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Processing of polyamide electrospun nanofibers with picosecond uv-laser irradiation

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Abstract

To optimize the cell colonization on electrospun polyamide nanofibers, the fiber scaffolds were processed with picosecond uv-laser irradiation. The ablation thresholds were determined in dry, wet and immersed condition. The morphology of the ablated areas was evaluated by confocal and scanning electron microscopy. It was found that the ablation thresholds of the nanofiber tissues are lower as for polyamide bulk material. While on bulk samples the ablation spot sizes are close to the focal diameter, on the fiber samples the ablation spots are more extended. Light scattering in the fiber tissue has to be taken into account. The results show that with exact setting of the laser parameters it is possible to reduce the heat-affected zone to a few micrometer. In addition, changing of the nanofiber tissue wettability by laser radiation was investigated.

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Keywords: Picosecond laser; laser ablation; polyamide nanofibers; electrospinning; ablation threshold; uv-laser

1. Introduction

In the field of tissue engineering materials and systems are developed to support or substitute diseased tissues or organs (Wintermantel and Ha 2009). Cell carrier systems of electrospun polyamide (PA) nanofibers have great potential, since they offer a favorable ratio of surface area to volume and high mechanical stability. Several studies on the cytotoxicity also confirm the potential use of polyamide for short time implantates (Wintermantel and Ha

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2009). Studies on different cell carrier systems of electrospun polymers have already shown that the growth and proliferation of settled cells are controlled by direct modification of the surface of the support system (Lim et al. 2011). The surface structure and chemistry of these tissue replacement systems have significant influence on the adhesion, development and functionality of cells (Lim et al. 2011).

Laser systems with ultra short pulses can be used for modification and processing of electrospun mats (Choi et al. 2007; He et al. 2011; Lee et al. 2011; Jenness et al. 2012; Kim et al. 2014; Adomavičiūtė et al. 2015). In contrast to laser machining with pulse durations in the nanosecond range ultrafast processing with femtosecond-laser pulses often takes place without substantial heat transfer to the surrounding material (Wu et al. 2011). Today ultraviolet (uv) picosecond (ps) lasers are reliable and comparably compact systems for industrial micro material processing. So in this work the use of uv-laser pulses with pulse durations of several ps where investigated as an possible alternative for femtosecond (fs) laser pulses for processing of polyamide 6.6 bulk material and nanofiber tissues. To selectively modify the surfaces of the nanofiber tissues for the control of cell growth accurate knowledge of ablation thresholds and laser generated changes in the topography of the materials used is necessary (Baudach et al. 2000; Gedvilas and Raciukaitis 2005).

2. Materials and Methods

2.1. Electrospun polyamide nanofiber scaffolds

Polyamide 6.6 (Sigma Aaldrich) was dissolved in a blend of 50% acetic acid (Carl Roth) and 50% formic acid (Carl Roth) to a concentration of 15% (w/v). The commercial electrospinning device "Nanospider" (Elmarco) was used for the electrospinning process. The process was carried out at 80 kV with a working distance of the electrodes at 240 mm. The temperature was kept at 22°C and the relative humidity was about 30%.

2.2. Picosecond laser ablation

The experimental setup was based on a Nd:YAG laser system (Coherent Talisker 355-4) with the following parameters: wavelength λ = 355 nm, pulse duration τ_p = 15 ps, repetition rate f_{Rep} up to 200 kHz, maximum output pulse energy Q = 26 µJ and a beam quality factor $M^2 < 1.3$. The laser radiation was focused onto the surface of the sample by an f-theta lens with a focal length of 103.2 mm giving a spot diameter of 13.6 µm. The spot diameter was deterimined in previous experiments with different bulk materials using the D^2-model described in chapter 3.1. A galvoscanning system (Nutfield Razor Head 10) guided the laser beam across the sample and was controlled by the software SAMLight. In addition, the sample could be moved using a computer-controlled x-y-z stage.

2.3. Microscopy

The processed samples were evaluated with various microscopic techniques. Scanning electron microscope (SEM) images were taken with a Phenom (LOT). The samples were coated with thin layers of carbon or platinum. For optical microscopy an Olympus microscope (BX 60) with a camera (SC 50) was used.

2.4. Contact angle / Wettability

To quantify the surface wettability, the water contact angle of sessile drops was measured at room temperature and under ambient air conditions using a drop shape analyzer (DSA25E, Krüss). Sessile drops were comprised of 2µl deionized water and were released onto the substrate surface through a (1 ml, 0.5 mm diameter) syringe and observed by a camera.