ray diffraction measurement, taking chitosan as reference. The effect of reaction variables as monomer/chitosan concentration, microwave power and exposure time on the graft co-polymerization was studied. A probable mechanism for grafting under microwave heating has been proposed. Viscosity of the grafted chitosan solutions and water/saline retention for the grafted chitosans were determined and compared with that of the chitosan. The microwave synthesized graft copolymer was found to have efficient adsorption ability for Zn_2C ions in aqueous solution. Effect of pH and Zn_2C concentration on adsorption was also studied [141].

3.14 Modern Applications of Nanotechnology in Textiles

Nanotechnology (NT) deals with materials 1 to 100 nm in length. At the National Nanotechnology Initiative (NNI), NT is defined as the understanding, manipulation, and control of matter at the above-stated length, such that the physical, chemical, and biological properties of the materials (individual atoms, molecules, and bulk matter) can be engineered, synthesized, and altered to develop the next generation of improved materials, devices, structures, and systems. NT at the molecular level can be used to develop desired textile characteristics, such as high tensile strength, unique surface structure, soft hand, durability, water repellency, fire retardancy, antimicrobial properties, and the like. Indeed, advances in NT have created enormous opportunities and challenges for the textile industry, including the cotton industry. The focus of this paper is to summarize recent applications of NT as they relate to textile fibers, yarns, and fabrics [142].

3.15 Optimization of Ultrasonic Extraction of 23 Elements from Cotton

Optimization of ultrasonic extraction of 23 elements from cotton was performed with different solvent volume ratios. For this purpose nitric acid, hydrochloric acid and water were mixed and applied in a mixture for the extraction of elements adsorbed on cotton material. The elements chosen for the extraction procedure (Al, As, Be, Bi, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Mg, Mn, Mo, Na, Ni, Pb, Sb, Si, Sn, Tl and Zn) were those that are important in textile processing. Some of them cause problems during fiber processing, dyeing or bleaching. The removal of elements from the processed fabric can be successfully done with ultrasonic extraction in the ultrasonic bath. Extraction procedure was optimized by software package Design Expert 6 (DX6) and the optimum of ultrasonic extraction was achieved with the mixture of 1 M HCl – 1 M HNO_3 – H_2O = 3.32/2.83/93.85 (v/v). Ultrasonic extraction was a fast and efficient extraction procedure easily applied on cotton textile material [143].

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

A novel microwave electrodeless lamp (MWL) rather than traditional electrode lamp (TEL) was used in a H_2O_2/MWL system as light source. This technique provided a new way to study the simultaneous effect of both UV–vis light and microwave irradiations. This study showed that H_2O_2/MWL process was 32% more effective than H_2O_2/TEL process in degrading azo dye Acid

Orange 7 (AO7). Further study found that the degradation of AO7 by the H_2O_2/MWL process was initiated by the attack of HO• radicals generated by the photolysis of H_2O_2. However, the direct photolysis of AO7 by MWL irradiation was not negligible. Effect of operation parameters, such as the initial concentrations of AO7 and H_2O_2 and pH, were investigated. A kinetic model of degradation of AO7 by H_2O_2/MWL process was found, in which not only the HO• oxidation but also direct photolysis were considered. The kinetic model was consistent with the experiment results. The degradation of AO7 by H_2O_2/MWL corresponded to a pseudo-first order reaction. The apparent reaction constant (k_{ap}) was a function of initial concentrations of H_2O_2 and AO7 and pH of the solution [144].

