

We will begin momentarily at 2pm ET



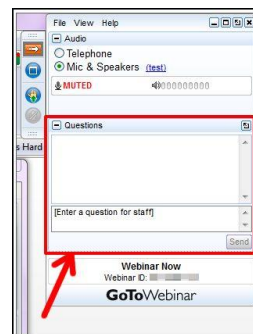
Slides available now! Recordings are available to ACS members.

www.acs.org/acswebinars

Contact ACS Webinars® at acswebinars@acs.org

1

Have Questions?



“Why am I muted?”

Don't worry. Everyone is muted except the presenter and host. Thank you and enjoy the show.

Type them into questions box!

Contact ACS Webinars® at acswebinars@acs.org

2

Have you discovered the missing element?



<http://bit.ly/benefitsACS>

Find the many benefits of ACS membership!

3

Benefits of ACS Membership



Chemical & Engineering News (C&EN)
The preeminent weekly news source.



NEW! Free Access to ACS Presentations on Demand®
ACS Member only access to over 1,000 presentation recordings from recent ACS meetings and select events.



NEW! ACS Career Navigator
Your source for leadership development, professional education, career services, and much more.

<http://bit.ly/benefitsACS>

4

Let's get Social...post, tweet, and link to ACS Webinars during today's broadcast!



facebook.com/acswwebinars



@acswwebinars



Search for "acswwebinars" and connect!

5

How has ACS Webinars® benefited you?



Quote in reference to: <http://bit.ly/CosmeticChemistry>

"This ACS Webinar presented just the right mix of actual chemistry and practical applications to make it worthwhile for every participant. I used to work in the field myself and really appreciated the way the presenter organized the material."

Fan of the Week

Frans Zonnevrijle, Consultant
Intex Diagnostika AG,
ACS member for 40 years strong!



Be a featured fan on an upcoming webinar! Write to us @ acswwebinars@acs.org

6



7

Learn from the best and brightest minds in chemistry! Hundreds of webinars presented by subject matter experts in the chemical enterprise.

Recordings are available to current ACS members and become part of the archive once they are edited and posted. www.acs.org/acswebinars

Broadcasts of ACS Webinars[®] continue to be available to the general public LIVE every Thursday at 2pm ET!

www.acs.org/acswebinars

8

Nominate an ACS Fellow in 2017!

www.nominatefellow.acs.org



The American Chemical Society Fellows Program was created by the ACS Board of Directors in December 2008 to recognize members of ACS for outstanding achievements in and contributions to science, the profession, and the Society.

Detailed guidelines and instructions for submitting nominations

www.acs.org/fellows

9



ChemIDP.org

ChemIDP™, an individual development planning tool for you.

- Know your career options
- Develop strategies to strengthen your skills
- Map a plan to achieve your career goals

ChemIDP.org

10



SAN FRANCISCO
APRIL
2-6
2017

**253rd American Chemical Society
National Meeting & Exposition**

Advanced Materials, Technologies, Systems & Processes
Register today at www.acs.org/ACSSF17 | Join the ACS and save up to \$400

Visit www.acs.org/ACSSF17 to learn more about registration, housing, programming, and events.

Download the ACS San Francisco mobile app from Google Play, Apple, or Amazon stores.

Follow @ACSNtMtg on Twitter for the latest news.

www.acs.org/ACSSF17

11

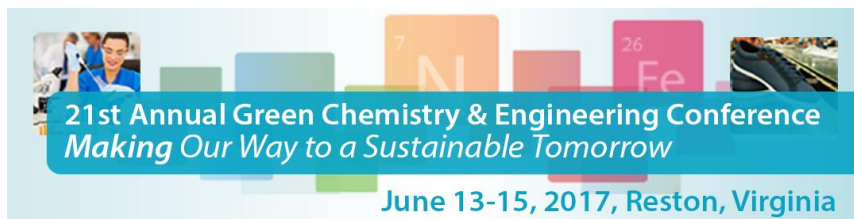
ACS Green Chemistry Institute[®]

Engaging you to reimagine chemistry and engineering for a sustainable future.



www.acs.org/greenchemistry

12



- Sustainable Chemicals
- Flexible Chemical Manufacturing
- More Efficient Processes
- Green Chemistry Curricula
- Circular Economy Considerations
- Sustainable Materials
- Academic-Industry Collaborations
- Chemicals Policy
- Cosmetics
- And More!

Early Bird Registration will be open from February 15 until April 28, 2017

gcande.org

13

Upcoming ACS GCI Webinar!

Nanomaterial Design Guided by the Principles of Green Chemistry

Thursday, May 18 @ 2:3pm ET



How can green chemistry be applied to nanotechnology to achieve the high performance needed for advanced applications while preventing or reducing health and environmental impacts? Join James Hutchison from the University of Oregon as he discusses the foundations for greener nanotechnology and presents a case study that uses nanomaterial product innovation guided by green chemistry.

