WOODHEAD PUBLISHING SERIES IN TEXTILES

Advances in the dyeing and finishing of technical textiles

Edited by M. L. Gulrajani



WP WOODHEAD PUBLISHING

Advances in the dyeing and finishing of technical textiles

Edited by M. L. Gulrajani







Oxford Cambridge

Philadelphia

New Delhi

Published by Woodhead Publishing Limited in association with The Textile Institute Woodhead Publishing Limited, 80 High Street, Sawston, Cambridge CB22 3HJ, UK www.woodheadpublishing.com www.woodheadpublishingonline.com

Woodhead Publishing, 1518 Walnut Street, Suite 1100, Philadelphia, PA 19102-3406, USA

Woodhead Publishing India Private Limited, G-2, Vardaan House, 7/28 Ansari Road, Daryaganj, New Delhi – 110002, India www.woodheadpublishingindia.com

First published 2013, Woodhead Publishing Limited

© Woodhead Publishing Limited, 2013. Note: The publishers have made every effort to ensure that permission for copyright material has been obtained by authors wishing to use such material. The authors and the publishers will be glad to hear from any copyright holder it has not been possible to contact. The authors have asserted their moral rights.

This book contains information obtained from authentic and highly regarded sources. Reprinted material is quoted with permission, and sources are indicated. Reasonable efforts have been made to publish reliable data and information, but the authors and the publishers cannot assume responsibility for the validity of all materials. Neither the authors nor the publishers, nor anyone else associated with this publication, shall be liable for any loss, damage or liability directly or indirectly caused or alleged to be caused by this book.

Neither this book nor any part may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, microfilming and recording, or by any information storage or retrieval system, without permission in writing from Woodhead Publishing Limited.

The consent of Woodhead Publishing Limited does not extend to copying for general distribution, for promotion, for creating new works, or for resale. Specific permission must be obtained in writing from Woodhead Publishing Limited for such copying.

Trademark notice: Product or corporate names may be trademarks or registered trademarks, and are used only for identification and explanation, without intent to infringe.

British Library Cataloguing in Publication Data A catalogue record for this book is available from the British Library.

Library of Congress Control Number: 2012953128

ISBN 978-0-85709-433-9 (print) ISBN 978-0-85709-761-3 (online) ISSN 2042-0803 Woodhead Publishing Series in Textiles (print) ISSN 2042-0811 Woodhead Publishing Series in Textiles (online)

The publishers' policy is to use permanent paper from mills that operate a sustainable forestry policy, and which has been manufactured from pulp which is processed using acid-free and elemental chlorine-free practices. Furthermore, the publishers ensure that the text paper and cover board used have met acceptable environmental accreditation standards.

Typeset by Toppan Best-set Premedia Limited, Hong Kong

Advances in the dyeing and finishing of technical textiles

The Textile Institute and Woodhead Publishing

The Textile Institute is a unique organisation in textiles, clothing and footwear. Incorporated in England by a Royal Charter granted in 1925, the Institute has individual and corporate members in over 90 countries. The aim of the Institute is to facilitate learning, recognise achievement, reward excellence and disseminate information within the global textiles, clothing and footwear industries.

Historically, The Textile Institute has published books of interest to its members and the textile industry. To maintain this policy, the Institute has entered into partnership with Woodhead Publishing Limited to ensure that Institute members and the textile industry continue to have access to high-calibre titles on textile science and technology.

Most Woodhead titles on textiles are now published in collaboration with The Textile Institute. Through this arrangement, the Institute provides an Editorial Board which advises Woodhead on appropriate titles for future publication and suggests possible editors and authors for these books. Each book published under this arrangement carries the Institute's logo.

Woodhead books published in collaboration with The Textile Institute are offered to Textile Institute members at a substantial discount. These books, together with those published by The Textile Institute that are still in print, are offered on the Woodhead web site at: www.woodheadpublishing.com. Textile Institute books still in print are also available directly from the Institute's web site at www.textileinstitutebooks.com

A list of Woodhead books on textiles science and technology, most of which have been published in collaboration with The Textile Institute, can be found towards the end of the contents pages.