3.17 Preparation of TiO_2-Pillared Montmorillonite as Photocatalyst Part II Photocatalytic Degradation of a Textile Azo Dye

Use of a photocatalyst based on TiO_2-pillared montmorillonite prepared by microwave has been studied with respect to photodegradation of Solophenyl red 3BL, an azo dye produced from textile plants. Experiments were carried out with an aqueous dye concentration of 100 mg L^{-1}, at different pH and photocatalyst contents (400–5000 mg L^{-1}). The lower the pH, the higher the dye photodegradation rate constants: 0.0966 and 0.0006 min^{-1}, obtained at pH=2.5 and pH=11 respectively. This is in agreement with a higher adsorption of the dye on the catalyst at acidic rather than at basic pH. At pH=5.8 and 2.5 g L^{-1} of TiO_2- pillared montmorillonite, initial degradation rate constant of the dye (0.0096 min^{-1}) was 1.4-fold lower with the synthesized photocatalyst than with commercial Degussa P25 (1 g L^{-1}) for about the same molar amount of TiO_2 in dispersion. According to XRD patterns, rate constants were related to the rate of TiO_2 crystallization within the catalyst. A photosensitized oxidation accounted for about 25±5%, and a direct excitation of the photocatalyst accounted for 80±10% of the global photo degradation process, leading mainly to oxidation of the dye by HO°[145].

3.18 Properties and Applications of Conductive Textiles

A novel technique for the chemical analysis of polypyrrole on textiles, particularly the degree of doping, is described. In addition, we discuss characterization of the electrical properties, including microwave properties, and the environmental stability of these composite structures as they relate to different types of doping agents. Applications of these useful composite structures will also be described [146].

3.19 Single-End Sizing of Yarn using a Slot Applicator

A single-end sizing process was developed to eliminate the problems associated with the traditional sizing method. By keeping the yarns separated in slots in the single-end sizing apparatus and drying them individually, less damage to the yarns occurred. In this paper, the process and device developed for single-end sizing are described and the properties of single-end sized yarn are compared with unsized yarn and commercially sized yarn [147].

3.20 Spectroscopic Characterization of Zinc Oxide Nanorods Synthesized by Solid-State Reaction

Well-crystallized zinc oxide nanorods have been fabricated by single step solid-state reaction using zinc acetate and sodium hydroxide, at room temperature. The sodium lauryl sulfate (SLS) stabilized zinc oxide nanorods were characterized by using X-ray diffraction, Fourier transform infrared spectroscopy, transmission electron microscopy and photoluminescence spectroscopy. The X-ray diffraction revealed the wurtzite structure of zinc oxide. The size estimation by XRD and TEM confirmed that the ZnO nanorods are made of single crystals. The growth of zinc oxide crystals into rod shape was found to be closely related to its hexagonal nature. The mass ratio of SLS:ZnO in the nanorods was found to be 1:10 based on the thermogravimetric analysis. Blue shift of photoluminescence emission was noticed in the ZnO nanorods when compared to that of ZnO bulk. FT-IR analysis confirmed the binding of SLS with ZnO nanorods. Apart from ease of preparation, this method has the advantage of eco-friendliness since the solvent and other harmful chemicals were eliminated in the synthesis protocol [148].

3.21 The Effect of Microwave Drying on Warp Sizing

A paper describes microwave usage in drying the size pick-up was presented. An analysis of three different drying processes in relation to physical-mechanical properties of sized yarn has been carried out. Under the same sizing conditions, but different drying methods, the following parameters were determined: breaking force, elongation at break, abrasion resistance and yarn hairiness. The application of microwave drying method for warp sizing showed to be equally good, or even better in some cases, compared to the conduct and convection drying methods [149].

3.22 The Effect of Microwave Radiation on the Cell Genome

Cultured V79 Chinese hamster cells were exposed to continuous radiation, frequency 7.7 GHz, power density 30 mW/cm^2 for 15, 30, and 60 min. The parameters investigated were the incorporation of [^{3}H] thymidine and the frequency of chromosome aberrations. Data obtained by 2 methods (the incorporation of [^{3}H] thymidine into DNA and autoradiography) showed that the inhibition of [^{3}H] thymidine incorporation took place by complete prevention of DNA from entering into the S phase. The normal rate of incorporation of [^{3}H] thymidine was recovered within 1 generation cycle of V79 cells. Mutagenic tests performed concurrently showed that even DNA macromolecules were involved in the process. In comparison with the control samples there was a higher frequency of specific chromosome lesions in cells that had been irradiated. Results discussed in this study suggest that microwave radiation causes changes in the synthesis as well as in the structure of DNA molecules [150].

