Unit 6.2 Sustainable pre-treatment, dyeing and printing

Content

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6.2.1 Waterless pre-treatments

purpose

- Preparation of textiles for dyeing, printing and/or finishing
- Elimination of water use for textile pre-treatment

treatments

- Plasma

- UV[1]
- Gamma irradiation
- Laser

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Plasma

- Plasma is a fourth state of matter or partially ionised gas which is produced from electrical discharge under atmospheric or low pressure.
- The particles of ionised gas collide with the textile surface and depending on the processing gas and treatment time different effects can be achieved.

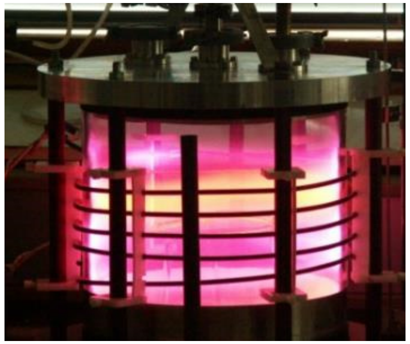

Figure 1. Plasma

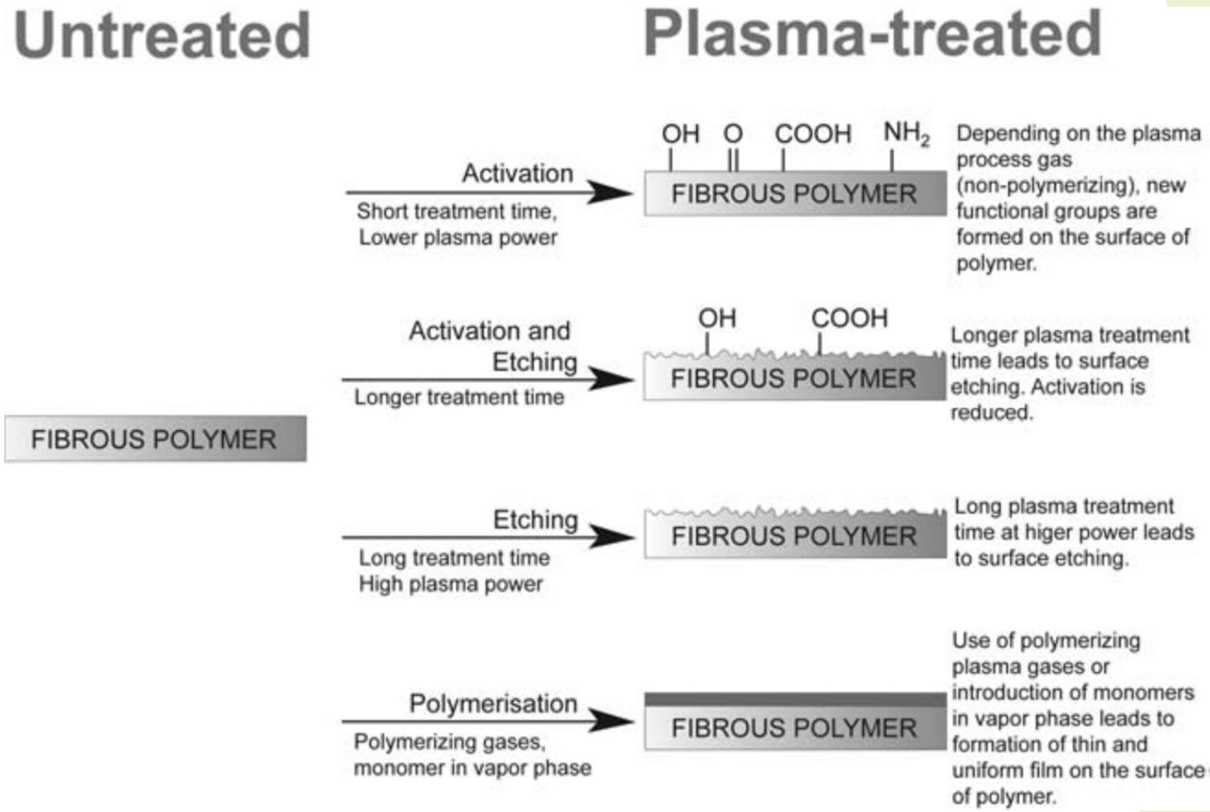

Figure 2. Surface effects on textiles after plasma treatment[2]

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Plasma pre-treatment

Increased hydrophilicity

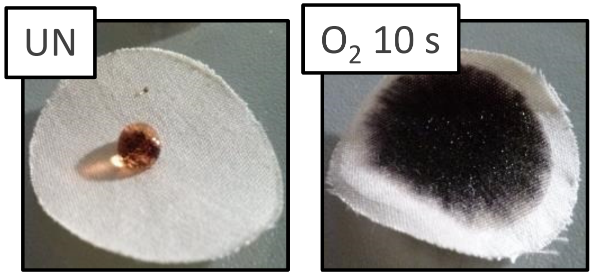

Figure 3. Cotton[3]

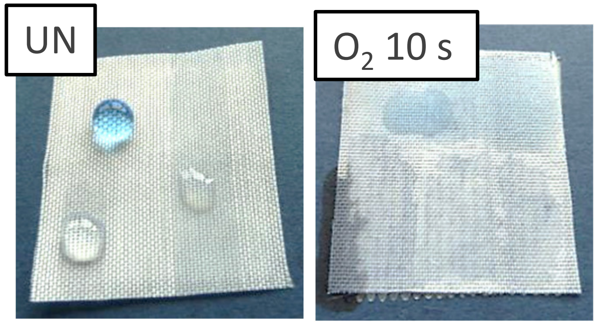

Figure 4. Polyester[4]

