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Laser cleaning of particulates from paper: Comparison between sized ground wood cellulose and pure cellulose

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ABSTRACT

Visible laser cleaning of charcoal particulates from yellow acid mechanical ground wood cellulose paper was compared with that from bleached sulphite softwood cellulose paper. About one order of magnitude of fluence range is available for a cleaning dynamics between the cleaning threshold and the destruction threshold for two laser pulses. Wood cellulose paper exhibited a higher destruction threshold of the original paper than that of the contaminated specimen because of heat transfer from the hot or evaporating charcoal particulates. In contrast, the contaminated bleached cellulose paper exhibited a higher destruction threshold due to shading by the particulates. The graphite particles are not only detached thermo-mechanically, but also by evaporation or combustion. A cleaning effect was found also outside the illuminated areas due to lateral blasting. Infrared measurements revealed dehydration/dehydrogenation reactions and cross-links by ether bonds together with structural changes of the cellulose chain arrangement and the degree of crystallinity.

1. 1 Introduction

Laser cleaning of cultural heritage objects has been of great attention recently [1–5]. The treatment of organic materials such as paper or polymers exhibits the possibility of photochemical and photothermal degradation to a much greater extent than inorganic substrates such as stone. Sensitive and comparably unstable polymeric and paper materials are still under fundamental investigation [6–20].

Substrate destruction is minimized when visible laser wavelengths are chosen. This can be easily realized by the second harmonic of a Nd:YAG laser radiating at 532 nm [5,8,9,21–23]. The presence of pigments represents a further challenge in this context [23–26].

The application of ultraviolet laser radiation can be an alternative approach to visible radiation. There, a minimized light penetration depth can provide a quasi ultra-precise non-contact scalpel [27,28]. The intelligent wavelength mixing of infrared and ultraviolet radiation could provide interesting options for laser cleaning of organic materials [29].

Yellowing is an undesired side effect of laser intervention particularly with IR but also with UV wavelengths [8,11,19,30–32]. Paper cleaning studies at 1064 nm, 532 nm, 355 nm, 266 nm and 248 nm showed that least yellowing was generated at 532 nm [14–17,20,21,33].

The present study describes the application of 532 nm on originally yellowish acid mechanical ground wood cellulose paper with alum-rosin sizing in comparison to pure cellulose, i.e. bleached sulphite softwood cellulose paper without fillers and sizing. Charcoal served as contaminant model.

2. 2 Experimental

Acid mechanical ground wood cellulose paper with alum-rosin sizing served as model for lignin containing yellowish paper (Fig. 1b) which was in broad use in 19th century and during 20th century's war times. Alum means aluminium sulphate. Rosin, a solid resin obtained from pines and conifers, is semi-transparent with colours varying from yellow to black. It is used for paper sizing besides e.g. glazing agent in varnishes, adhesives, and sealing wax. The basic mechanism of rosin sizing involves the interaction of aluminium ions with the cellulose to provide bonds between the cellulose and the rosin [34]. Alum increases bonding between fibres during sheet formation resulting in increased wet strength of the paper.

This is compared with a practically pure cellulose sample, i.e. bleached sulphite softwood cellulose paper with no filler and no sizing (Fig. 2b). The bleached sulphite softwood cellulose paper is produced from a sulphite process which produces wood pulp, almost pure cellulose fibres, by using various salts of sulphurous acid to extract the lignin from the wood chips in large pressure

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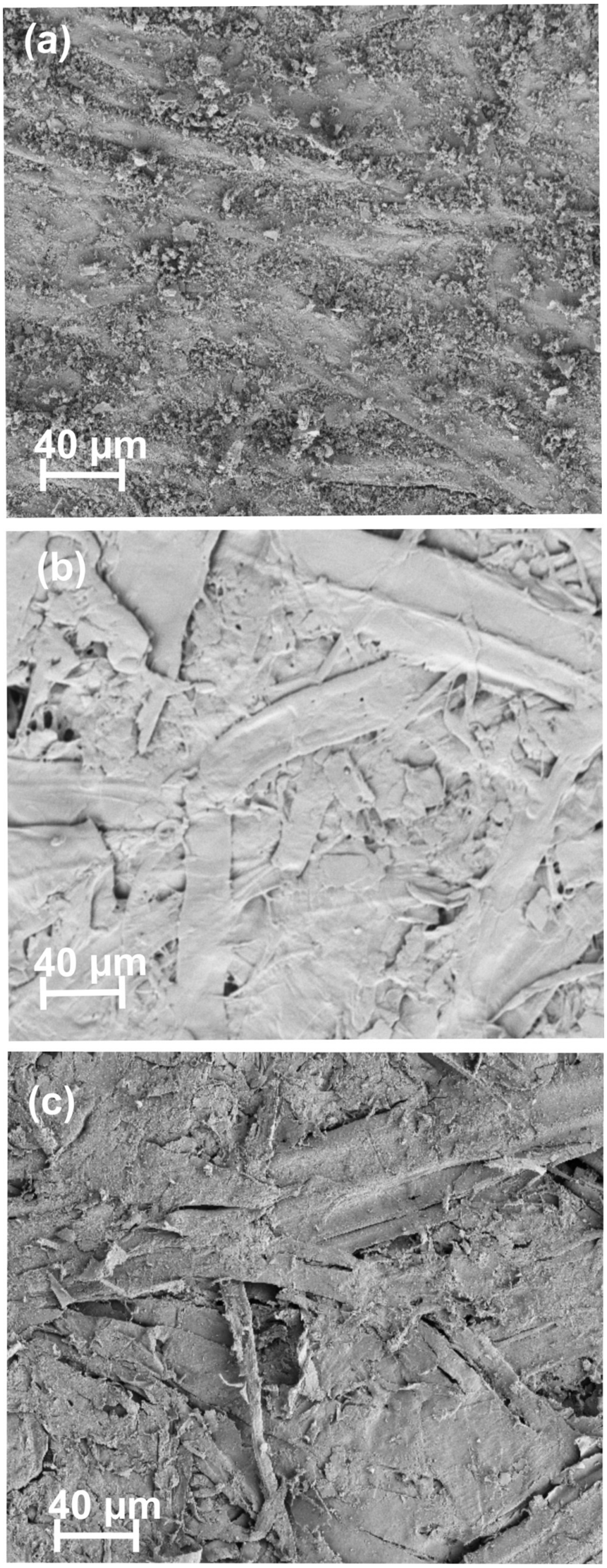