3.23 Thermal Analysis in the Cellulose, Paper and Textile Industry

The present paper reports the main results presented at the 8th ICTA Conference on the thermal analysis of the cellulose, paper and textile industry. An attempt was made to classify the presentations. Thermo-destruction studies on cellulose allow the thermo-oxidative effect of various ions to be classified. Experimental results give evidence that boron-containing cellulose fibres present a different combustibility mechanism than phosphorus-containing antipyrenes. The relaxation and phase transition of cellulose are evidenced by DTA and calorimetry and a classification of plasticizers is made. An original clamping technique for TMA is presented to study very thin paper samples. Interactions between dyes and fibers are analyzed and a kinetic model, expressing sorbed dye rate, is proposed. The use of microwaves in the textile industry is described for polymerization, thermal treatment and dyeing. It appears that the use of microwaves gives a very uniform dye migration with a

50 times higher kinetic rate for acrylic compounds and 200 times higher for viscose [151].

3.24 Technique to Reduce Water and Energy Consumption in Polyester Dyeing

Polyester fibers require high amounts of water and energy for dyeing. An overview of techniques developed to reduce water and energy consumption addresses dyeing with microwave heating, rapid dyeing systems, solvent dyeing systems, foam dyeing, pad-store-wash methods, microencapsulate dyeing, electrostatic powder spraying, microemulsion dyeing, ultrasonic dyeing, alkaline dyeing systems, and supercritical fluid dyeing. Although many techniques have lower water and energy requirements, further research is necessary to render them commercially successful [152].

3.25 Microwave Effect

Researchers studied the effect of microwaves on the thermal and molecular stabilization of thermoplastic fibers. Microwaves without a Lossy (material that absorbs microwaves) acted on polyethylene terephthalate partially oriented yarn (PET-POY), resulting in higher orientation angles and a marginal improvement in the crystalline index. The presence of Lossy resulted in a substantial increase in the X-ray order factor and a decrease in the orientation angle. Even in the presence of Lossy, the birefringence level never reached the desired level of orientation expected from drawn and heat set yarns. Higher exposure times did not significantly affect fiber morphology. The cold crystallization phenomena was conspicuously absent in samples subjected to microwave radiation in the presence of Lossy [153].

3.26 Molecular Magic with Microwaves

Although microwave heating is used in such processes as tempering meat, cooking bacon, drying potato chips, vulcanizing rubber, and drying pharmaceutical compounds, the technology is used much less frequently than radio frequency and conventional gas and electric heating. At the First World Congress on Microwave Processing, held in January 1997, 330 scientists, engineers, and executives exchanged information on potential new uses for microwave technology in such areas as organic synthesis, materials processing, and waste remediation. Ajay Bose of the Stevens Institute of Technology said that microwave-assisted chemistry could revolutionize the pharmaceutical and biotechnology industries by reducing the use of solvents and chromatographic materials, and by increasing the precision of heating processes. Rajender S. Varma of Sam Houston State University in Texas showed how microwaves make organic synthesis simpler and more environmentally friendly. IBM uses microwave technology to impregnate glass fabric for circuit boards preparation [154].

3.27 Wrinkle-Resistant Advances

Wrinkle-resistant, 100 percent cotton fabrics are expanding into new markets. Sales for these fabrics, which were originally used in men's slacks and shirts, have grown at a phenomenal pace. Sales of 100 percent wrinkle-resistant slacks, for example, grew by 15 million pairs in 1995. Major players in the men's slacks category now include Haggar, Levi Strauss, Farah, Lee Casuals, Thomson, and Duck Head Apparel. Product development soon extended the wrinkle-resistant label to shirtings and, more recently, to women's wear, sheets, and wool suits. Wrinkle-resistant technology involves a precure and a postcure process, but each manufacturer uses a proprietary process, and changes and modifications to the basic technology are frequent. Presset of Marietta, Georgia, is developing a microwave curing process that is promising because it causes less damage than conventional methods [155].