[Register Now!](#)

What You Will Learn

- The opportunity to achieve a net environmental benefit by bringing together green chemistry with nanoscience
- The role that green chemistry plays in designing high performance nanomaterials and efficient nanomaterial production
- How green chemistry and nanoscience can be used together to develop innovative new products with environmental benefits



Experts



James Hutchison
University of Oregon



Joe Fortunak
Howard University

Co-Produced With



<http://bit.ly/GreenNano>

14

Upcoming ACS Webinars

www.acs.org/acswebinars



Thursday, April 13, 2017



The Good, The Bad and the Uncertain: Public Perception of the Chemical Enterprise

Session 3 of the Industry Science Series

Mark Jones, Executive External Strategy and Communications Fellow, Dow Chemical
William Carroll, Founder, Carroll Applied Science and Adjunct Professor of Chemistry, Indiana University

Thursday, April 20, 2017



Cystic Fibrosis: Discovery of CFTR Modulators

Session 4 of the 2017 Drug Design and Delivery Symposium

Peter Grootenhuys, Senior Director Chemistry, Vertex
Nick Meanwell, Executive Director, Bristol-Myers Squibb

Contact ACS Webinars® at acswebinars@acs.org

15



“Sustainability Challenges of the Textiles, Dyeing and Finishing Industries: Opportunities for Innovation”



Joe Fortunak
Professor of Chemistry, Howard University



Richard Blackburn
Associate Professor,
University of Leeds

Slides available now! Recordings are edited and will be posted.

www.acs.org/acswebinars

This ACS Webinar is being co-produced with the ACS Green Chemistry Institute

16



Sustainability Challenges of the Textiles, Dyeing and Finishing Industries: Opportunities for Innovation

Dr. Richard Blackburn

Sustainable Materials Research Group

University of Leeds

 @RichardBlackb18



Audience Survey Question 
ANSWER THE QUESTION ON BLUE SCREEN IN ONE MOMENT

Which is the most sustainable textile fibre?



Cotton



Polyester



Wool



Nylon

Polyester image By Bearas (Own work) [CC BY-SA 4.0 (<http://creativecommons.org/licenses/by-sa/4.0/>)], via Wikimedia Commons

Wool image By 4028mdk09 (Own work) [CC BY-SA 3.0 (<http://creativecommons.org/licenses/by-sa/3.0/>)], via Wikimedia Commons

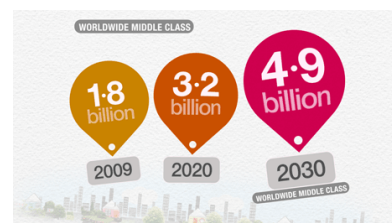
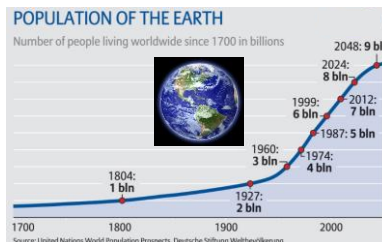
Nylon image By shortszene (Own work) [GFDL (<http://www.gnu.org/copyleft/fdl.html>) or CC-BY-SA-3.0 (<http://creativecommons.org/licenses/by-sa/3.0/>)], via Wikimedia Commons

Necessity for Sustainable Products



UNIVERSITY OF LEEDS

- 2012 - world population 7 billion
- 2050 - expected to rise to over 9 billion
- Increases demand
 - food, energy, water, resources, chemicals
- Increases environmental burden
 - pollution
 - depletion of finite non-renewable resources (e.g. fossil fuels)



- **Synthetic chemical products and processes afford a significant improvement in quality of life**
- **Growing middle class want these consumer products too**



19

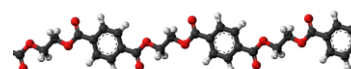
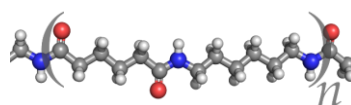
Synthetic Fibre Revolution



UNIVERSITY OF LEEDS

20th Century polymers

- nylon, 1935
- polyurethane, 1937
- polyester: Terylene, 1941; Dacron, 1946
- acrylic, 1944
- polypropylene and HDPE, 1951



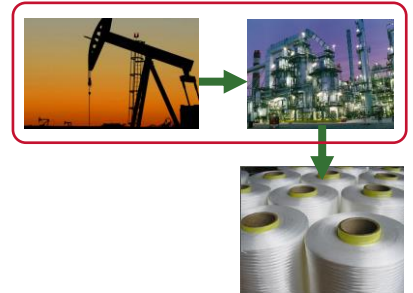
20

Synthetic Fibre Sustainability Challenges



UNIVERSITY OF LEEDS

- Non-degradable, non-renewable
- But, polyester highest share of textile market
 - >50m tpa
- **Raw materials for fibres must change**
- Recyclable – **mechanical** or **chemical**?



21

Sustainability Considerations



UNIVERSITY OF LEEDS



22

Public Perception



UNIVERSITY OF LEEDS

- Demand (and rejection) for consumer products can be driven by the public and the media
- “*Biodegradable*”, “*Natural*”, “*Organic*”
 - perceived by the public to be good for the environment
- “*Synthetic*”, “*Non-organic*”, “*GM*”
 - perceived by the public to be bad for the environment
- “*Chemistry*”
 - Public perception of science...
- Do the public understand what “*Sustainable*” means?



