Enzyme Printed Fabrics: Bio-functionalisation of Synthetic Textiles by Digital Inkjet Printing

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Abstract

This thesis explores the possibilities of printing enzymes using resource-efficient technologies to promote the binding of other proteins and biomaterials on synthetic textiles. This strategy can be used to develop advanced textiles for applications, for example, in antimicrobial, drug delivery and biosensing. Digital inkjet printing was combined with enzyme technology to ensure minimum use of water, chemicals and energy in textile manufacturing processes.

Inks containing two enzymes, lysozyme and tyrosinase, were formulated by adjusting several rheological and ionic properties. The activity of these enzymes was optimised while being printed through two different industrial grade piezoelectric printheads. The theoretical printability of the prepared inks was calculated. The effect of printhead temperature and number of printing passes on the activity was evaluated. Polyester (polyethylene terephthalate) and polyamide-6,6 were pre-treated through several techniques to understand their effect on enzyme adhesion, binding and activity retention. Tyrosinase was used to bind lysozyme on plasma activated polyamide-6,6 surface. The effects of printing these two enzymes in various sequences, i.e. tyrosinase before lysozyme and vice-versa on binding stability and activity, were studied. Influence of the printing process on enzyme kinetics was evaluated. Ability to store and reuse printed fabrics was also studied.

Lysozyme and tyrosinase containing inks showed activity retention of 85% and 60%, respectively. Activity of lysozyme containing ink was optimum at 10–15 mPa.s when glycerol was used as a viscosity modifier. However, the optimum viscosity for tyrosinase containing ink was at 6–9 mPa.s, and carboxymethyl cellulose was found to be the most favourable modifier. For both inks, a surfactant amount below the critical micelle concentration was considered to be the most effective for printing. Among the studied fabric pre-treatment methods (alkaline, cutinase and plasma), it was found that the activity and stability of the enzyme were dependent on the nature of the pretreatment processes, which can be beneficial for different application areas, e.g. drug release and bio-sensing. Upon printing both inks on a plasma treated polyamide-6,6, tyrosinase was able to catalyse lysozyme protein to bind it on fabric. A maximum of 68% lytic activity was retained by lysozyme when it was printed after tyrosinase. This fabric showed inhibition of bacterial growth and retained almost half of its initial activity when cold stored for a month.

Keywords: Digital printing, inkjet, enzyme, printhead, rheology, immobilisation, piezoelectric, drop-on-demand, resource-efficient textiles, biological ink, lysozyme, tyrosinase, polyphenol oxidase, polyethylene terephthalate, polyester, polyamide-6,6, nylon, surface modification, plasma, antimicrobial, antibacterial

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