Increased dyeability

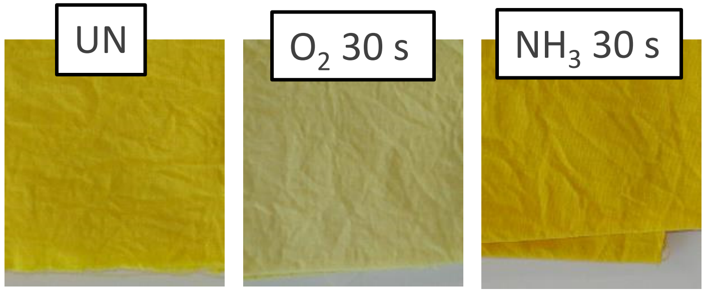

Figure 5. CO dyed with curcumin[3]

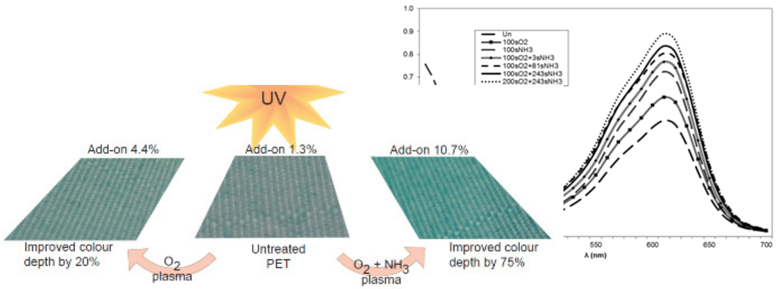

Figure 6. PES dyed with UV-responsive microcapsules[5]

Increased functionality

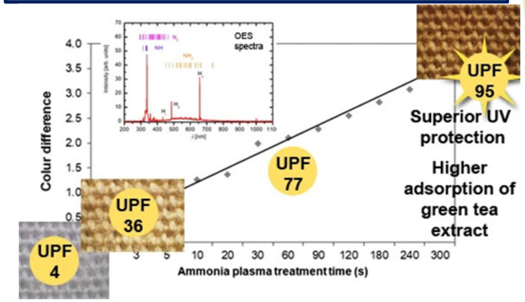

Figure 7. CO dyed with green tea[3]

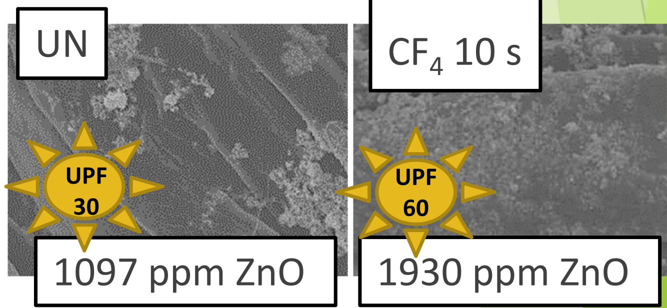

Figure 8. ZnO on CO[6]

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UV treatment

- Ultraviolet (UV) radiation is an electromagnetic radiation with a wavelength from 400 to 100 nm.
- Surface of the fibres must be able to absorb UV radiation directly or through previously applied photo initiator (which has to be odour-free, non-toxic, inexpensive and easily removable by aqueous washing).
- The surface modification is known as photosensitized oxidation process.
- UV treatment is not appropriate for textiles sensitive to UV degradation.

UV treatment is more applicable in finishing process, i.e. for curing 3D printing on textiles and fiber-reinforced composites.

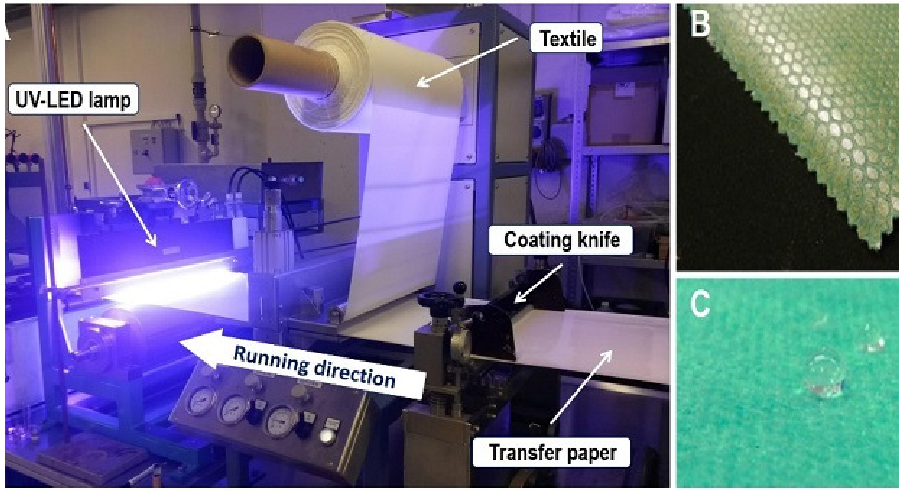

Figure 9. Transfer coating process with UV-LED curing[7]

Gamma irradiation

- Gamma radiation is an electromagnetic penetrative ionizing radiation produced during the radioactive decay of the atomic nucleus.
- Treatment results in bond breaking, the effects being formation of excited states, short life radicals and formation of new bonds.
- In industry gamma irradiation is used for sterilization and DNA alteration in plants, and in research for modification material properties.
- Limitations: high price and safety