Physics



Chemistry

23

Ideal Sustainable Product



UNIVERSITY OF LEEDS

- Provide an **equivalent function** to the product it replaces
- **Performs as well as or better** than the existing product
- Is designed to be **desirable**
- Be available at a **competitive or lower price**
- Have a minimum environmental footprint for **all the processes involved**
- Be manufactured from **renewable resources**
- Use only **ingredients that are safe** to both humans and the environment
- **No negative impact** on food supply or water



24

Textile Dyeing Processes



UNIVERSITY OF LEEDS

- Traditional dyeing processes use 5.8 trillion litres water p.a.
 - ~3.7 billion Olympic swimming pools
- 10-20% dye remains after dyeing (plus other chemicals), leaving potential for wastewater pollution
 - One fifth of the world's industrial water pollution (World Bank)
- 391 billion kWh energy for dyeing processes
- **Innovative technologies needed to reduce, or eliminate, water, energy and auxiliary chemicals in dyeing**



25

Treatment of Textile Dyeing Effluent



UNIVERSITY OF LEEDS

- Wastewater from dyeing processes one of biggest contributors to textile effluent
- Mainly residual dyes and auxiliary chemicals
- >50,000 tpa dye discharged into effluent

Dye Class	Fibre	Loss to Effluent (% applied)
acid	polyamide (nylon)	5-20
basic	acrylic	0-5
direct	cotton	5-30
disperse	polyester	0-10
metal-complex	wool/polyamide	2-10
reactive	cotton	10-50
sulphur	cotton	10-40
vat	cotton	5-20



26

Treatment of Textile Dyeing Effluent



UNIVERSITY OF LEEDS

- Dyeing effluent in a watercourse aesthetically undesirable, but has a more serious environmental impact
- High BOD combined with spectral absorption of dye
 - Can affect photosynthetic processes
 - Reduction in O₂ levels in water → suffocation of aquatic flora and fauna
- Dyestuffs may be also have aquatic toxicity (metals, AOX)
- Several methods developed to remove colour from effluent
- Varying in effectiveness, economic cost, and environmental impact (of the treatment process itself)



Blackburn RS, *Environ. Sci. Technol.* **2004**, 38, 4905.



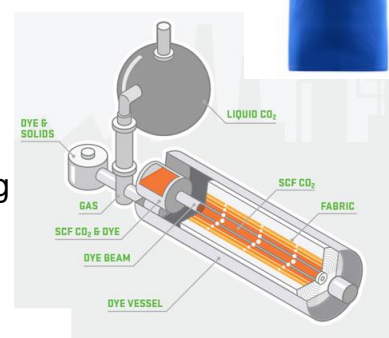
27

Polyester Dyeing Process



UNIVERSITY OF LEEDS

- Hydrophobic fibre dyed with hydrophobic disperse dye
- Traditional aqueous process requires dispersing agents/surfactants and high temperatures (typically 130 °C) under pressure
- Other dyeing auxiliaries often required
- Large amount of waste dye left over in effluent
- Surface dye removed with surfactants and/or reducing agents
- **Innovation in scCO₂ dyeing to completely change polyester dyeing process**



28

scCO₂ dyeing



UNIVERSITY OF LEEDS

System comparison with traditional polyester dyeing

WATER

Zero water used

PROCESS CHEMICALS

No auxiliary chemicals

WASTEWATER

Nearly 100% dye used in process. Zero waste

FOOTPRINT

¼ of physical footprint to dye same mass of fabric

ENERGY

Reduces energy consumption by 63%

EFFICIENCY

40% faster than traditional dyeing processes



drydye



29

scCO₂ dyeing - limitations



UNIVERSITY OF LEEDS

- Machines are more expensive than traditional water-dyeing machines
 - “costs will come down through scale and lower water and energy expenses“
- Only works on polyester fabrics and can't be used to dye cotton
 - Cotton makes up about 35% global fibre market
 - Some relatively unsuccessful work on modifying cotton
- **Significant opportunity to develop low or zero water dyeing systems for coloration of cellulose**



30

Coloration of Cotton



UNIVERSITY OF LEEDS

- Dyeing of cotton primarily conducted using **reactive dyes**
- Despite development of dyes with high fixation, dyeing still uses high quantities of **salt, water** (and energy), and creates **colour pollution**



- **Soil too alkaline to support crops**
- **Kills aquatic life**
- **Fresh watercourses turned saline downstream from dyehouses**
- **Difficult to remove from effluent**



- **10-40% dyestuff hydrolysed**
 - Goes down drain
 - Aesthetically unpleasant
 - Blocks sunlight and kills aquatic life
- **Clean effluent**
 - High cost



- **High level in dyeing**
- **Incredible volume in wash-off**
 - Up to 10 separate rinsings
 - High energy consumption
 - 50% total cost dyeing procedure

31

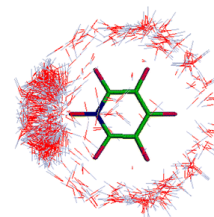
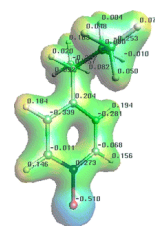


Wash-off of Reactive Dyeings on Cotton



UNIVERSITY OF LEEDS

- Dye transfer inhibiting (DTI) polymers (used in laundry detergents) were employed to remove unfixed dyes
- Much more efficient, economical and sustainable process developed
- Significantly reduces operation time, water consumption and energy consumption
 - poly(vinylpyridine-*N*-oxide) polymers were the most effective
 - poly(vinylpyridine betaine) polymers also highly efficient



Procedure	Time (min)	Water (L/kg fabric)	Energy (MJ/kg fabric)
recommended wash-off	250	60	9.21
DTI wash-off	50	30	0.84

Amin MN, Blackburn RS, *ACS Sus. Chem. Eng.* **2015**, 3, 725.