We are always happy to receive suggestions for new books from potential editors. To enquire about contributing to our textiles series, please send your name, contact address and details of the topic(s) you are interested in to francis. dodds@woodheadpublishing.com. We look forward to hearing from you.

The Woodhead team responsible for publishing this book:

Commissioning Editor: Kathryn Picking Publications Coordinator: Emily Cole

Project Editor: Rachel Cox

Editorial and Production Manager: Mary Campbell

Production Editor: Richard Fairclough

Cover Designer: Terry Callanan

Contributor contact details

(* = main contact)

Editor and Chapter 12

Dr Mohan L. Gulrajani
Department of Textile Technology
Indian Institute of Technology
Delhi
Hauz Khas
New Delhi – 110016
India

E-mail: mlg54@hotmail.com

Chapter 1

Professor Robert M. Christie School of Textiles and Design Heriot-Watt University Scottish Borders Campus Galashiels TD1 3HF UK

E-mail: r.m.christie@hw.ac.uk

Chapters 2 and 3

Dr N. Sekar
Department of Dyestuff
Technology
Institute of Chemical Technology
Matunga
India

E-mail: n.sekar@ictmumbai.edu.in

Chapter 4

Dr G. Nelson Burgundy Gold Limited 68 Beech View Road Kingsley Cheshire WA6 8DG UK

E-mail: gnelson@burgundygold. com

Chapter 5

Dr Dileep M. Wakankar Clariant Chemicals (India) Ltd Sandoz Baug, Kolshet Thane (West) 400 607 Maharashtra India

E-mail: dileep.wakankar@clariant. com; wroopa.dileep@rediffmail. com

Chapter 6

R. Senthil Kumar* and
S. Sundaresan
Department of Textile Technology
Post Box No. 2034
Kumaraguru College of Technology
Saravanampatty (post)
Coimbatore-641049
Tamilnadu
India

E-mail: sen29iit@yahoo.co.in

Chapter 7

Dr Deepti Gupta
Department of Textile Technology
Indian Institute of Technology
Delhi
Hauz Khas
New Delhi – 110016
India

E-mail: deepti@textile.iitd.ernet.in; deeptibgupta@gmail.com

Chapter 8

Dr Roshan Paul* and E. Genescà Textile Technologies Division LEITAT Technological Center Calle de la Innovació 2 08225 Terrassa Barcelona Spain

E-mail: rpaul@leitat.org; paulrosh@ yahoo.com

Chapter 9

C. N. Sivaramakrishnan Anmol Polymers Private Limited New Delhi India

E-mail: cns8024@gmail.com

Chapter 10

Kerry Maguire King

[TC] Textile/Clothing Technology

Corporation

5651 Dillard Drive

Cary, NC 27518

USA

E-mail: kking@tc2.com

Chapter 11

Dr Rinn M. Cloud MGJ Endowed Chair in Textiles One Bear Place 97346 Baylor University Waco, TX 76798-7346 USA

E-mail: rinn_cloud@baylor.edu

Chapter 13

Professor (Ms) Manjeet Jassal* and Professor A. K. Agrawal Department of Textile Technology Indian Institute of Technology Delhi Hauz Khas New Delhi – 110016 India

E-mail: manjeet.jassal@smita-iitd. com

Chapter 14

Professor Mangala Joshi* and Dr B. S. Butola Department of Textile Technology Indian Institute of Technology Delhi Hauz Khas New Delhi – 110016 India