Increased dyeability

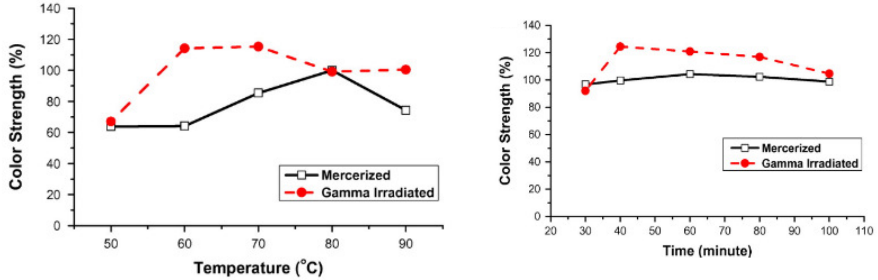

Figure 10. Dyeability of cotton after gamma irradiation[8]

Enhanced linkage between textile and coatings

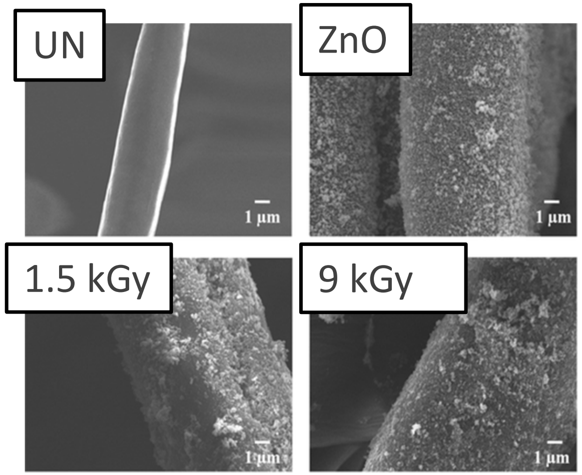

Figure 11. ZnO NP coated CO[9]

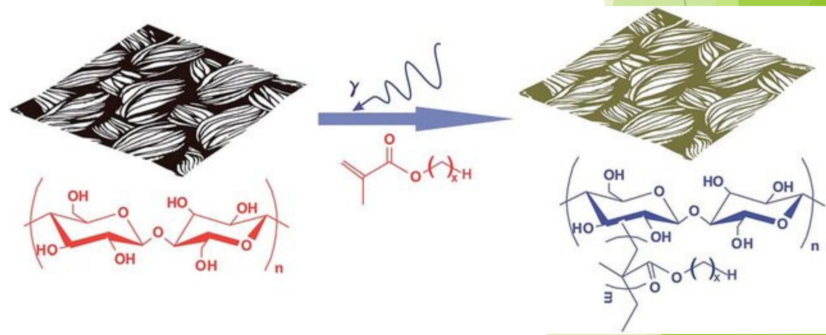

Figure 12. Graft polymerization process for synthesizing super-hydrophobic fabrics [10]

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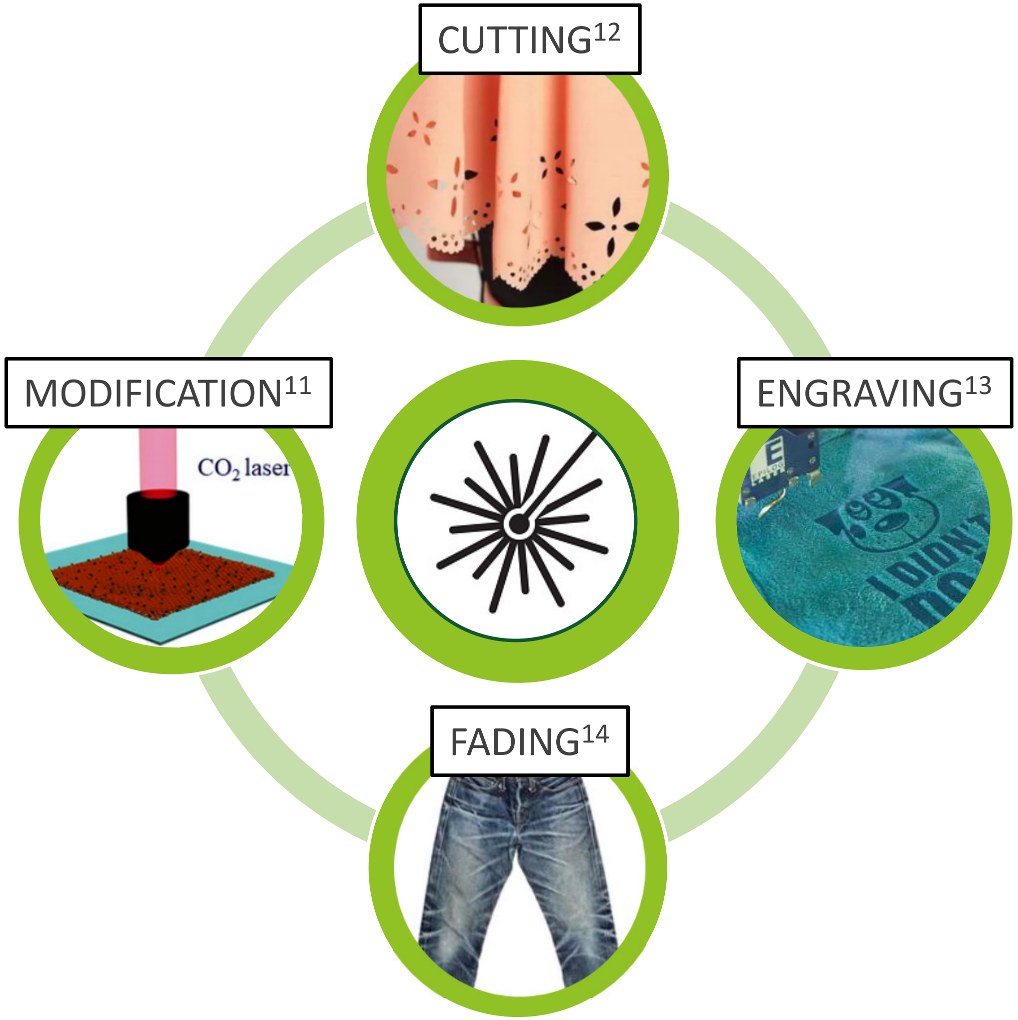
Laser

- LASER (Light Amplification by Stimulated Emission of Radiation)
- Lasers are optical devices that are developed to obtain very strong, coherent, and single colour light.
- In textile industry and research the most common laser used is carbon dioxide (CO_2) laser with wavelengths of 10.6 µm.



