L-Act biological surface modification

Fraunhofer IFAM & Fraunhofer IZI

Green process

Introduction

Polymers are the ideal material for many applications throughout all industries. They are stable and resistant to degradation, which is at the same time a problem, when an activation of the hydrophobic surface is required. This is usually achieved by drastic chemical or physical methods, which can be expensive, difficult to control and often leave a chemically ill-defined surface.

Nature has been solving this problem already. Probably starting with the occurrence of the first plants on dry land almost 500 million years ago lignin has become the presently second abundant natural polymer. Fungi living on wood can of course not swallow it, so they have developed stable enzymes which can stick for long time and under extreme conditions to the hydrophobic lignin.

With L-Act Fraunhofer has developed patented methods to use these unique features in novel applications for polymer surfaces.

Title image: Trametes versicolor. © Travel - iStock

Advantages

L-Act surface activation is an outstanding method compared to many other methods established to activate inert polymer surfaces:

- No energy consumption
- No additional chemicals required
- The required enzyme can be produced economically in large quantities.
- Perfect control of the addressed surface area, anywhere where a liquid can go
- Stable surface conversion

Key facts

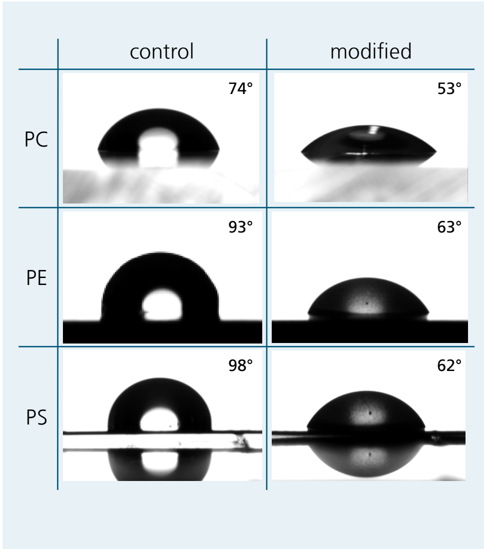
- Make polymers wettable
- For cell culture
- For painting
- Activation of inert surfaces
- Biological origin
- Green process
- Affordable, costs per m^2 are < € 1
- Fast

Contact Angle

The natural enzyme is designed to bind to hydrophobic surfaces, which is turning them hydrophilic and useful for multiple applications. It has been able to activate any surface but teflon®.

We tested polymers made from

- polystyrene (PS)
- polyethylen (PE)
- polypropylene (PP)
- Polycarbonates (PC)
- cycloolefins (TOPAS)



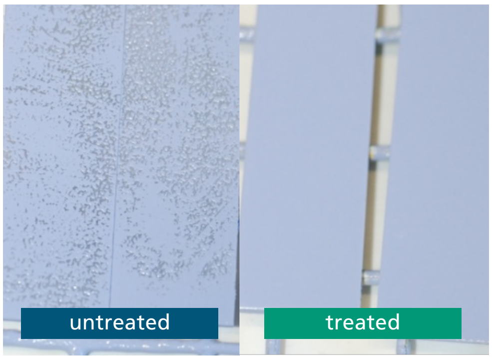
Contact angle of water drops after L-act treatment.

Treated surfaces are stable for more than one year (open and dry at room temperature).

Painting

The activation of polymer surfaces can be used as a pretreatment befor paint and laquer applications. L-Act can substitute classical methods like chemical, flame, corona and plasma treatment.

- Low energy consumption
- Low price
- Environmental friendly
- No hazardous waste
- Applicable on complex 3D-components



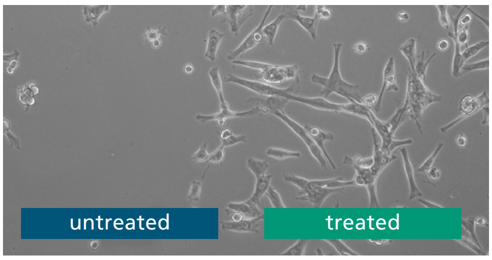
Polypropylene substrates with a VOC-containing 2-C polyurethane lacquer.

Cell culture

L-Act helps to activate surface making them suitable for cell culture.

L-Act can replace energy consuming surface activation (plasma, chemical, …), avoids the generation of toxic remains on the polymer surfaces and is applicable to any hydrophobic polymer surface.