3.28 Microwave Processing of Nonwovens: An Introduction

An overview of the use of microwaves for heating and drying focuses on the interactions of microwaves with materials, applicator designs, and potential applications of microwaves in the nonwoven fabric industry. Currently, the industry does not use microwaves for any type of processing. In their interactions with materials, microwaves are novel in that heat is generated within the material itself and in that different materials heat to different extents (i.e. microwaves are selective). These properties necessitate significant modifications in both processing and equipment. The design of the applicator, which is the component in which the powers of the microwaves are applied to the material, is critical to microwave power conversion efficiency. Microwaves have potential applications in nonwoven fabric manufacture, particularly where the advantages of faster processing, reduced power consumption, selective heating, reduced space or cooling requirements, and more uniform heating can be exploited [156].

3.29 Microwave Absorption by Textiles

Courtaulds is researching microwave absorption by textiles with the aim of reducing their reflectance of radiation to between 94 and 600 GHz. These textiles could be used in the manufacture of protective apparel or covers for vehicles and weapons that would be difficult to detect. Polyolefins, viscose, or acrylic containing carbon, iron, and/or ferrite particles are woven into fabrics with a rough surface and with a thickness of greater than 0.5 millimeters. The wavelength of the surface roughness must be between 1 and 30 millimeters and must be comparable to the wavelength of microwave radiation likely to be encountered. An organic liquid finish is capable of contributing to the reduction of microwave reflection from the surface [157].

3.30 Microwave Processes for the Combined Desizing, Scouring, and Bleaching of Grey Cotton Fabrics

The article focuses on the study to shorten the time of the combined pretreatment process on cotton fabrics by using microwave energy. The use of microwave energy led to rapid drying and resulted in a loss of strength and whiteness. Another problem observed in the microwave processes was the degree of desizing. A prepared peroxidisulfate salt and Leonil EB was used to increase the degree of desizing. A pre-steaming process was applied before the microwave period [158].

3.31 Usage of Microwave Energy in Textile Production Sector

Application areas of microwave energy, which has been used for many years in science and technology, are increasing. The studies about the usage in textile industry are recent and open to improvements. It is known that usage of microwave energy provides advantages in whole processes in textile industry like pre-treating, dyeing, bare finishing and drying. In this study microwave energy in Turkish textile finishing applications are researched and its advantages, process efficiencies and contributions to energy gain are given. Microwave energy has not been efficiently used in Turkish textile sector.

Promotion of microwave technology is expected to contribute to Turkey's economy especially in terms of energy and time conservation.

The use of MW energy is more efficient than conventional method. Extending the use of microwave technology in textile sector will benefit the industry in terms of time and energy and hence the production cost. Studies addressing the use of MW in textile sector show an increasing trend. Various institutions, organizations and associations can help reduce energy consumption and the corresponding costs in Turkish economy and hence increase its competitiveness, through increasing the awareness of their members and investors concerning the advantages of microwave technology [159].

3.32 Microwave-Promoted Rapid Curing Reaction of Phenolic Fibers

The reaction of the as-spun fiber derived from melt spinning of a novolac resin with a solution of formaldehyde and hydrochloric acid was carried out under microwave irradiation by controlling the heating rate from room temperature up to the boiling point (103 ℃). The homogeneous highly crosslinked phenolic fiber with the maximum tensile strength and the maximum dynamic modulus of 139 MPa and 2970 MPa, respectively, was obtained at 1.2 ℃ min^{-1} in 86 min. The fiber has a similar tensile strength, dynamic modulus and crosslinking degree with the fiber derived from the conventional reflux method at heating rate of 0.20 ℃ min^{-1} in 8 h. The results suggest that the microwave irradiation promotes not only the diffusion of CH_2OH from the skin into the inner layer of the fiber but also the reaction of CH_2OH with the phenolic ring in a suitable range. During pyrolysis the increase of crosslinking degree in the phenolic fibers diminishes the formation of low molecular weight compounds generated from the unstable terminal groups and inner units, while it promotes the formation of graphite layers [160].