E-mail: mangala@textile.iitd.ac.in

Woodhead Publishing Series in Textiles

1	Watson's textile design and colour Seventh edition
	Edited by Z. Grosicki

2 Watson's advanced textile design

Edited by Z. Grosicki

3 Weaving Second edition

P. R. Lord and M. H. Mohamed

4 Handbook of textile fibres Volume 1: Natural fibres

J. Gordon Cook

5 Handbook of textile fibres Volume 2: Man-made fibres

J. Gordon Cook

6 Recycling textile and plastic waste Edited by A. R. Horrocks

7 New fibers Second edition T. Hongu and G. O. Phillips

8 Atlas of fibre fracture and damage to textiles Second edition J. W. S. Hearle, B. Lomas and W. D. Cooke

9 Ecotextile '98
Edited by A. R. Horrocks

10 Physical testing of textiles

B. P. Saville

11 Geometric symmetry in patterns and tilings C. E. Horne

12 **Handbook of technical textiles** *Edited by A. R. Horrocks and S. C. Anand*

13 **Textiles in automotive engineering** W. Fung and J. M. Hardcastle

14 Handbook of textile design J. Wilson

15 **High-performance fibres** *Edited by J. W. S. Hearle*

16 Knitting technology Third edition D. J. Spencer

17	Medical textiles				
	Edited by S. C. Anand				

18 Regenerated cellulose fibres Edited by C. Woodings

- 19 **Silk, mohair, cashmere and other luxury fibres** *Edited by R. R. Franck*
- 20 Smart fibres, fabrics and clothing Edited by X. M. Tao
- 21 Yarn texturing technology
 J. W. S. Hearle, L. Hollick and D. K. Wilson
- 22 Encyclopedia of textile finishing H-K. Rouette
- 23 Coated and laminated textiles W. Fung
- 24 Fancy yarns
 R. H. Gong and R. M. Wright
- 25 Wool: Science and technology
 Edited by W. S. Simpson and G. Crawshaw
- 26 Dictionary of textile finishing H-K. Rouette
- 27 Environmental impact of textiles K. Slater
- 28 Handbook of yarn production *P. R. Lord*
- 29 **Textile processing with enzymes** *Edited by A. Cavaco-Paulo and G. Gübitz*
- 30 The China and Hong Kong denim industry Y. Li, L. Yao and K. W. Yeung
- 31 The World Trade Organization and international denim trading Y. Li, Y. Shen, L. Yao and E. Newton
- 32 Chemical finishing of textiles W. D. Schindler and P. J. Hauser
- 33 Clothing appearance and fit J. Fan, W. Yu and L. Hunter
- 34 Handbook of fibre rope technology H. A. McKenna, J. W. S. Hearle and N. O'Hear
- 35 Structure and mechanics of woven fabrics J. Hu
- 36 Synthetic fibres: nylon, polyester, acrylic, polyolefin Edited by J. E. McIntyre
- 37 Woollen and worsted woven fabric design E. G. Gilligan
- 38 Analytical electrochemistry in textiles P. Westbroek, G. Priniotakis and P. Kiekens

39	Bast	and	other	plant	fibres
	R. R.	Fra	nck		

40 Chemical testing of textiles Edited by Q. Fan

41 **Design and manufacture of textile composites** *Edited by A. C. Long*

42 Effect of mechanical and physical properties on fabric hand Edited by H. M. Behery

43 New millennium fibers
T. Hongu, M. Takigami and G. O. Phillips

44 **Textiles for protection** *Edited by R. A. Scott*

45 **Textiles in sport** *Edited by R. Shishoo*

46 Wearable electronics and photonics Edited by X. M. Tao

47 Biodegradable and sustainable fibres Edited by R. S. Blackburn

48 Medical textiles and biomaterials for healthcare Edited by S. C. Anand, M. Miraftab, S. Rajendran and J. F. Kennedy

49 **Total colour management in textiles** *Edited by J. Xin*

50 **Recycling in textiles** *Edited by Y. Wang*

51 Clothing biosensory engineering Y. Li and A. S. W. Wong

52 **Biomechanical engineering of textiles and clothing** *Edited by Y. Li and D. X-Q. Dai*