32



Bigger Problems with Cotton



UNIVERSITY OF LEEDS

- **NATURAL** doesn't necessarily mean sustainable
- Cotton production >25 million tpa
- High levels of pesticides (25% world total)
- High levels of insecticides (11% world total)
- Very high irrigation levels
 - 1 kg of cotton fibre requires 20,000-40,000 L
 - Water average person consumes in a lifetime
- Only grows in certain climates
 - Deforestation to grow cotton
- High area of land for mass of useable fibre



33



Sustainable Cotton?



UNIVERSITY OF LEEDS

Organic cotton

- Widely promoted as the answer to cotton's problems
- Global production (in over 20 countries, mainly India) only 1.1% of world cotton production
- No genetically modified seed permitted
- No herbicides or pesticides
- Ethical labour employment standards
- Requires approximately 1.4x area of land to produce same mass of fibre
- Still has very high water consumption
- Not a viable alternative on a global scale to completely replace non-organic cotton



34



Sustainable Cotton?



UNIVERSITY OF LEEDS

Better cotton

- GM pest-resistant strain referred to as 'Bt cotton'
 - Naturally occurring protein (used by organic gardeners) – kills bollworm pests (moth larva)
 - Reduces pesticide sprays from 5 sprays to 0
 - Poisoning of workers virtually eliminated
 - More productive, particularly in India
 - Bt cotton is regarded as less 'natural'
 - Cannot be classed as 'organic'
- Better Cotton Initiative (BCI) set up to foster improvements in the sustainability of cotton production methods



35

Alternative Sustainable Cellulosic Fibres



UNIVERSITY OF LEEDS

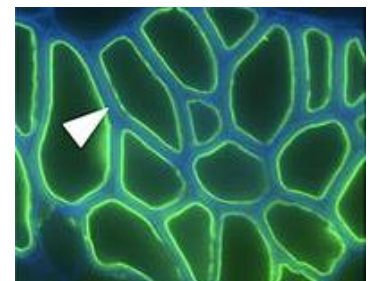
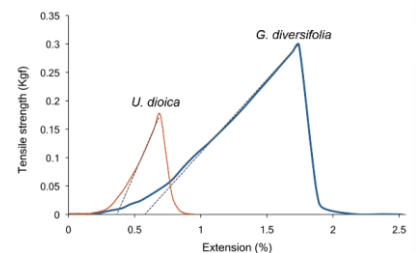
Bast Fibres

- From stem of plants (flax, hemp, jute, ramie, nettle, kenaf, abaca)
- **Plants with opportunities for performance fibres (e.g. Himalayan nettle)**

Lanzilao G, Goswami P, Blackburn RS, *Mater. Letts.*, **2016**, 181, 200.

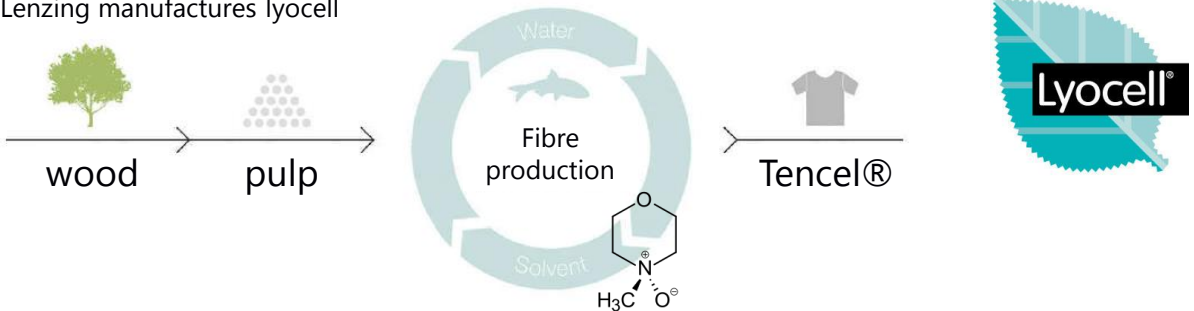
- Processing to separate ultimate fibres is of concern
- **Opportunities for innovation into alternative separation techniques (e.g. enzyme-assisted technologies)**

Blake AW, Marcus SE, Copeland JE, Blackburn RS, Knox JP, *Planta*, **2008**, 228, 1.



TENCEL® (lyocell) – Most Sustainable Fibre Production Process

- Regenerated cellulose made from trees
- Lenzing manufactures lyocell



- Wood from certified forests
- Direct closed-loop dissolution process
- *N*-methylmorpholine-*N*-oxide (NMMO)
- >99% recovery of solvent

Goswami P, Blackburn RS, Taylor J, White P. *Cellulose*, **2011**, 18, 1063.