3.33 Polypyrrole Coated Textiles

Using an infrared camera, thermal mapping of microwave irradiated conducting polymer textiles showed a detectable temperature increase in all PPy-pTSA coated nylon–lycra textiles, irrespective of polymerization time, dopant concentration, and choice of dopant or irradiation frequency. We observed a wide-ranging modulation of microwave reflection, transmission and absorption with dopant concentration and polymerization time. As expected, uncoated samples were transparent to microwave radiation and showed no increase in temperature upon irradiation. Lightly doped samples had high transmission whereas highly doped samples were highly reflective. Polymerization time affected the variation of R, T, A in the same manner. The increase in temperature upon microwave irradiation demonstrated that the conducting polymers absorbed the microwave radiation and it was possible to produce temperature maps of this absorption. For polymerization times up to around 15 min microwave transmission was high. The absorption of incident radiation, and subsequent temperature increase in the sample was pronounced at polymerization times between 30 and 120 min.

For longer polymerization times of 180 and 300 min the absorption levels were still relatively high, though the increased levels of reflection allowed less temperature increase in the sample. On the other hand, even very small amounts of dopant increased the maximum temperature achieved on irradiation significantly. This may be attributed to increased levels of interaction of microwaves with the charged dopant anions. The maximum temperature difference of around 4℃ in the conducting fabrics relative to ambient temperature was observed in samples having 48% absorption and 26.5±4% reflection. Samples polymerized for 60 or 120 min with a dopant concentration of 0.018 mol/l or polymerized for 180 min with a dopant concentration of 0.009 mol/l yielded optimum absorption [161].

3.34 Curing of Polymers and Composites by Microwave Energy

Studies on application of microwaves to cure polymers and composites and the hitherto were presented. It is generally agreed upon that microwaves as an alternative energy source offer various advantages over thermal cure. These include a more rapid curing time, higher efficiency and production rate, and more uniform heating. However, the reported studies are largely qualitative or semi-quantitative and focused primarily on changes in temperature and absorbed power in the sample during cure. No fundamental study of the interaction between the electromagnetic waves and the organic material during cure on the molecular level has been reported. It is clear from this review that we need an understanding of how the polymer network forms in the microwave field, how it differs from the thermally cured network and what are its mechanical/physical properties. At the Polytechnic University we have embarked upon a comprehensive program aimed at modeling the formation of thermoset networks in the electromagnetic field from first principles. Our study will focus upon experimental and theoretical aspects of chemorheology of cure by microwaves and its subsequent effect on physical/mechanical properties [162].

3.35 Antimicrobial Properties of Cotton Medical Textiles

The antibacterial and antifungal activity of antimicrobial finishes based on citric acid on cotton medical textiles was examined. The ability to effectively reduce the number of gram-negative, gram-positive bacteria and yeast was evaluated, specifically comparing the antibacterial activity after two different drying/curing methods. Citric acid (CA) and diethyl–tetradecyl–[3–(trimethoxysilyl)-propyl] ammonium chloride (Quat) were used for hygiene and disinfection purposes of medical textiles in this study. It was applied by pad-dry process and its fixation to cellulose hydroxyls was enhanced either by high curing temperatures or microwaves (MW). Determination of antibacterial activity of finished products was performed according to ISO 20743:2007 standard before the washing and after the 10 washing cycles. Antibacterial activity was tested on gram-negative bacteria *Escherichia coli*, gram-positive *Staphylococcus aureus* and yeast *Candida albicans*. Obtained results are confirming the possibility of eco-friendly CA application, for the purpose of antimicrobial finishing of cotton medical textiles. Prevention of nosocomial infections with the citric acid is possible using both curing methods (convection and microwave) and furthermore, the treatment is durable up to 10 washing cycles. Citric acid, as one of the suitable active substances, is crosslinked to the cellulose hydroxyls by the formation of ester linkages. Its antimicrobial effectiveness against the chosen microorganisms proved to be the best against *S. aureus*. Applied finish bath has additional crease proof effectiveness, providing sufficient both antimicrobial and crease proof effectiveness, so as the durability against 10 washing cycles [163].

