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Textile-fixed Catalysts - a new Tool for Heterogeneous Catalysis

AUTHORS

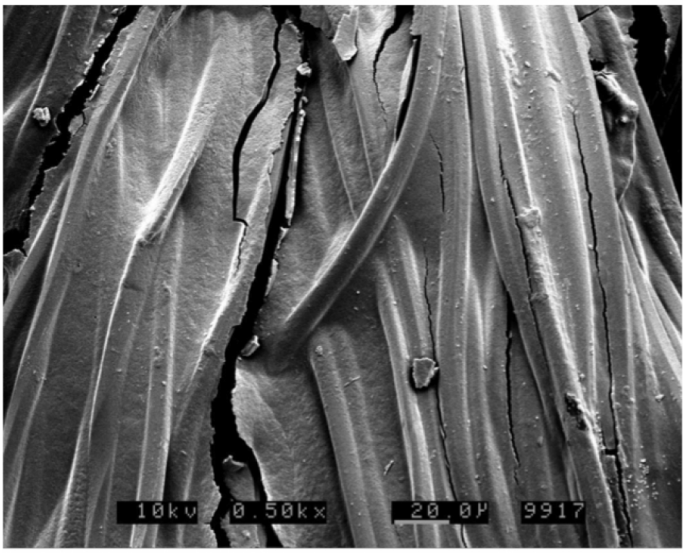
Klaus OPWIS / DEUTSCHES TEXTILFORSCHUNGSZENTRUM NORD-WEST GGMBH, ADLERSTRASSE 1, KREFELD
Jessica SCHNEIDER / DEUTSCHES TEXTILFORSCHUNGSZENTRUM NORD-WEST GGMBH, ADLERSTRASSE 1, KREFELD
Thomas MAYER-GALL / DEUTSCHES TEXTILFORSCHUNGSZENTRUM NORD-WEST GGMBH, ADLERSTRASSE 1, KREFELD
Jochen Stefan GUTMANN / DEUTSCHES TEXTILFORSCHUNGSZENTRUM NORD-WEST GGMBH, ADLERSTRASSE 1, KREFELD

PURPOSE OF THE ABSTRACT

The efficiency of many chemical processes is based on the use of catalysts. For many applications the catalysts are embedded in a solid matrix, which allows the recycling of the catalysts and the separation of the products. Such immobilizations offer the multiple or even permanent use. Common carrier materials are from polymeric or mineral nature. But their production and the charging with the catalysts are often complex and high-prized. In contrast, textile carrier materials made of cotton, polyamide or polyester are considerably inexpensive. The flexible construction of fabrics enables reactor constructions of arbitrary geometry and a quick removal of the catalyst without any residues after the reaction. Moreover, their open structure guarantees an optimal substrate turn-over and the active surface is easily adjustable by the fiber diameter. Here, we report some simple but efficient methods for the permanent fixation of various catalysts such as enzymes, organo-metallic and organic species on fiber forming polymers such as photo-induced grafting, the use of bifunctional anchor molecules, monomeric and polymeric cross-linking agents or specific catalyst modifications for a direct immobilization. The textiles were characterized by means of surface sensitive analyses such as UV-Vis or FT-IR(ATR) spectroscopy, scanning electron microscopy and EDX. In addition, the catalytic activity and the reusability of the textile-fixed catalysts were measured on the base of suitable model reactions. We have started our investigations with the immobilization of enzymes representing the class of biocatalysts. The successful immobilization procedures have been proven via scanning electron microscopy and other spectroscopic methods. We succeed in enzyme loads from 20 - 70 mg/g textile carrier. Exemplarily, Figure 1 shows a SEM picture of cotton fibers after the immobilization of catalase. All immobilization products show a distinct bio-catalytic activity even after 20 reuses. Depending on the used procedure the integral activity over 20 reuses reaches up to 350 % [1-4]. Afterwards, we have transferred our photo-chemical approach successfully to the immobilization of metal porphyrins and bispidines representing the class of organo-metallic catalysts [5]. The textile-fixed catalysts are useful for, e.g., various oxidation reactions and ?click chemistry? in organic synthesis. In collaboration with the Nobel Laureate 2021 Prof. Dr. Benjamin List (Max-Planck-Institut fuer Kohlenforschung, Muehlheim, Germany) we have broaden our concept successfully to organic catalysts [6]. With the help of ultraviolet light, the catalysts can be easily grafted onto simple nylon fabrics typically known from ladies tights. These textile-fixed catalysts can be used for various enantioselective chemical syntheses of industrial relevance. Especially a textile-fixed cinchona alkaloid shows an amazing performance with regard to catalytic activity, enantioselectivity and recyclability. For example, the desymmetrization of cyclic anhydrides (schematically shown in Figure 2) runs for more than 250 cycles without a significant loss of its catalytic activity and an impressive enantiomeric ratio of 96.5:3.5. Finally, we report our latest results on the immobilization of oxidoreductases (peroxidases and laccases) on textile carrier materials

