Bio-Functional Polymer Coatings Based on Chemical Vapor Deposition

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INTRODUCTION

Future biomedical implant devices will use advanced surface engineering technologies to actively modulate tissue integration. Towards this goal, vapor-based polymer coatings have been interesting candidates for the coating of implant devices, because of their advanced processibility and their excellent intrinsic biocompatibility. For instance, a specific vapor-deposited polymer (polyxylylene) is already used in FDA approved drug-eluting stents. The commercially available coatings lack however, anchor groups for further modification and therefore don’t allow for immobilization of biomolecules.

EXPERIMENTAL

[2.2]-Paracyclophane Synthesis. Chemicals were purchased from Aldrich and were used without further purification. Friedel-Crafts acylation of [2.2]-paracyclophane with the corresponding acid anhydride, or acid chloride, using an excess of AlCl3 resulted in 4-acetyl [2.2]-paracyclophanes in high yields.

CVD Polymerization. Reactive coatings were obtained from the corresponding [2.2]-paracyclophanes by CVD polymerization using an installation consisting of a sublimation zone, a pyrolysis zone and a deposition chamber. The pressure was adjusted to 0.1 to 0.2 mbar and the pyrolysis zone was heated to 550 – 650 °C resulting in transparent films on the substrate.

Im mobilization. Micro CP was done by wetting a PDMS stamp with a solution of (+)-biotinyl-3,6,9-trioxadecanediylhydrazides in ethanol (1 mM). The stamp was dried with a stream of nitrogen for 20 s and pressed onto the sample surface for 60 s. The sample was removed, rinsed with distilled water followed by self-assembly of the target molecule.

RESULTS AND DISCUSSION

For CVD polymerization (Scheme 1), carefully purified dimer 1a to 4a were evaporated at a reduced pressure of 0.2 mbar at a temperature above 110 °C. In the case of 4-phenylacetyl[2.2]-paracyclophane (3a), polymerization delivered transparent and topologically uniform polymer films of thicknesses between 40 and 200 nm. The film thickness was mainly determined by the amount of 3a used for polymerization. The elemental composition of polymer 3b was determined by X-ray photoelectron spectroscopy (XPS) to be in good accordance with the theoretical composition. Decomposition of the phenylacetyl group was negligible, when pyrolysis temperatures under 780 °C and a working pressure between 0.15 and 0.2 mbar were chosen. The IR spectrum of polymer 3b confirmed the presence of the intact carbonyl bond as indicated by characteristic signals at wavelengths of 1665 and 1600 cm⁻¹. At higher pyrolysis temperatures (above 780°C), however, decomposition of the ketone group was observed according to the IR spectrum. Polymer 3b was chemically stable under ambient conditions for several weeks as determined by IR spectroscopy. Similar to other functionalized poly-p-xylylenes, polymer 3b showed good adhesion on various substrates, such as poly(dimethylsiloxane)(PDMS), poly(tetrafluoroethylene), gold, glass, or silicon. Polymer 3b is insoluble in ethanol or aqueous solutions. Incubation of a gold substrate coated with polymer 3 in an aqueous phosphate buffered saline (PBS) buffer (pH 7.4) for 7 d at room temperature did not affect its mechanical stability. Due to its structural analogy to benzophenone, the polymer’s aromatic keto group is photochemically activated at wavelengths around 340 nm and spontaneously reacts with surrounding molecules via C-H abstraction. Therefore, polymer 3b may have broad technical implications for preparation of bioinert and bacterial-resistant surfaces or as adhesion promoters of drug-releasing coatings for stent coatings.

Figure 1. Adsorption of fluorescence-labeled fibrinogen onto polymer 3b, which was photo-patterned with a 4-arm star-PEG (10kD) (dark regions). Square size is 50 µm.

Beside the photo-activated reaction of the phenyl acetyl group, ketones have also the potential to react with hydrazines or hydrazides. This is an excellent coupling reaction for specific immobilization of biomolecules.

In addition, surface-directed reactions via trifluoroacetyl groups was demonstrated by immobilization of biotin hydrazides and identified suitable reaction conditions that suit the surface character of the reaction as well as the specific requirements of CP (Fig. 2). Observed patterns were stable under ambient conditions, including sonication in a tenside-containing buffer (0.5% SDS buffer). Control experiments conducted with polystyrene and poly-p-xylylene did not show protein binding and confirmed the covalent nature of the binding.

Figure 2. TRITC-labeled streptavidin immobilized to a substrate coated with poly(trifluoroacetyl-p-xylylene) (1b). Patterning was achieved via microcontact printing of a biotin hydrazide. Spot diameter is 50 µm.

CONCLUSIONS

In this work, a class of polymer coatings (acetyl-functionalized poly-p-xylylenes) has been prepared by chemical vapor deposition (CVD) polymerization that provides chemically reactive groups for the immobilization of biomolecules. Surfaces and surface ligation reactions are characterized by infrared spectroscopy and X-ray
photoelectron spectroscopy. Bioinertness (Suppression of unspecific protein adsorption and cell adhesion) is monitored via fluorescence microscopy. These reactive coatings are compatible with soft lithographic processes allowing for patterning of proteins, oligosaccharides, DNA, and mammalian cells.

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REFERENCES