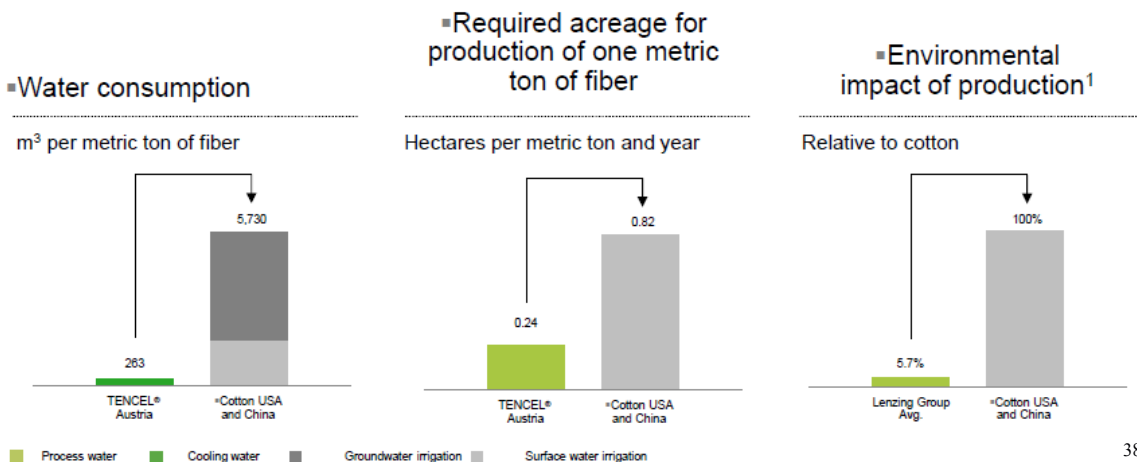
Široký J, Blackburn RS, Bechtold T, Taylor J, White P. *Carb. Polym.*, **2011**, 84, 299.



37

Green Footprint vs. Cotton

- More than 50% of Lenzing’s fuel consumption sourced from renewable resource



38

- New Lenzing fibre manufactured from industry waste, both cotton and lyocell
- Made from pulp that contains cotton scraps left over from cutting operations



Audience Survey Question 
ANSWER THE QUESTION ON BLUE SCREEN IN ONE MOMENT

Which textile fibre is lightweight and breathable, cool in the heat, warm in the cold, carries away moisture, has excellent odour management properties and a low carbon footprint?



Cotton



Polyester



Wool



Nylon

Polyester image By Bearas (Own work) [CC BY-SA 4.0 (<http://creativecommons.org/licenses/by-sa/4.0/>)], via Wikimedia Commons

Wool image By 4028mdk09 (Own work) [CC BY-SA 3.0 (<http://creativecommons.org/licenses/by-sa/3.0/>)], via Wikimedia Commons

Nylon image By shortszone (Own work) [GFDL (<http://www.gnu.org/copyleft/fdl.html>) or CC-BY-SA-3.0 (<http://creativecommons.org/licenses/by-sa/3.0/>)], via Wikimedia Commons

- Designing environmentally friendly and comfortable footwear
- Wool Runner – minimalist sneaker made of superfine New Zealand merino wool



Best Way to Mix Colours?

Nano-level

- Mixture of different dye molecules in dyebath to create desired shade

Micro-level

- Mixture of different dyed fibres in yarn formation process to create desired shade

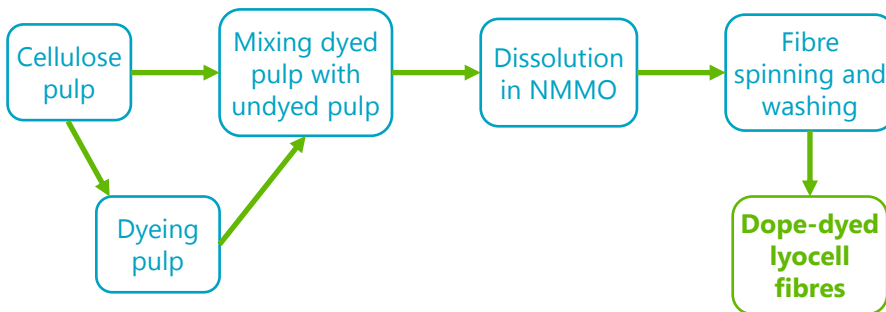


Does Fibre Coloration Have to be Through Dyeing?



UNIVERSITY OF LEEDS

- **Dope-dyeing:** incorporation of colorant into spinning process
- Lyocell process makes this possible for cellulosics