and their potential application, e.g., in the gentle enzymatic degradation of food colors, the synthesis of natural flavors and the degradation of micropollutants in sewage water [7,8]. In summary, low-cost textile fabrics were identified as alternative carrier materials for catalysts. With a low preparative and economic expense fabrics with a high load, a high catalytic activity and excellent permanence against desorption can be produced. Therefore, our Textile-fixed Catalysts represent a new tool for heterogeneous catalysis with widespread potential applications in pharmaceutics, chemistry and eco-friendly white biotechnology.

FIGURES



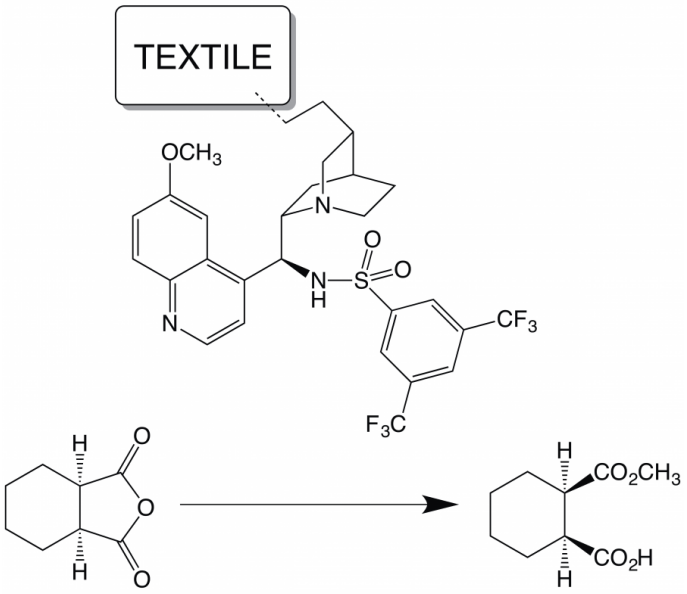


FIGURE 1

Figure 1

SEM of cotton fibers after the immobilization of catalase.

FIGURE 2

Figure 2

Use of textile-fixed organic catalysts for asymmetric syntheses.

KEYWORDS

textile | immobilization | enzymes | organic catalysts

BIBLIOGRAPHY

[1] Opwis K, Knittel D, Schollmeyer E (2004). Immobilization of Catalase on Textile Carrier Materials. AATCC Review 4, 25-28.

[2] Opwis K, Knittel D, Bahners T, Schollmeyer E (2005). Photochemical Enzyme Immobilization on Textile Carrier Materials. Engineering in Life Sciences 5, 63-67.

[3] Opwis K, Knittel D, Schollmeyer E (2007). Functionalization of Catalase for a Photochemical Immobilization on Poly(ethylene terephthalate). Biotechnology Journal 2, 347-352.

[4] Kiehl K, Straube T, Opwis K, Gutmann JS (2015). Strategies for permanent immobilization of enzymes on textile carriers. Eng. Life Sci. 15, 622-626.

[5] Opwis K, Mayer-Gall T, Textor T, Schollmeyer E (2009). Immobilization of Organometallic Catalysts on Textile Carrier Materials, in: Polymer Surface Modification: Relevance to Adhesion, Vol. 5, Mittal KL (Ed.), 177-185, Brill, Leiden.

[6] Lee JW, Mayer-Gall T, Opwis K, Song CE, Gutmann JS, List B (2013). Organotextile Catalysis. Science 341, 1225-1229.

[7] Wunschik DS, Ingenbosch KN, Suess P, Liebelt U, Quint S, Dyllick-Brenzinger M, Zuhse R, Menyes U, Hoffmann-Jacobsen K, Opwis K, Gutmann JS (2020). Enzymatic epoxidation of cyclohexene by peroxidase

immobilization on a textile and an adapted reactor design, Enzyme and Microbial Technology 136, 109512.

[8] Courth K, Binsch M, Ali W, Ingenbosch K, Zorn H, Hoffmann-Jacobsen K, Gutmann JS, Opwis K (2021). Immobilization of Peroxidase on Textile Carrier Materials and their Application in the Bleaching of Colored Whey, Journal of Dairy Science 104, 1548-1559.