Beyond this we have extablished further know how for including additional modifications.



Polypropylene.

Polystyrene.

Printing

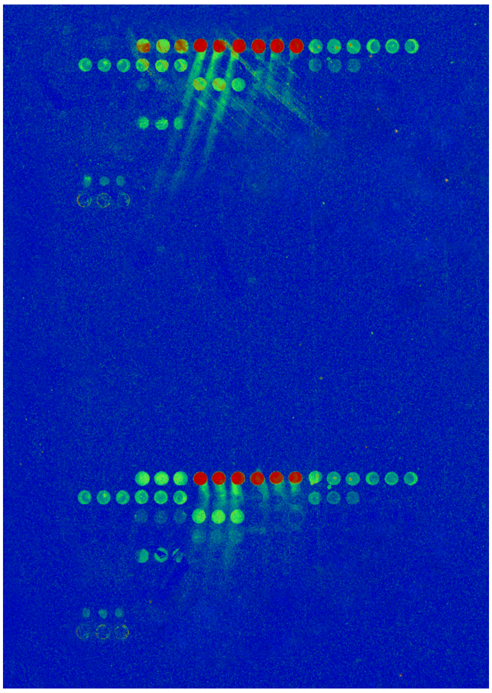
Most methods of activating surfaces require rough conditions and are diffcult to steer. L-Act can be used to activate selected areas with sharp boarderlines.

In the example on the last page the printing is used grow adhesive cells in a well defined pattern.

Priming inert surfaces – arrays

Chemical modification of surfaces often starts with chemicals, which are not well tolerated by polymers or not suitable for the final application.

Modification of surfaces and subsequent chemical coupling of peptides generates useful and fluorescence background free peptide arrays on TOPAS. This is a special technology just recently developed measuring antibodies directed at different peptide epitopes after vaccination, infections and in autoimmune disease.

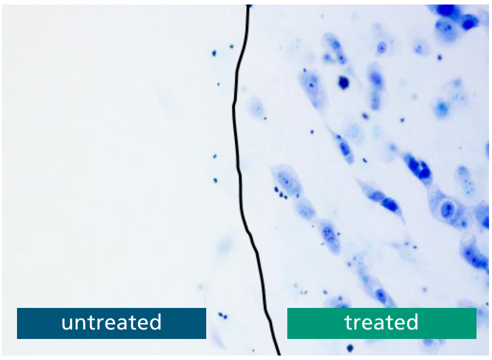


A series of peptide epitopes spotted in triplicates on activated TOPAS binding antibodies raised against a vaccine. Detection with Cy-5 labelled antibodies.

Medical implants

Polyetheretherketone (PEEK) is high potential polymer for dental and othopedic implants. PEEK is bioinert. To generate bioactivity peak must be treated by plasma, sputtering, wet chemical modifications and depositions.

- Laccase can turn PEEK very easily into a bio-active implant.
- The process can be applied easily under GMP conditions.
- No special machines or manufacturing lines are required.

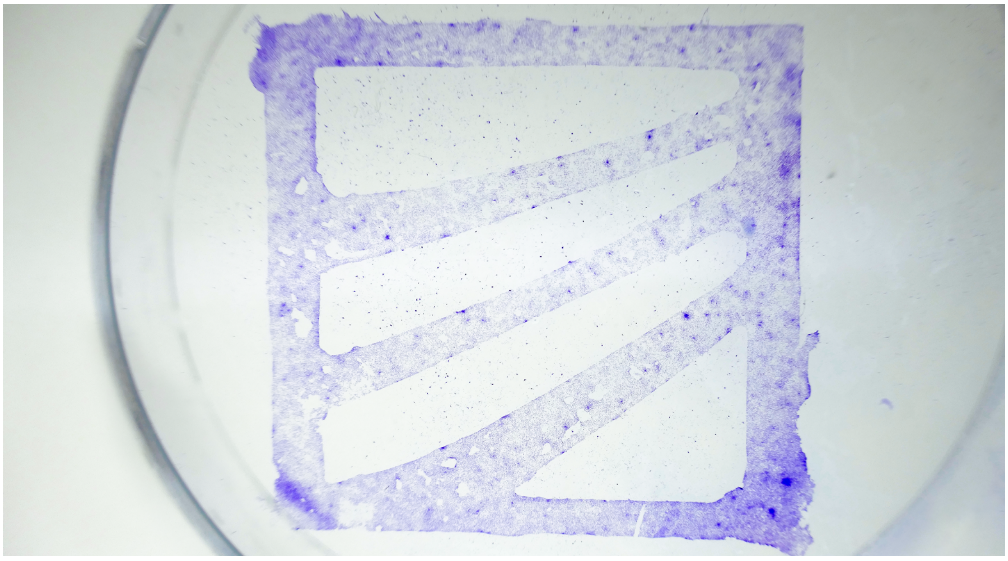


HT22 cells (mouse neuronal cell line) on PEEK, medical grade.