3.36 Eradication of Insects from Wool Textile

Museum personnel, private collectors, and university staff responsible for maintaining textile collections frequently are required to make decisions or are asked questions pertaining to insect control on wool textile. Decision making in this area becomes increasingly difficult with new developments in chemical pesticides and alternative methods of eradication. It is the intent of this paper to present an overview of chemical and nonchemical methods of pest control applicable to museum and home use. The discussion of chemical insecticides is not limited to those EPA-approved for museums, institutions, or public buildings because many questions concerning fabric pest control come from private collectors. Furthermore, some of the less toxic insecticides approved for home use may eventually be approved for use in museums and other public buildings.

In addition to common methods of controlling insect growth on wool textiles, several unusual and alternative chemical, biological, and nonchemical methods of pest control are discussed below. These may serve as an inspiration for future research. Even though this paper focuses on elimination methods for controlling fabric pests, preventive measures (i.e., good housekeeping practices and periodic inspection of wool, feathers, furs, etc.) can reduce the risk of introducing insect populations onto dwellings and storage areas or providing conditions that favor insect development [164, 165].

3.37 Microwave Radiations for Heat-Setting of Polyester Fibers

The use of radio and microwave frequency is gaining importance for industrial applications such as heating, drying, and other processing. The most important advantage of using microwave is that it is non-contact or localized heating and the heat is produced within the material. This can be much more effective than indirect heating where the heat propagation is by heat conduction through the material. We have been investigating the influence of microwave radiation on different fibers for the last few years. In the present investigation we used microwave frequency of 2450 MHz to investigate its effect on polyester fibers. The polyester fibers were heat set in air as well as a liquid, which acted as lossy substances. The liquid was chosen on the basis of earlier experiments, which showed the maximum effect. A comparative study was also carried out rushing conventional heating in silicone oil. Using the method of X-ray diffraction (XRD) we calculated the changes in % crystallinity and orientation. It was found that as the time of treatment under microwave radiation increased from 15 sec. to 120 sec. the order factor was found to increase from 0.32 to 0.71. The crystalline orientation as determined from the azimuthal scan was also found to increase. Such structural changes can be highly beneficial for the processing of fabric in industry. The microwave radiation process is fast, reliable and energy saving [166].

3.38 Microwave Irradiation Technique to Enhance Protein Fiber Properties

Microwave irradiation technique was used for the chemical modification and grafting of protein fibrous materials, such as domestic silk (*Bombyx mori*), tussah silk (*Antheraea pernyi*), and wool fibers. Epoxide compounds denacol EX810 and EX313 reacted effectively with the protein substrates. As alkali catalysts, sodium hydroxide was more effective than sodium thiocyanate. The optimum concentration was 0.25 w%. Weight gain values up to 8% were attained with 10-15 min irradiation time at 200 W power. Graftcoppymerisation of vinyl monomers onto protein fiber resulted in variable weight gains, depending on the kind of fiber, the grafting monomer used, and the concentration of the padding solution. For example, after grafting with iso – propyl methacrylate (IPMA), the weight gain of fibrous proteins took place in the following order: *Bombyx mori* silk > tussah silk > wool. *Bombyx mori* silk gained more weight with IPMA than with 2- hydroxyehtyl methacrylate (HEMA) or methacrylamide (MAA). The weight gain of *Bombyx mori* silk with HEMA significantly increased when the initial monomer concentration was raised to 400% owf, reaching a maximum value of 40%. The tensile properties of the protein fibres grafted with IPMA, MAA, and HEMA remaind unchanged or slightly improved compared to the reference fibres. Fibers modified with epoxides showed a drop in tensile performance. The surface morphology of fibres treated with Epoxide compounds or graft – copolymerized with vinyl monomers was almost unaffected, with the exception of HEMA – grafted fibers, which showed the presence of homopolymer deposited onto the surface at a weight gain exceeding 20 % [167].