



# JOURNAL OF RESEARCH

Textile, Apparel, & Materials Professionals

## Editor in Chief

**Gang Sun**, University of California, Davis

## Associate Editors

**RV Adivarekar**, Institute of Chemical Technology  
**Ozgun Atalay**, Harvard University  
**Apurba Banerjee**, Brrr<sup>o</sup> Incorporated  
**Jiangning Che**, California State Polytechnic University, Pomona  
**Emiel DenHartog**, North Carolina State University  
**Renuka Dhandapani**, Cotton Incorporated  
**Ahmed El-Shafei**, North Carolina State University  
**Matthew Farrell**, Cotton Incorporated  
**Sabyasachi Gaan**, EMPA  
**Peter J. Hauser**, North Carolina State University (retired)  
**Md. Dawood Husain**, NED University  
**Chi Wai Kan**, Hong Kong Polytechnic University  
**Juhea Kim**, Korea Institute of Industrial Technology  
**Bipin Kumar**, Indian Institute of Technology Delhi  
**Calvin YM Lam**, Charming Printing Ltd.  
**Seungsin Lee**, Yonsei University  
**Rong Liu**, Hong Kong Polytechnic University  
**Robert Monticello**, International Antimicrobial Council  
**Anil Netravali**, Cornell University  
**Roshan Paul**, Indo-German Science & Technology Centre  
**David Proctor**, International Antimicrobial Council  
**Seshadri S. Ramkumar**, Texas Tech University  
**Xuehong Ren**, Jiangnan University  
**Ram Sabnis**, Georgia-Pacific LLC  
**Ajoy Sarkar**, Fashion Institute of Technology  
**Yiqi Yang**, University of Nebraska-Lincoln

## Editorial Advisory Board

**Martin Bide**, University of Rhode Island  
**Fred Cook**, Georgia Institute of Technology  
**Ian Hardin**, University of Georgia  
**Majid Sarmadi**, University of Wisconsin-Madison

## AATCC Officers

President: **Kerry King**, Spoonflower Inc.  
President-Elect: **Harrie Schoots**, Ascend Performance Materials  
Immediate Past-President: **Rembert "Bert" Truesdale III**,  
TenCate Protective Fabrics  
Treasurer: **R. Michael Tyndall**

## AATCC Journal of Research Staff

**Brian C. Francois**, Publisher/Executive Vice President  
**Maria C. Thiry**, Publications Director  
**Ann Holland**, Acquisitions Editor  
**J. Michael Quante**, Science Editor  
**Bliss C. Abrantes**, Design, Production, & Circulation

## Subscriptions

[www.aatcc.org/pub/subscribe](http://www.aatcc.org/pub/subscribe)  
Email: [colemanb@aatcc.org](mailto:colemanb@aatcc.org)  
Phone: +1.919.549.3543  
Fax: +1.919.549.8933

**AATCC members:** free with membership

## Institutional Subscribers

Electronic subscriptions only: includes subscriptions to both electronic publications *AATCC Journal of Research* and *AATCC Review*

## Publish with us

[www.aatcc.org/pub/publish](http://www.aatcc.org/pub/publish)  
Email: [hollanda@aatcc.org](mailto:hollanda@aatcc.org)  
Fax: +1.919.549.8933

AATCC | 1 Davis Drive | PO Box 12215  
Research Triangle Park, NC 27709-2215 | USA

*AATCC Journal of Research* is published bimonthly in electronic format.

## Permissions

Copyright for *AATCC Journal of Research* is owned by AATCC, unless otherwise noted. To copy or distribute beyond the fair use provisions of the US Copyright Act, contact Copyright Clearance Center Inc. ([www.copyright.com](http://www.copyright.com)). Specify ISSN 2330-5517. Authors, visit [www.aatcc.org/pub/get-permission](http://www.aatcc.org/pub/get-permission).

Mention of any trade name or proprietary product in *AATCC Journal of Research* does not constitute a guarantee or warranty of the product by the AATCC and does not imply its approval to the exclusion of other products that may also be suitable.

*AATCC Journal of Research* (Online ISSN 2330-5517)  
© 2019, American Association of Textile Chemists and Colorists