What are laccases

Laccases (benzenediol oxygen oxidoreductase, EC 1.10.3.2) are phenol oxidases that catalyze the oxidation of substrates such as polyphenols, methoxy-substituted phenols, diamines, and some inorganic compounds. In nature these enzymes are responsible for the degradation of lignocellulosic material, which is a structural part of wood. The modification of lignocellulosic materials (26) is attributed to the possible creation of phenoxy radicals at the fiber surface, and the cross-linking or loosening of the lignin structure, which is composed of non-hydrolyzable C–C and C–O bonds, resulting in degradation or polymerization.

Natural derived laccases are produced by fungi, living directly on the chopped trees.



Printing activated patterns: A filter matrix soaked with laccase solution was used to print the Fraunhofer logo in a petri dish (PS, not suitable for cell adhesion), generating a well defined surface area easily populated by eukaryotic cells.

Literature

Key publications

- Figueiredo Macedo de Lima J, Aguiar Jordao Mainardi MDC, Puppin-Rotani RM, Pereira Rodrigues-Filho U, Suzy Liporoni PC, Calegaro ML, Rischka K*, Baggio Aguiar FH. **Bioinspired catechol chemistry for dentin remineralization: A new approach for the treatment of dentin hypersensitivity.** Dent Mater. 2020 Apr;36(4):501-511. doi: 10.1016/j.dental.2020.01.012. Epub 2020 Feb 5.
- Corrales Ureña YR, Souza-Schiaber Z, Lisboa-Filho PN, Marquenet F, Noeske PM, Gätjen L, Rischka K. **Functionalization of hydrophobic surfaces with anti-microbial peptides immobilized on a bio-interfactant layer.** RSC Adv. 2020 Jan 2;10(1):376-386. doi: 10.1039/c9ra07380a. eCollection 2019 Dec 20.
- Macul Perez F, Corrales Ureña YR, Rischka K, Leite Cavalcanti W, Noeske PM, Safari AA, Wei G, Colombi Ciacchi L. **Bio-interfactants as double-sided tapes for graphene oxide.** Nanoscale. 2019 Mar 7;11(10):4236-4247. doi: 10.1039/c8nr08607a
- Brinkmann A, Szardenings M, Rischka K. **Enzyme ersetzen Plasmabehandlung.** J Oberfl Techn. 2018 May;58(5):32-33. doi: 10.1007/s35144-018-0107-9
- Corrales Ureña YR, Leite Cavalcanti W, Soltau M, Vollabos K, Rischka K, Noeske PM, Brune K, Dieckhoff S. **Interfactant action of an amphiphilic polymer upon directing graphene oxide layer formation on sapphire substrates.** Appl. Adhes. Sci. 2017 May;5(10). doi: 10.1186/s40563-017-0089-5
- Corrales Ureña YR, Gaetjen L, Vieira Nascimento M, Lisboa Filho PN, Leite Cavalcanti W, Noeske PM, Rischka K. **Investigations of biofilms formed on silica in contact with aqueous formulations containing laccase and maltodextrin.** Appl. Adhes. Sci. 2016 Feb 12;4(2).
- Corrales Ureña YR, Lisboa-Filho PN, Szardenings M, Gaetjen L, Noeske PM, Rischka K. **Formation and composition of adsorbates on hydrophobic carbon surfaces from aqueous laccase-maltodextrin mixture suspension.** Appl. Surf. Sci. 2016 Nov 1; 385: 216-224.

Patents

- **Composite with improved paint adhesion and method for producing the same.** EP3009469 B1
- **Method for marking or immobilizing a target structure.** EP2895858 (B1), CA2885036 (C), US9193986 (B2)
- **Method for activating a surface by increasing the hydrophilicity and/or for binding target structures.** US10011825 (B2), EP2861731 (B1)

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