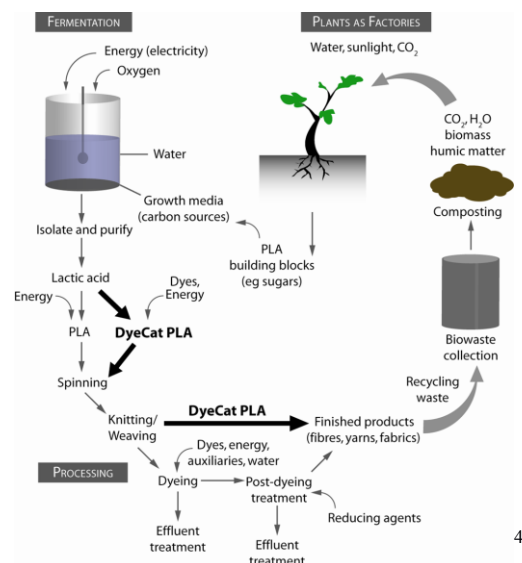
43

DyeCat Process



UNIVERSITY OF LEEDS

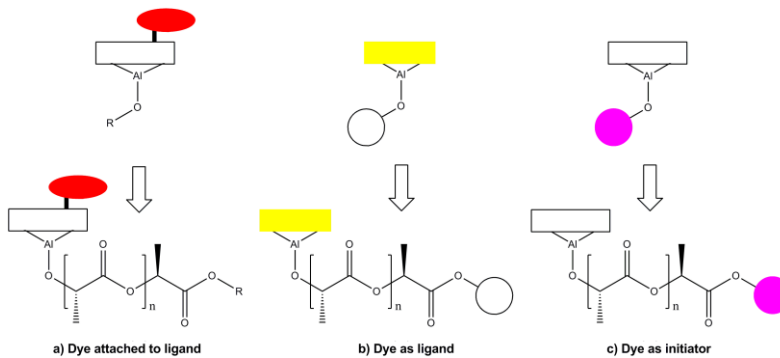
- Catalytic process that allows colour to be integrated directly into polyesters
- Eliminates need for conventional dyeing
- Colour in fibre is generated at the same time the polymer is made
- Colours 'locked into' fibre providing a technically superior product
- No need for wasteful dyeing processes
- **DyeCat poly(lactic acid) fibre**
 - **Renewable**
 - **Technically superior**
 - **Saves chemicals and energy**



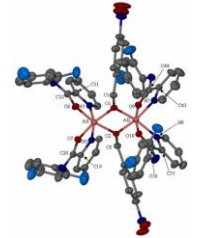
44

DyeCat Process

- Coloration of polymer during synthesis
- Demonstrated on PLA using coloured catalysts

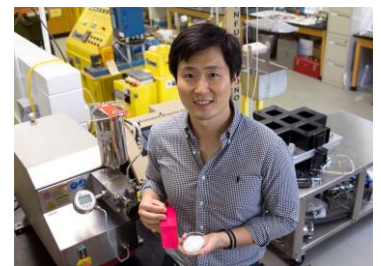


MacRae RO, Pask CM, Burdsall LK, Blackburn RS, Rayner CM, McGowan PC, *Angew. Chem. Int. Ed.* **2010**, 50, 291.



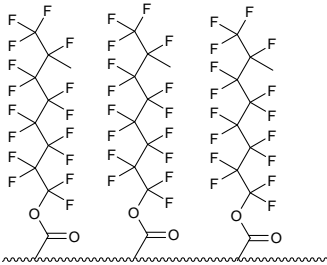
Novel, Sustainable and Cost-Effective Textile Dyeing using Nanocellulosic Fibres

- Dr. Yunsang Kim *et al.*, University of Georgia
- Innovative dyeing processes using coloured nanocellulose
- nano-sized cellulose fibrils (wood pulp) + dye → dyed nanocellulose dispersion
- Apply dyed nanocellulose dispersion onto the textile material using low water process
- Coloured nanocellulose permanently binds to textile surface
- Greatly reduces energy and water needed



Criticism of Chemistry use for Repellency in Outdoor Apparel

- Durable water repellents (DWR) applied to textiles to impart repellent functionality from water and oil
- For the last 60 years, per- and polyfluoroalkyl substances (PFASs) used in textile finishing



- Outdoor apparel industry has been directly targeted by Greenpeace
- The industry's PFAS use has been discussed in three reports since 2012
- **However, ratio of PFAS use in the outdoor apparel industry compared to whole textile industry unknown**

"...significant adverse effects have **not** been found in the general human population, however, significant adverse effects have been identified in laboratory animals and wildlife"
US EPA



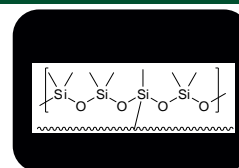
47

Significant Attention to Alternative Chemistries

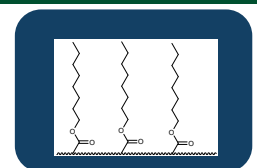
Suitable for Requirements?

- Mixed opinions on outdoor apparel requirements
- Involves wide range of activities, varying weather conditions, and demands on the wearer
- 'Wetting' of the fabric can cause detrimental cooling of the wearer – 'life protection'
- **Re-evaluation of consumer requirements**

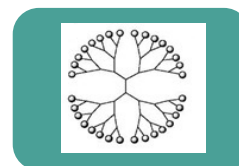
Surface terminal groups	Critical surface tension γ_c (mN/m) at 20°C
-CF ₃	6
-CF ₂	18
-CH ₃	22
-CH ₂	31



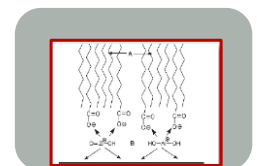
Silicones



Hydrocarbons



Dendritic/hyper-branched chemistry



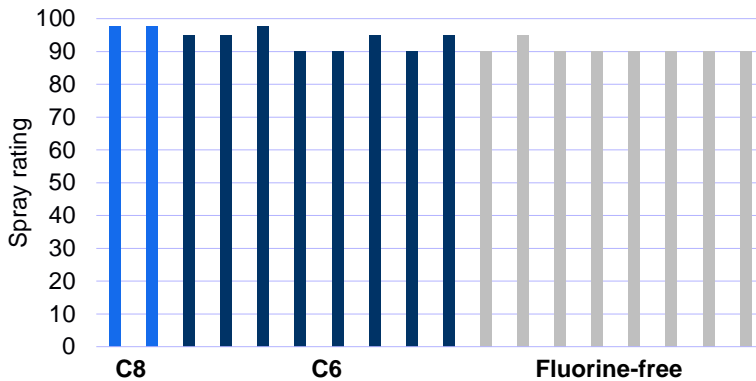
Wax-based repellents



48

Move to Fluorine-Free: Sufficient Functionality?