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Laser pre-treatment

Increased dyeability

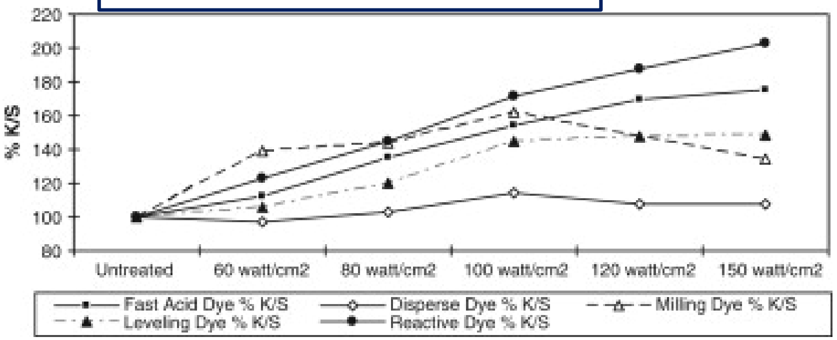

Figure 13. %K/S of untreated and treated PA fabrics[15]

Decreased pilling tendency

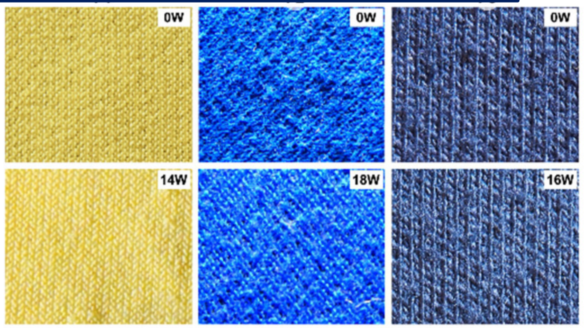

Figure 14. Knitwear surfaces after pilling test[16]

Surface and wettability changes

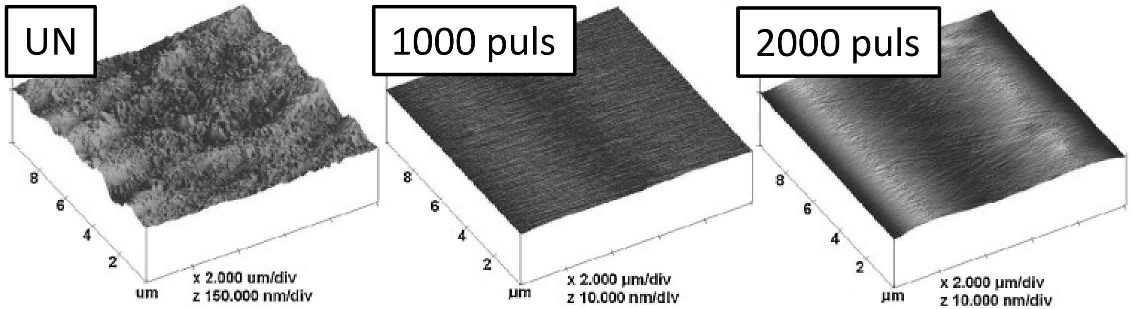

Figure 15. Surface morphology of untreated and laser treated PLA[17]

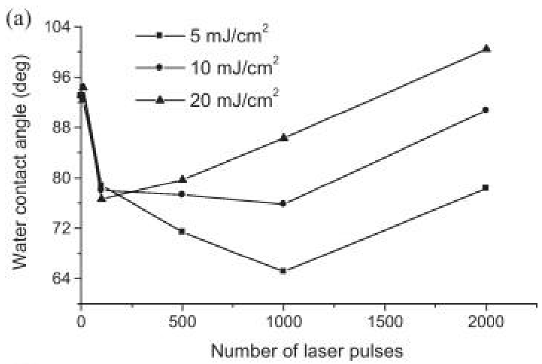

Figure 16. Water contact angles on PLA[17]

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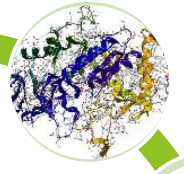
6.2.2 Sustainable pre-treatments

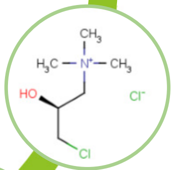
purpose

- Preparation of textile for dyeing, printing and/or finishing
- Replacement of harsh chemicals for textile pre-treatment

treatments


Enzymes[18]


Chitosan[19]



Cationization


Bio-mordants[20]

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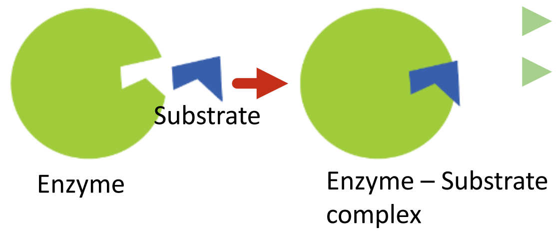
Enzymes

- Enzymes are chemically complex 3D proteins of high molecular weight, they are biocatalysts, which can speed up the chemical processes.
- Enzymes are classified and named according to the chemical reaction they catalyze.
- Enzymes are relatively fragile substances and they are susceptible to degradation due high temperature, ionizing radiation, light, acids, alkalis, and biological factors.
- Commercially enzymes are obtained from animal tissue, plants and microbes.
- Enzymes are biodegradable and eco-friendly.

