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Microcutting of multi-layer foils with IR and green ns-pulsed fibre lasers for Li-Ion batteries

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Abstract

Li-Ion batteries are crucial components in mobile devices that range from cellular phones to electrical vehicles. With the increasing demand in the market for these devices, manufacturers are required to reduce production cycle times. The main components of the Li-Ion batteries are anode and cathode foils, which are cut in required forms by punching. These materials consist of Cu sheets sandwiched between graphite layers for anode, and Al sheets sandwiched between Li metal oxide layers for cathode. In punching, the process quality degrades in time due to tool wear. This eventually causes machine down times for tool repair or change, which can increase the whole process cycle time drastically. Laser remote cutting based on ablation can be adequate solution to substitute the current technology, if the cutting edge quality and productivity can be matched to punching. This paper investigates laser microcutting of Li-Ion battery anode and cathode thin foils with ns-pulsed fibre lasers. These laser sources are cost effective and provide industrially robust operation. Two systems operating with 1 µm and 0.5 µm wavelength and 250 ns and 1 ns pulse durations respectively were compared. The cut kerfs were evaluated in terms of clearance, which is defined as the extent of the exposed middle layer of the sandwich (i.e. Cu or Al) at the laser cut kerf.

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Keywords: Laser cutting; Laser micro machining; Li-Ion battery

1. Introduction

Li-ion batteries are crucial components for improved mobility of electronical devices. Laptop computers, cell phones and hybrid vehicles are only a few examples to products that make use of this technology [1-3]. With increasing demand in energy, their production the production faster and cheaper production becomes evidently important.

Electrodes constitute the key elements of the Li-ion batteries. The electrodes are in the shape of thin sheets and are composed of Cu sheets sandwiched between graphite layers for anode, and Al sheets sandwiched between Li metal oxide layers for cathode. These sheets are conventionally cut by punching on the fly in required shape and size. Due to increasing tool wear, the process quality degrades in time due to tool wear. Eventually, the tool requires change, which causes down time. The repair or replacement of the tool itself is another added cost.

Nomenclature

d_0	Beam diameter at focal point
E	Pulse energy
K	Thermal conductivity
λ	Laser wavelength
τ	Laser pulse duration
T_m	Melting point
P_{avg}	Average power
PRR	Pulse repetition rate
v	Scan speed
v_{cut}	Maximum cutting speed for a given P_{avg}
v_{max}	Maximum cutting speed
w_{kerf}	Kerf width

Laser remote cutting is an emerging process with applications in both macro and micro dimensional ranges [4]. In particular, no process gas is used to expel the material as in the conventional laser cutting. Material removal can be

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achieved by melting, vaporization or ablation. Pulsed laser sources operating in ns regime are often used for ablation based remote cutting [5-9]. As a matter of fact, ablation based remote microcutting can be an adequate solution to change the current process, since it is a no-contact process without the presence of a physical tool. However productivity and quality of laser cutting should be comparable to punching.

The main defect in laser remote cutting of multi layered li-ion battery electrodes is clearance. As see in Fig. 1, clearance is defined as the extent of the exposed metal plate (i.e. Cu or Al) at the laser cut kerf. Clearance should be minimized, if not totally eliminated for the safe of the Li-ion battery to avoid short circuits. Moreover the exposed metal plate can cut other sheets during stacking and transportation.

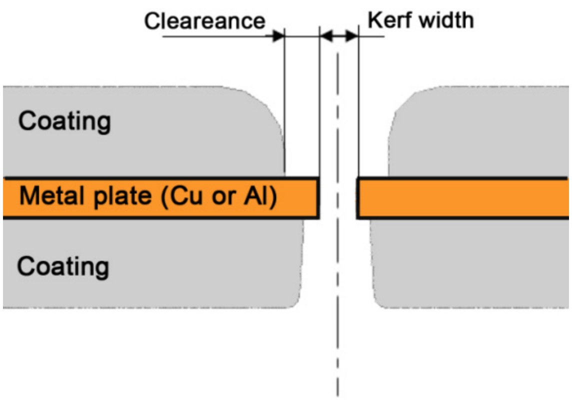

Fig. 1. Schematic representation of a remote laser cut electrode cross section.

In literature only a few number of works explored the possibility of remote laser cutting of Li-ion electrodes [11-14]. Among these, pulsed lasers have been studies sparingly [11], whereas the effect of pulse duration and wavelength appears to be absent. In this work two fibre laser systems operating in IR and green wavelengths are compared. The results are compared to achieve a benchmark in quality and productivity.

2. Experimental details

2.1. Materials and systems

Anode and cathode materials were based on thin metallic sheets sandwiched between coating layers. Copper sheets coated with graphite consisted the anode material (140 µm thick). Cathode was formed by Al sheet sandwiched between two layers of Li metal oxide coating (120 µm thick).

Two laser systems operating in ns regime were used to cut both of the electrode materials. A Q-switched fibre laser in fundamental wavelength (λ=1064 nm) with 250 ns pulse duration was used coupled to a scanner head. The scanner head was equipped with an f-theta lens. The calculated beam diameter was 39 µm. The system could reach up to 6000 mm/s scan speed (v). The laser could generate up to 50 W of average power (P_{avg}) and operated between 20-80 kHz pulse repetition rate (PRR) range. The second system was a master oscillator power amplifier (MOPA) fibre laser with second harmonic generator (λ=532 nm) and 1 ns pulse duration. The calculated beam diameter of the system was 22 µm. The system was implemented to high precision linear axes, which manipulated the workpiece with a maximum scan speed of 600 mm/s. The laser could generate up to 6 W of average power and

Table 1. General specifications of the used laser systems.

	IR laser	Green laser
Brand and model	IPG YLP-1/100/50/50	IPG YLPG-5
Architecture	Fibre, Q-switched	Fibre, MOPA
λ	1064 nm	532 nm
Max P_{avg}	50 W	6 W
PRR	20-80 kHz	20-300 kHz
Max. E	1020 µJ	20 µJ
τ	250 ns	1 ns
d_0	39 µm	22 µm

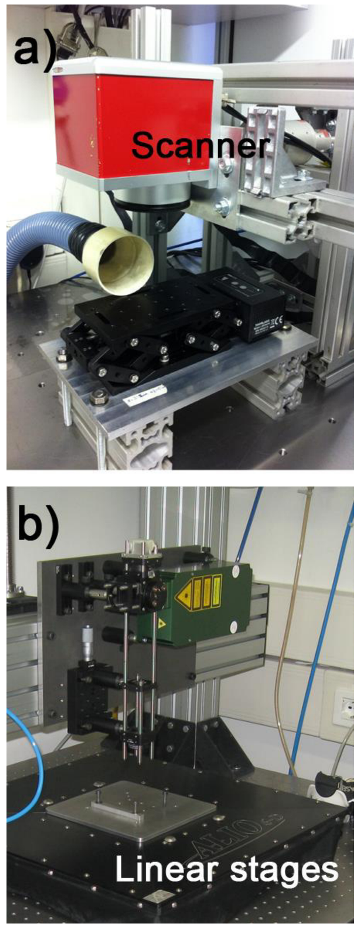

Fig. 2. Laser microcutting systems belonging to a) IR laser, b) green laser.