Characterisation of repellent fabrics currently in use from a number of brands



Spray test BS EN ISO 4920
Industry standard for testing resistance to surface wetting



49

Fast Fashion

- Fast, low price and disposable “supermarket” clothing
- Demand for apparel will double by 2025
- Environmental Impact
 - US imports >1 billion garments annually from China alone
 - 80% textiles end up in landfill (50 million tpa)
 - Dramatic increase in environmental damage caused by the textile industry
 - Safety compromised in evermore cost-cutting supply chain
- Human disasters (e.g. Rana Plaza, Bangladesh - 1,100 deaths, 2,500 injuries)
- **An enormous change is needed in the minds and attitudes of retailers and consumers**



- Greater use of sustainable raw materials
- Lower energy & water consumption and pollution generation in production
- Lower impact in use
 - Water, energy, chemicals in cleaning/laundry
- Design for easy disassembly/disposal/ recycling
- **DESIGN FOR REDUCED CONSUMPTION AND LONGER LIFE**
 - **'Disposable' products unsustainable**



Audience Survey Question
ANSWER THE QUESTION ON BLUE SCREEN IN ONE MOMENT



Which is the most sustainable textile fibre?

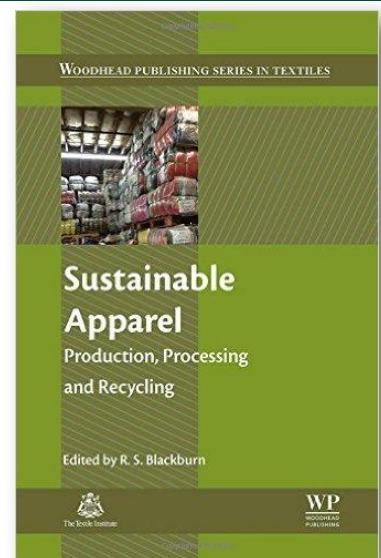
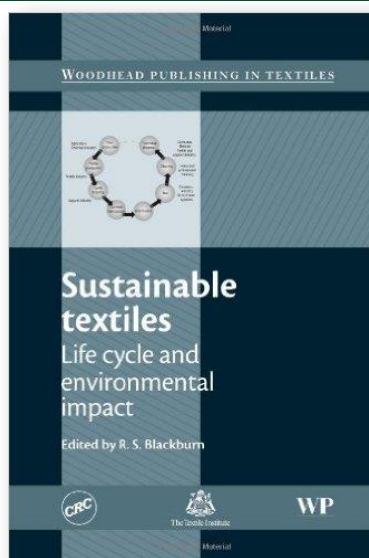
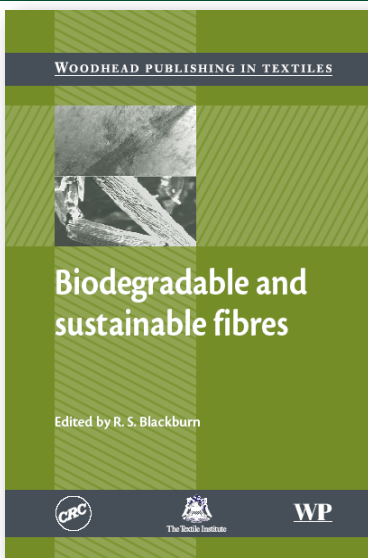
- Cotton
- Polyester
- Something else



- Sustainability issues in the textiles industry have often been tackled in industry by tinkering and incremental change
- Step-change solutions are needed to bring about truly sustainable apparel and footwear products



Further Reading...



Thank you

Dr. Richard S. Blackburn
r.s.blackburn@leeds.ac.uk
@RichardBlackb18



“Sustainability Challenges of the Textiles, Dyeing and Finishing Industries: Opportunities for Innovation”



Joe Fortunak
Professor of Chemistry, Howard University

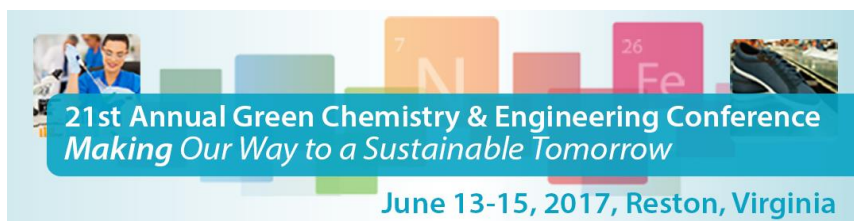


Richard Blackburn
Associate Professor,
University of Leeds

Slides available now! Recordings are edited and will be posted.

www.acs.org/acswebinars

This ACS Webinar is being co-produced with the ACS Green Chemistry Institute



- Sustainable Chemicals
- Flexible Chemical Manufacturing
- More Efficient Processes
- Green Chemistry Curricula
- Circular Economy Considerations
- Sustainable Materials
- Academic-Industry Collaborations
- Chemicals Policy
- Cosmetics
- And More!