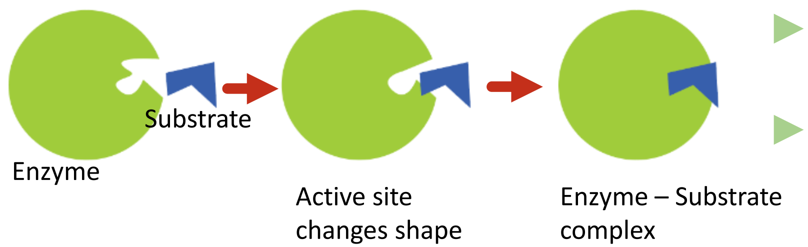
Mechanism of enzyme action

Lock and key model



- Early theory
- Enzyme-substrate have specific shape to fit exactly into another

Induced fit model



- Enzymes are flexible structures
- Active site can change the shape to fit with substrate

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Enzymes

Table 1. Use of enzymes in pre-treatment

Process	Classical chemistry	Enzyme
Desizing (removal of coating on yarns applied for their protection during weaving)	Acids, alkalis, or oxidizing agents	Amylase, lipase
Scouring (cleaning process for raw (cellulose) textiles before dyeing, printing, finishing)	Alkalis, high temperature	Pectinase, cellulase, cutinase
Bleaching	Bleach	Oxidoreductase, xylanase
Shrinkproofing of wool	Chlorine-based	Proteinase, lipase

Use of enzymes in post-treatment

- Bio-polishing
- Bio-stoning

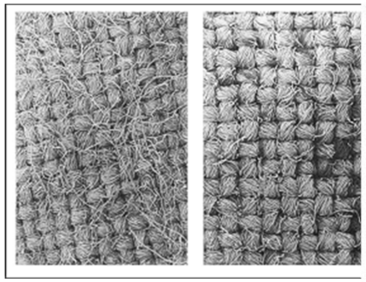

Figure 17. Use of enzymes for bio-polishing (left) and bio-stoning (right)[21]

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Chitosan

- Chitosan is natural resource refined from the waste products of the crabbing and shrimp industry.
- Cationic in nature
- Biodegradable
- Antimicrobial

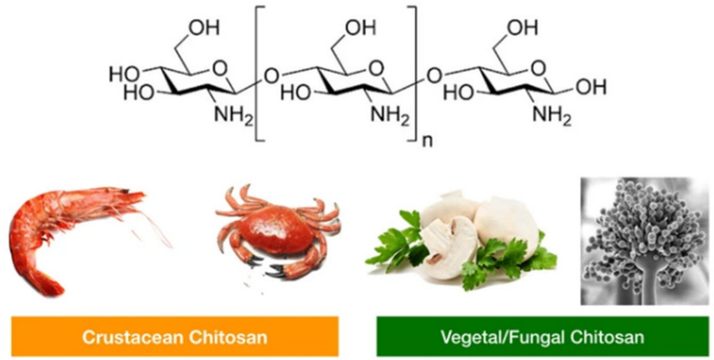

Figure 18. Chitosan source[22]

Increased dyeability

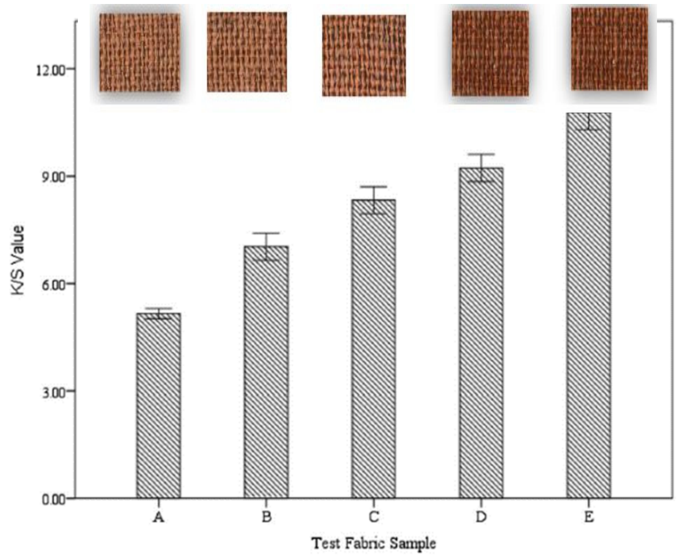

Figure 19. K/S of treated cellulose textiles[23]

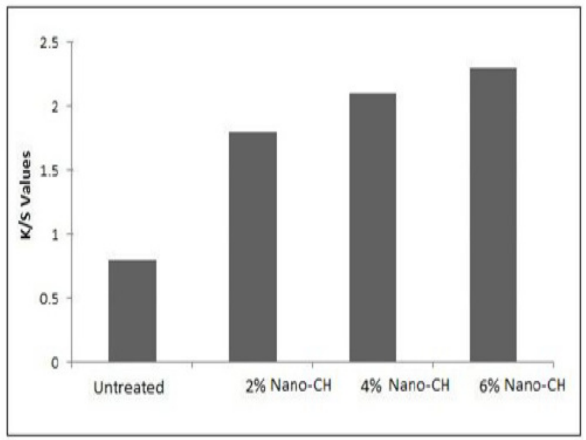

Figure 20. K/S of treated PET[25]

Cationization

- Sustainable chemical pre-treatment of cellulosic textiles
- Introduction of positively charged sites on cellulosic textiles
- Enables electrostatic attraction between the fiber and the negatively charged dye molecules
- Elimination of the need for electrolytes in the cotton dyeing process and increasing the dye exhaustion and colour yield of the fabric.