53 **Digital printing of textiles** *Edited by H. Ujiie*

54 Intelligent textiles and clothing Edited by H. R. Mattila

55 Innovation and technology of women's intimate apparel W. Yu, J. Fan, S. C. Harlock and S. P. Ng

56 Thermal and moisture transport in fibrous materials Edited by N. Pan and P. Gibson

57 **Geosynthetics in civil engineering** *Edited by R. W. Sarsby*

58 **Handbook of nonwovens** Edited by S. Russell

59 **Cotton: Science and technology** *Edited by S. Gordon and Y-L. Hsieh*

60 Ecotextiles

Edited by M. Miraftab and A. R. Horrocks

xviii Woodhead Publishing Series in Textiles

61	Composite forming technologie
	Edited by A. C. Long

62 **Plasma technology for textiles** *Edited by R. Shishoo*

63 Smart textiles for medicine and healthcare Edited by L. Van Langenhove

64 **Sizing in clothing** *Edited by S. Ashdown*

65 Shape memory polymers and textiles

66 Environmental aspects of textile dyeing Edited by R. Christie

67 Nanofibers and nanotechnology in textiles Edited by P. Brown and K. Stevens

68 Physical properties of textile fibres Fourth edition W. E. Morton and J. W. S. Hearle

69 Advances in apparel production Edited by C. Fairhurst

70 Advances in fire retardant materials Edited by A. R. Horrocks and D. Price

71 **Polyesters and polyamides**Edited by B. L. Deopura, R. Alagirusamy, M. Joshi and B. S. Gupta

72 **Advances in wool technology** *Edited by N. A. G. Johnson and I. Russell*

73 **Military textiles** *Edited by E. Wilusz*

74 3D fibrous assemblies: Properties, applications and modelling of three-dimensional textile structures
J. Hu

75 **Medical and healthcare textiles**Edited by S. C. Anand, J. F. Kennedy, M. Miraftab and S. Rajendran

76 **Fabric testing** *Edited by J. Hu*

77 **Biologically inspired textiles** *Edited by A. Abbott and M. Ellison*

78 Friction in textile materials

Edited by B. S. Gupta

79 **Textile advances in the automotive industry** *Edited by R. Shishoo*

80 Structure and mechanics of textile fibre assemblies Edited by P. Schwartz

81 Engineering textiles: Integrating the design and manufacture of textile products

Edited by Y. E. El-Mogahzy

82	Polyolefin	fibres:	Industrial	and	medical	applications
	Edited by	S. C. O	. Ugholue			

83 Smart clothes and wearable technology Edited by J. McCann and D. Bryson

84 Identification of textile fibres Edited by M. Houck

85 Advanced textiles for wound care Edited by S. Rajendran

86 Fatigue failure of textile fibres Edited by M. Miraftab

87 Advances in carpet technology Edited by K. Goswami

88 Handbook of textile fibre structure Volume 1 and Volume 2

Edited by S. J. Eichhorn, J. W. S. Hearle, M. Jaffe and T. Kikutani

89 Advances in knitting technology Edited by K-F. Au

90 Smart textile coatings and laminates Edited by W. C. Smith

91 Handbook of tensile properties of textile and technical fibres Edited by A. R. Bunsell

92 Interior textiles: Design and developments Edited by T. Rowe

93 **Textiles for cold weather apparel** *Edited by J. T. Williams*

94 Modelling and predicting textile behaviour Edited by X. Chen

95 **Textiles, polymers and composites for buildings** *Edited by G. Pohl*

96 Engineering apparel fabrics and garments
J. Fan and L. Hunter

97 **Surface modification of textiles** *Edited by Q. Wei*

98 Sustainable textiles
Edited by R. S. Blackburn

99 Advances in yarn spinning technology Edited by C. A. Lawrence

100 Handbook of medical textiles Edited by V. T. Bartels

101 **Technical textile yarns** *Edited by R. Alagirusamy and A. Das*

102 Applications of nonwovens in technical textiles Edited by R. A. Chapman

103 Colour measurement: Principles, advances and industrial applications Edited by M. L. Gulrajani

Woodhead	l Publishing	Series	in	Textiles
----------	--------------	--------	----	-----------------