Early Bird Registration will be open from February 15 until April 28, 2017

gcande.org

57

Upcoming ACS Webinars

www.acs.org/acswebinars



Thursday, April 13, 2017

The Good, The Bad and the Uncertain: Public Perception of the Chemical Enterprise

Session 3 of the Industry Science Series

Mark Jones, Executive External Strategy and Communications Fellow, Dow Chemical
William Carroll, Founder, Carroll Applied Science and Adjunct Professor of Chemistry, Indiana University



Thursday, April 20, 2017

Cystic Fibrosis: Discovery of CFTR Modulators

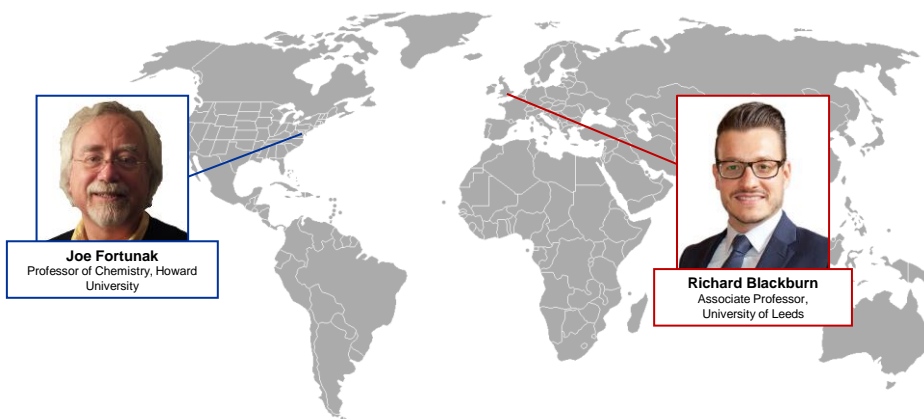
Session 4 of the 2017 Drug Design and Delivery Symposium

Peter Grootenhuis, Senior Director Chemistry, Vertex
Nick Meanwell, Executive Director, Bristol-Myers Squibb

Contact ACS Webinars® at acswebinars@acs.org

58

“Sustainability Challenges of the Textiles, Dyeing and Finishing Industries: Opportunities for Innovation”



Joe Fortunak
Professor of Chemistry, Howard University

Richard Blackburn
Associate Professor,
University of Leeds

Slides available now! Recordings are edited and will be posted.

www.acs.org/acswebinars

This ACS Webinar is being co-produced with the ACS Green Chemistry Institute

59

How has ACS Webinars® benefited you?

Quote in reference to: <http://bit.ly/CosmeticChemistry>

“This ACS Webinar presented just the right mix of actual chemistry and practical applications to make it worthwhile for every participant. I used to work in the field myself and really appreciated the way the presenter organized the material.”

Fan of the Week

Frans Zonnevrijle, Consultant
Intex Diagnostika AG,
ACS member for 40 years strong!



Be a featured fan on an upcoming webinar! Write to us @ acswebinars@acs.org

60

Upcoming ACS GCI Webinar!



Nanomaterial Design Guided by the Principles of Green Chemistry

Thursday, May 18 @ 2-3pm ET



How can green chemistry be applied to nanotechnology to achieve the high performance needed for advanced applications while preventing or reducing health and environmental impacts? Join James Hutchison from the University of Oregon as he discusses the foundations for greener nanotechnology and presents a case study that uses nanomaterial product innovation guided by green chemistry.

[Register Now!](#)

What You Will Learn

- The opportunity to achieve a net environmental benefit by bringing together green chemistry with nanoscience
- The role that green chemistry plays in designing high performance nanomaterials and efficient nanomaterial production
- How green chemistry and nanoscience can be used together to develop innovative new products with environmental benefits



Experts



James Hutchison
University of Oregon



Joe Fortunak
Howard University

Co-Produced With



<http://bit.ly/GreenNano>

61



facebook.com/acswwebinars
@acswwebinars
youtube.com/acswwebinars

Stay connected...
Email us!
acswwebinars@acs.org

ACS Webinars
CLICK • WATCH • LEARN • DISCUSS
www.acs.org/acswwebinars

Search for "acswwebinars" and connect!

62

Benefits of ACS Membership



Chemical & Engineering News (C&EN)
The preeminent weekly news source.



NEW! Free Access to ACS Presentations on Demand®
ACS Member only access to over 1,000 presentation recordings from recent ACS meetings and select events.



NEW! ACS Career Navigator
Your source for leadership development, professional education, career services, and much more.

<http://bit.ly/benefitsACS>

63

ACS Webinars® does not endorse any products or services. The views expressed in this presentation are those of the presenter and do not necessarily reflect the views or policies of the American Chemical Society.



Contact ACS Webinars® at acswebinars@acs.org

64

Upcoming ACS Webinars
www.acs.org/acswebinars



Thursday, April 13, 2017

The Good, The Bad and the Uncertain: Public Perception of the Chemical Enterprise

Session 3 of the Industry Science Series

Mark Jones, Executive External Strategy and Communications Fellow, Dow Chemical
William Carroll, Founder, Carroll Applied Science and Adjunct Professor of Chemistry, Indiana University



Thursday, April 20, 2017

Cystic Fibrosis: Discovery of CFTR Modulators

Session 4 of the 2017 Drug Design and Delivery Symposium

Peter Grootenhuis, Senior Director Chemistry, Vertex
Nick Meanwell, Executive Director, Bristol-Myers Squibb

Contact ACS Webinars[®] at acswebinars@acs.org

65