Table 2. Most common chemical cationic agents

Name of the cationic agent
3-(Chloro-2-hydroxypropyl) trimethylammonium chloride (CHPTAC)
2,3-epoxypropyltrimethyl ammonium chloride (EPTAC), also known as glycidyltrimethylammonium chloride (GTA)

Increased dyeability

Figure 21. Colour of untreated (left) and cationised (right) cotton dyed with vat dyes[25]

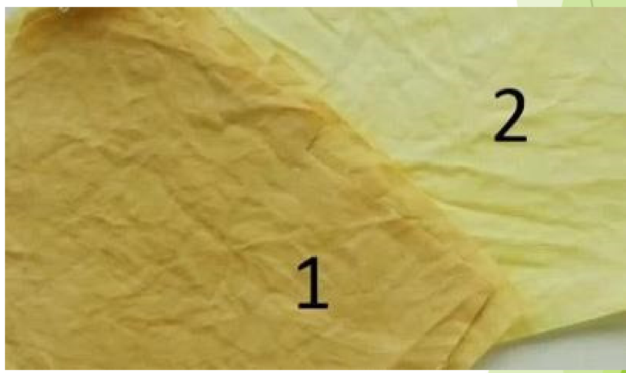

Figure 22. Colour of cationised (1) and untreated (2) cotton dyed with natural dye[26]

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Bio-mordants

- Mordanting is a pre-treatment to dyeing with natural dyes
- To achieve higher dye adsorption
- To change the hue of the dyed textile
- To increase fixation of natural dyes

Table 3. Metal mordants and bio-mordants

Metal mordants (environmentally acceptable)	**Bio-mordants** (derivates from biowastes, biomaterials, and by-products from food, beverage, timber, agriculture industries)
Potassium aluminum sulfate (Alum)	Tannin (tree bark, plant leaves, insect galls)
Iron sulfate	Cream of tartar (potassium hydrogen tartrate; acidic byproduct of fermenting grapes into wine)
Stannous chloride (Tin)	Chitosan (waste product of crabbing and shrimp industry)
Copper sulfate	Soy milk (soya bean seed waste)

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6.2.3 Water-free and water-low dyeing

purpose

- Reduction of water pollution
- Reduction or elimination of water use for dyeing

treatments

- CO_2 – Dyeing in carbon dioxide
- Foam dyeing
- Spun dyeing

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Dyeing in CO_2

- The use of CO_2 instead of water for dyeing eliminates the use of water as well as processing chemicals
- The temperature of the vessel with the dyed fabric is reduced and as a result the CO_2 leaves the vessel in the form of a gas. 95% of this released CO_2 is recovered and stored in the form of liquid for further use.
- Only polyester fabrics can be dyed.

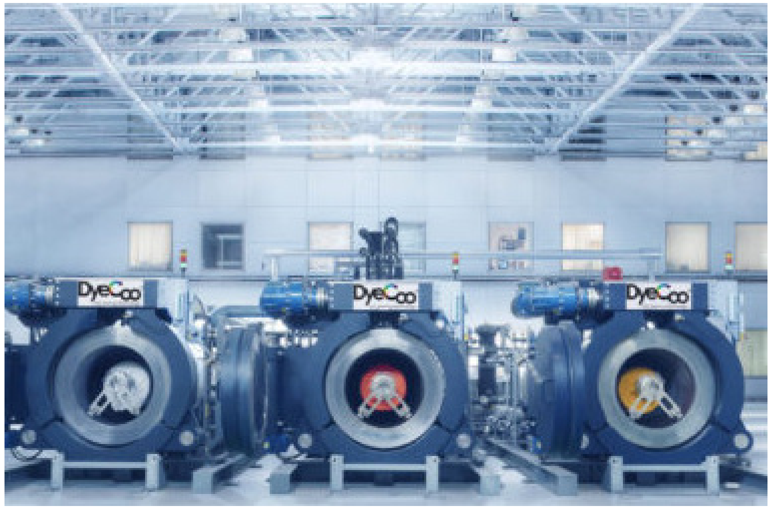

Figure 23. Dyeing PES in CO_2[27]

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Foam dyeing

- The main dyeing medium is foam (dispersion of a gas in a liquid)
- Foam is formed from aqueous solution of dye, foaming agent and carrier for dye.
- Fabric is padded with foam and treated at high temperature to enable fixation of dye

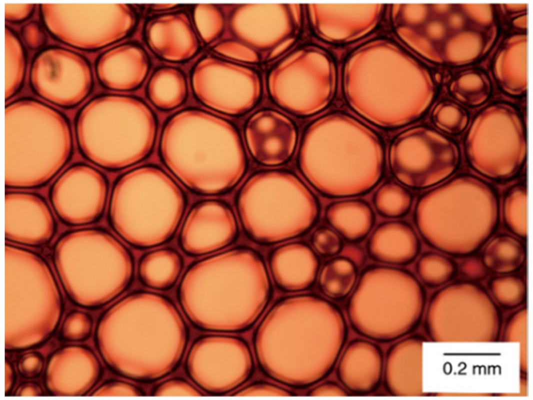

Figure 24. Foam dyeing solution[28]

