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Pulsed laser processing of paper materials

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Abstract

At present the trends in paper and packaging industries are the personalization of products and the use of novel high-tech materials. Laser processes as non-contact and flexible techniques seem to be the obvious choice to address those developments. In this paper we present a basic understanding of the occurring mechanisms of laser based engraving of different paper and paperboard materials, using a picosecond laser source at 1064 nm. The influences on the beam-paper-interaction of grammage, the composition of the paper matrix, as well as the paper inherent cellulose fibers were investigated. Here the ablation threshold of commercially available paper was determined and a matrix ablation effect under the 1064 nm radiation observed. These results were characterized and qualified mainly by means of laser scanning microscope (LSM) micrographs in combination with color-space analytics.

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Keywords: laser-based paper processing; IR-wavelength; ultra-short-pulses

1. Introduction

Nowadays paper as oldest fiber composite material is a functionalized high-tech material. Laser machining allows the production of finely and delicate design elements by cutting, scoring, perforating and engraving.

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Especially at small charge numbers or individual demands, common processes reach their limits and the laser process is advantageous (H. Pilii et al. 2009). The currently used laser systems are cw-CO2 lasers. These systems may affect unwanted material changes like bleaching or changing of colors e.g. at the cutting edges during the laser process by thermal decomposition of the material (A. Stepanov et al. 2010).

On the other hand also material inherent properties hamper the processing of paper materials. These are its manifold of thickness, different ingredients and finishing for example. Either a broad process window or specialized systems are needed to achieve a high quality laser processing.

In this study we utilize a 1064 nm picosecond pulsed laser system and show basic results of machining commercially available, standard paper substrates. These materials received no property enhancing treatments like absorption enhancing additives or a smoothening finish and thus can display the very basic laser-matter-interaction at short pulsed laser processing of paper.

2. Experimental Details

The chosen laser for this study was an ultra short pulsed system with a pulse duration of 12 picoseconds at a variable repetition rate (single pulse up to 8.2 MHz), a spot diameter of 30 µm and a maximum average power of 50 W at a wavelength of 1064 nm. In our experiments, repetition rate was fixed at 200 kHz and the pulse overlap Ω was set to be equally spaced in x- and y-direction. The parameters to vary were therefore the average power (3.1 W, 6.4 W, 9.5 W), number of transitions n (1 to 20), and overlap Ω (10 % to 90 %). The used average powers result in peak fluences F_0 of 4.39 J/cm², 9.05 J/cm², and 13.44 J/cm².

The thickness and basic optical properties, as a result of spectroscopic measurements, of the two used paper materials P1 and P2 are shown in Table 1. These are standard commercially available paper without any special coating or filler material. The used materials P1 and P2 are of similar composition, have therefore comparable optical properties, and differ in their overall thickness. The paper consists mainly of cellulose fibers, calcium carbonate as filler material, and a small fraction of binders. The optical properties are only measured for the overall paper and not for the single components.

Table 1. Thickness and optical properties of used papers.

Name	Grammage	Thickness	Reflectance (at 1064 nm)	Transmittance (at 1064 nm)	Absorptivity (at 1064 nm)
P1	220 g/m²	290 ± 8,2 µm	73,4 %	9,3 %	17,3 %
P2	300 g/m²	370 ± 2,1 µm	74,2 %	7,5 %	18,3 %

Next to the optical properties, the composition of the paper material causes a quite inhomogeneous structure (K. Niskanen et al. 1998) as seen in Fig. 1(a). Here especially the voids within the structure are visible. In Addition to the rough surface, the structure of the paper influences the laser processing and cause special obstacles like local change of absorptivity.