Fig. 1. Scanning electron micrographs of alum-rosin sized ground wood cellulose paper. (a) Contaminated with charcoal (high coverage); (b) original; (c) laser-cleaned, $N = 1$, $F = 1.71$ J/cm^2.

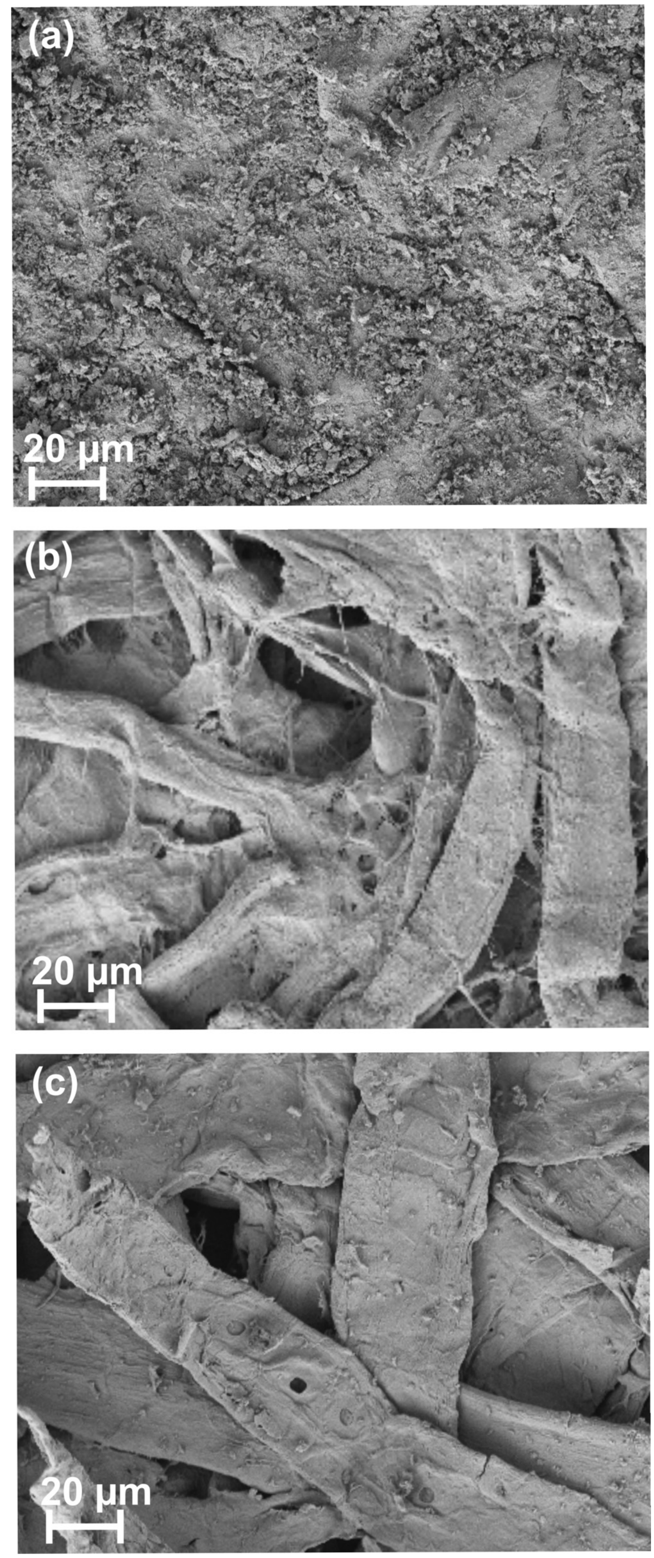

Fig. 2. Scanning electron micrographs of bleached sulphite softwood cellulose paper. (a) Contaminated with charcoal (high coverage); (b) original; (c) laser-cleaned, $N = 1$, $F = 1.71$ J/cm^2.