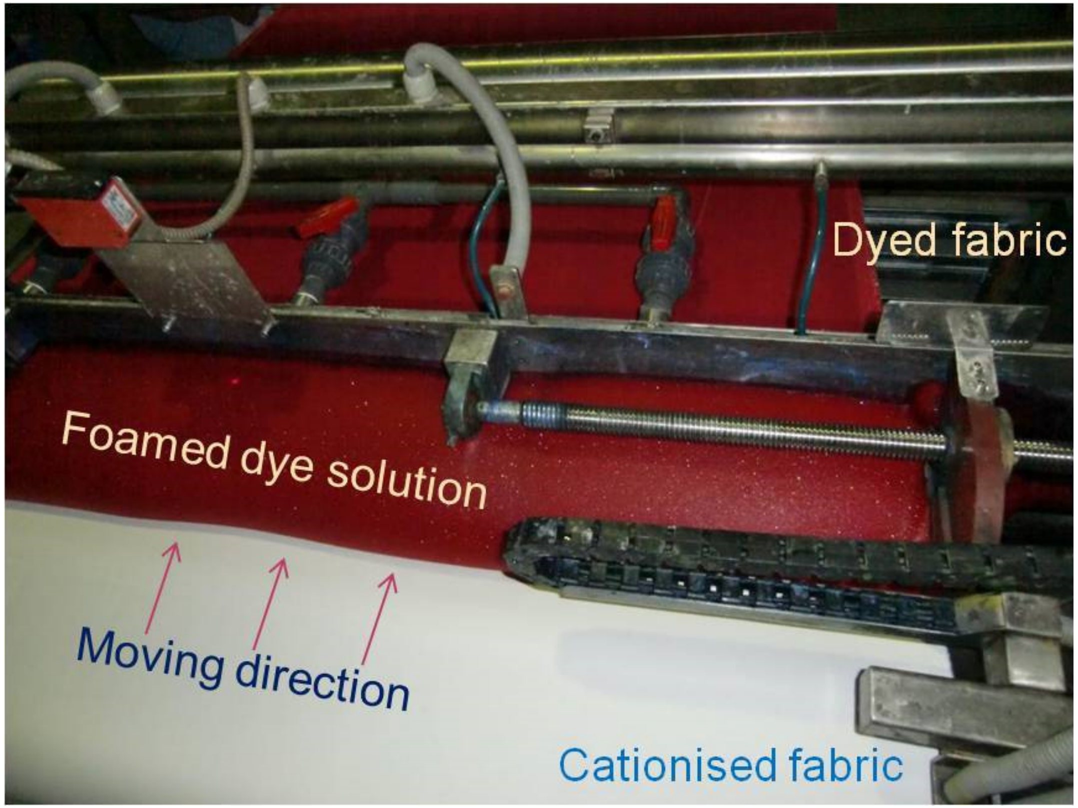

Figure 25. Foam dyeing[29]

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Spun dyeing

- Other names: mass dyeing, dope dyeing, gel dyeing, solution dyeing
- The process of coloring fibers or yarns by incorporating pigments or dyes during fibre spinning.
- Only man-made fibers can be spun-dyed.

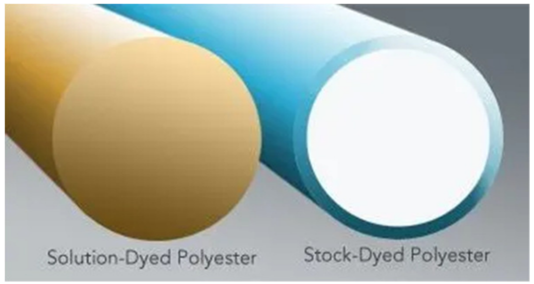

Figure 26. Solution (left) and stock (right) dyed PES[30]

Melt spinning dyeing

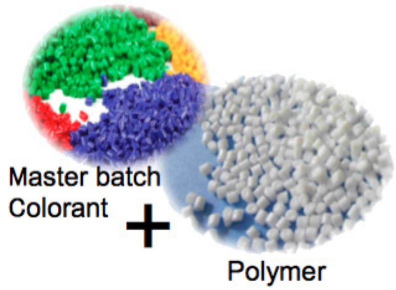

Figure 27. Colorant and polymer for melt spinning[31]

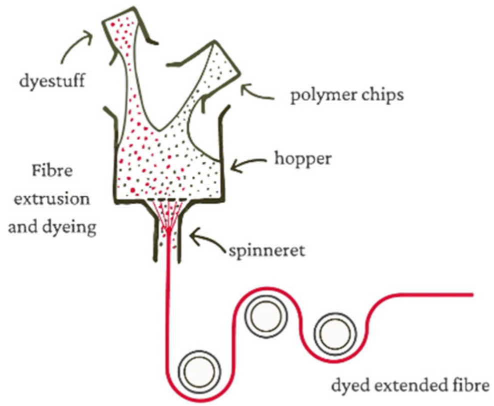

Figure 28. Schematic presentation of spun dyeing in melt spinning process[32]

Solution spinning dyeing

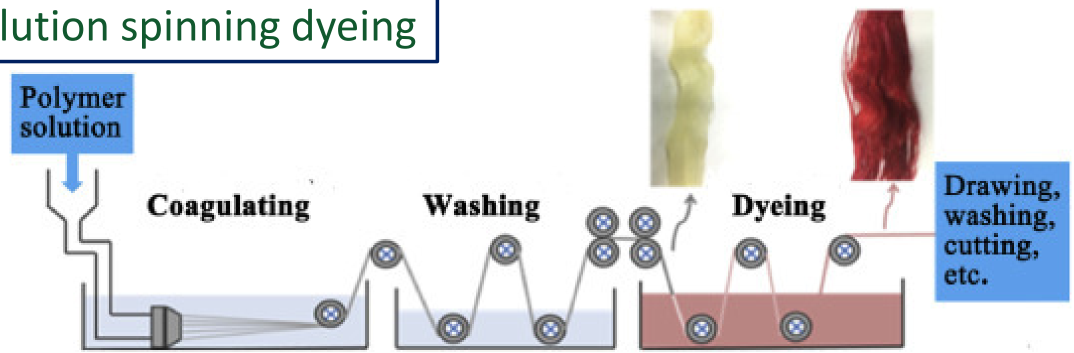

Figure 29. Schematic presentation of spun dyeing in solution spinning process[33]