///	VVoodifiedd i dolloffillig oefied i'r fextiled
104	Fibrous and composite materials for civil engineering applications Edited by R. Fangueiro
105	New product development in textiles: Innovation and production
103	Edited by L. Horne
106	Improving comfort in clothing
	Edited by G. Song
107	Advances in textile biotechnology
	Edited by V. A. Nierstrasz and A. Cavaco-Paulo
108	Textiles for hygiene and infection control
	Edited by B. McCarthy
109	Nanofunctional textiles
	Edited by Y. Li
110	Joining textiles: Principles and applications
	Edited by I. Jones and G. Stylios
111	Soft computing in textile engineering
	Edited by A. Majumdar
112	Textile design
	Edited by A. Briggs-Goode and K. Townsend
113	Biotextiles as medical implants
	Edited by M. King and B. Gupta
114	Textile thermal bioengineering
	Edited by Y. Li
115	Woven textile structure
	B. K. Behera and P. K. Hari
116	Handbook of textile and industrial dyeing. Volume 1: Principles, processes
	and types of dyes
117	Edited by M. Clark
117	Handbook of textile and industrial dyeing. Volume 2: Applications of dyes Edited by M. Clark
110	
118	Handbook of natural fibres. Volume 1: Types, properties and factors affecting breeding and cultivation
	Edited by R. Kozlowski
119	Handbook of natural fibres. Volume 2: Processing and applications
117	Edited by R. Kozlowski
120	Functional textiles for improved performance, protection and health
120	Edited by N. Pan and G. Sun
121	Computer technology for textiles and apparel
	Edited by J. Hu

© Woodhead Publishing Limited, 2013

122 Advances in military textiles and personal equipment

Handbook of sustainable textile production

Specialist yarn and fabric structures

Edited by E. Sparks

Edited by R. H. Gong

M. I. Tobler-Rohr

123

124

125	Woven textiles: Principles, developments and applications
	Edited by K. Gandhi

126 Textiles and fashion: Materials design and technology Edited by R. Sinclair

127 Industrial cutting of textile materials
I. Vilumsone-Nemes

128 Colour design: Theories and applications Edited by J. Best

129 False twist textured yarns C. Atkinson

130 Modelling, simulation and control of the dyeing process R. Shamey and X. Zhao

131 Process control in textile manufacturing
Edited by A. Majumdar, A. Das, R. Alagirusamy
and V. K. Kothari

132 Understanding and improving the durability of textiles Edited by P. A. Annis

133 Smart textiles for protection Edited by R. A. Chapman

134 Functional nanofibers and applications Edited by Q. Wei

135 The global textile and clothing industry: Technological advances and future challenges

Edited by R. Shishoo

136 Simulation in textile technology: Theory and applications Edited by D. Veit

137 Pattern cutting for clothing using CAD: How to use Lectra Modaris pattern cutting software

M. Stott

138 Advances in the dyeing and finishing of technical textiles M. L. Gulrajani

139 Multidisciplinary know-how for smart textile development T. Kirstein

140 Handbook of fire resistant textiles F-S. Kilinc-Balci

141 Handbook of footwear design and manufacture A. Luximon

142 **Textile-led design for the active ageing population** *J. McCann and D. Bryson*

Optimising decision making in the apparel supply chain using artificial intelligence (AI)

W. K. Wong, Z. X. Guo and S. Y. S. Leung

144 Mechanisms of flat weaving technology V. Choogin, P. Bandara and E. Chepelyuk

xxii Woodhead Publishing Series in Textiles

- 145 Innovative jacquard textile design using digital technologies F. Ng and J. Zhou
- 146 Advances in shape memory polymers *J. Hu*
- 147 Clothing manufacture management: A systematic approach to planning, scheduling and control

 J. Gersak
- 148 Anthropometry, apparel sizing and design D. Gupta and N. Zakaria

Contents

	Contributor contact details Woodhead Publishing Series in Textiles	xi xv
Part I	Advances in dyes and colourants	1
1	Chromic materials for technical textile applications R. M. Christie, Heriot-Watt University, UK	3
1.1	Introduction	3
1.2	Thermochromism	6
1.3	Photochromism	16
1.4	Ionochromism	25
1.5	Electrochromism	27
1.6	Miscellaneous chromic materials	30
1.7	Future trends	31
1.8	Sources of further information	32
1.9	References	33
2	Optical effect pigments for technical textile applications N. Sekar, Institute of Chemical Technology, India	37
2.1	Introduction	37
2.2	Different types of pigments and dyes	38
2.3	Substrate-based effect pigments	42
2.4	Future trends	45
2.5	References	45
3	UV-absorbent, antimicrobial, water-repellent and other types of functional dye for technical textile applications N. Sekar, Institute of Chemical Technology, India	47
3.1	Introduction	47
3.2	High light-fast dyes – dyes with inbuilt UV-absorbing units	48