



Tough and translucent hydrogel electrode for electrochemical cleaning of paper artworks

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Received: 10 July 2019 / Accepted: 28 October 2019 / Published online: 5 November 2019
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Abstract

Due to the favorable retention power and viscosity, the hydrogel that is loaded with an aqueous detergent, represents a promising cleaning tool for removing the foreign matters such as polymer adhesive, starch paste, and animal glue from paper artworks. However, it is still challenging to eliminate other stains, including organic dyes, commercial drinks, foxing, and mildew. Herein, we present an alternative methodology, translucent hydrogel-containing electrolyte-based electrochemical cleaning (EC), which incorporates electrochemical reactions into the hydrogel-based cleaning process using the extremely tough and translucent alginate/polyacrylamide hydrogel as cathode and PbO_2 as anode. The proposed approach is generally applicable to eliminate different stains such as organic dyes, commercial drinks, mildew, and foxing from paper under several mA/cm^2 and a few minutes in a small controlled area. For the excellent mechanical strength, the hydrogel electrode can be reused for several times without losing its efficiency and easily peeled-off from paper as one body without any gel residues after cleaning. We further demonstrate the effect of EC on the treated paper, including the morphology, degree of polymerization, crystal structure, and mechanical properties. We conclude that the influence of EC on the paper is slight under the mild treatment.

Keywords Translucent · Tough · Hydrogel electrode · Electrochemical cleaning · Paper artwork

Introduction

Paper is one of the primary supports of culture and art. It is easily subjected to various pollutions, including factitious stains (e.g., organic dyes and commercial drinks), environmental contaminations (e.g., deposits of dust and molds), and degradation products of the paper itself. These

contaminations not only detract the aesthetics of paper artworks, but also accelerate the damage of paper [1]. Therefore, a cleaning process is necessary in the conservation of paper artworks. However, this process is delicate, because it is potentially invasive for the original materials, as well as completely irreversible. To clean soiled papers, different approaches such as traditional water cleaning, laser cleaning, and hydrogel-based cleaning have been reported [2–4]. Among these methods, hydrogel-based cleaning is a promising technique, because it significantly decreases the penetration of liquid into paper fibers, and thus minimizes damages [5]. To enhance the cleaning efficiency, an additional detergent is generally loaded in the hydrogel. For instance, a micro-emulsion was introduced into the acrylamide/bisacrylamide hydrogel to dissolve the synthetic polymeric adhesives [6]; α -amylase and proteinase were loaded in gellan hydrogels to hydrolyze starch paste and animal glue in papers, respectively [5, 7]; the gellan gum hydrogel holds titanium dioxide for removing fungi from papers with the assistance of UV radiation [8]. A combination of hydrogel and electrochemistry has been designed to conduct

Electronic supplementary material The online version of this article (<https://doi.org/10.1007/s13726-019-00765-9>) contains supplementary material, which is available to authorized users.

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