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6.2.4 Dyeing with sustainable dyes

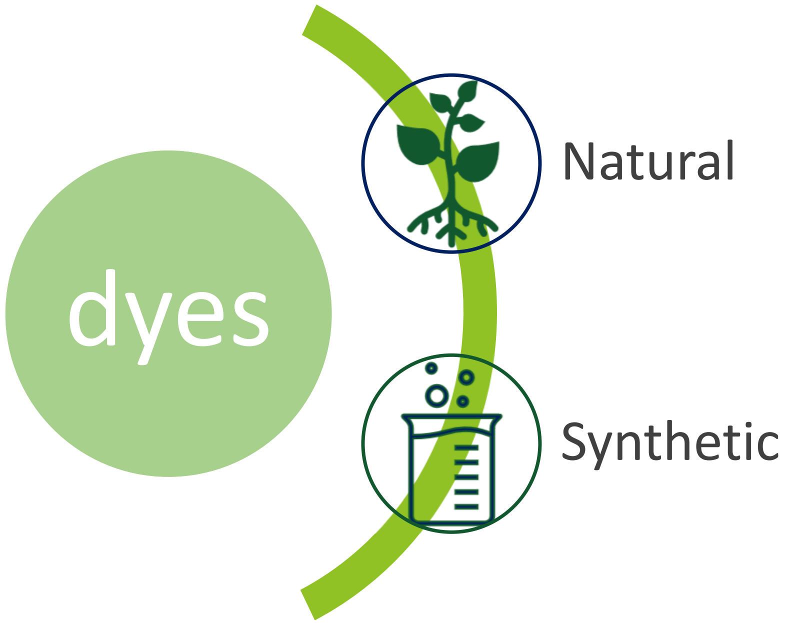

Figure 30. Indigo dyebath[34]

Figure 31. Field of indigo plant[35]

Figure 32. OEKO TEX label[36]

Figure 33. GOTS label[37]

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6.2.4 Dyeing with sustainable dyes

Origin of natural dyes:

- Cultivated plants
- Cultivated animals
- Food-waste
- Alien invasive plants
- Other source of plants

Figure 34. Madder[38]

Figure 35. Indigo[39]

Figure 36. Sappan[40]

Figure 37. Cochineal[41]

Figure 38. Food waste[42]

Figure 39. Alien invasive plants[43]

Figure 40. Other source[45]

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6.2.4 Dyeing with sustainable dyes

Figure 41. Caffe and avocado pit as textile dye

Figure 42. Staghorn sumac, Japanese knotweed and goldenrod as textile dye

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6.2.4 Dyeing with sustainable dyes

Figure 43. Achroma dyes from food and herbal waste[45]

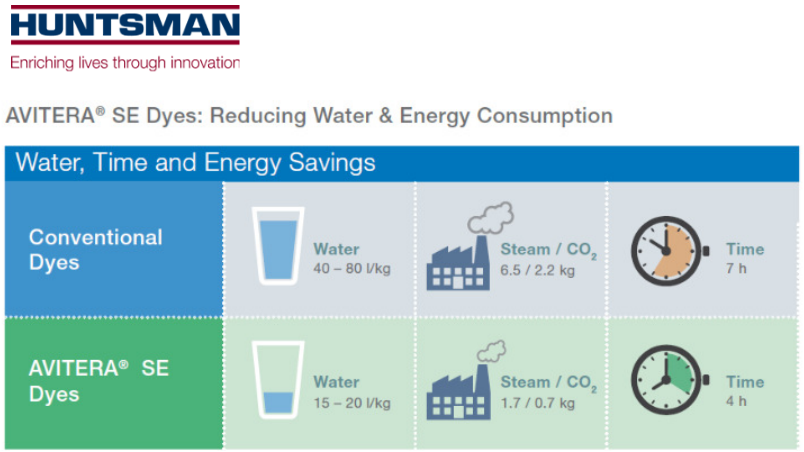

Figure 44. Para-chloro-aniline(PCA) free reactive dyes[46]

Figure 45. ECO awarded indigo dye[47]

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6.2.5 Digital printing

- A specialized form of roll-to-roll wide-format inkjet printing
- It was developed as 'suitable for sampling only'
- Reduces the water and energy consumption, waste, and water pollution associated with traditional textile printing
- No limitation on the usage of colours, printing detailed patterns, tonal transitions and graphically complex designs
- Evolution and development of digital printing contributed to the creation of the two main types of digital textile printers (multi-pass and single-pass)

Figure 46. Digitally-printed home textiles[48]

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6.2.5 Digital printing

- The mayor difference between a single-pass and multi-pass printer is in the way ink is distributed onto the fabric.

Table 3. Difference between multi- and single-pass printers

Multi-pass printers[49]	Single-pass printers[50]
	
Slower and lower production (4 meters per minute / up to million meters per year)	Faster and higher production (40 meters per minute / up to 20 million meters per year)
Smaller, very flexible, lower cost	Bulk, not flexible, very expensive

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6.2.5 Digital printing

The process

Figure 47. Flow of digital printing[51]

Table 4. Inks and textiles for digital printing

Inks for printing	Textiles suitable for printing
Direct-Disperse	For PES and PES blends. A post-print heat process is required.
Acid dyes	For PA and silk. Requires steaming to set the inks and washing to remove any residue. Post-print heat processing is used to permanently set the dye.
Reactive dyes	For cellulosic textiles. Requires steaming to set the inks and washing to remove any residue.
Pigment inks	For cellulosic textiles. Inks include binders that enable the pigments to adhere to the surface of fabric. A rotary heat calendar is used to fix the pigments to the fabric. Advanced pigment inks enable manufacturers to skip the post-print steaming and washing processes to reduce water and energy consumption.

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