FAST LITHIUM-ION BATTERY ELECTRODE CUTTING WITH HIGH-POWER FEMTOSECOND PULSES

Due to lithium-ion batteries' high energy density, lightweight design, and good lifetime, they play a crucial role in many modern industries, from portable electronics and electric vehicles to both home and industrial energy storage systems. As these spaces and others continue to grow, the demand for lithium-ion batteries grows with it, motivating the continuous improvement of production methods. The batteries are composed of layers of coated metal foils (electrodes), the processing of which requires high speed, single pass cutting and good edge quality, for which ultrashort pulsed lasers are ideally suited.

In prior work, we demonstrated foil cutting using picosecond pulse widths and TimeShift™ pulse tailoring (Application Note 60). Building on that, here we present cutting results for anode and cathode Li-ion battery foils using the IceFyre® FS IR200 femtosecond laser. The cathode material used for the tests consisted of approximately 17 µm aluminum foil with an NMC, or Lithium Nickel Cobalt Manganese Oxide, coating on both sides for a total thickness of approximately 100 µm. The anode Material consisted of approximately 10 µm thick copper foil coated on both sides with graphite, for a total thickness of 98 µm. As before, we demonstrate the advantages of processing using TimeShift technology for burst mode, versus conventional single-pulse processing. To assess performance, we look at both maximum cutting speed, as well as the coating "pull back" (how much the coating has receded from the cut edge) and provide images for visual comparison.

For burst processing, the PRF (pulse repetition frequency) was fixed at 200 kHz and a range of burst sub-pulse counts, from 10 to 80, was used, while for single pulse processing, we first explored several different PRFs to find a single optimized cutting condition. Figure 1 shows net cut speed with burst plotted versus burst count for both foils. The single pulse results are represented by horizontal dashed lines at their best cut speeds.

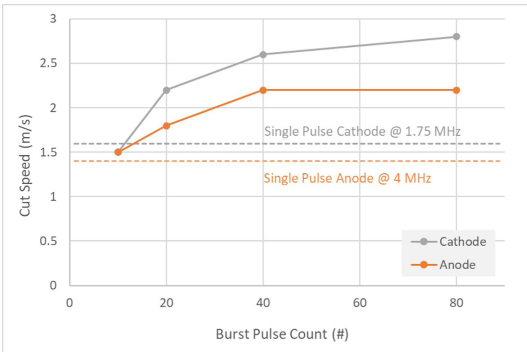

Figure 1. Net cut speed versus burst pulse count for cathode and anode foils.

From this data we can see that burst mode quickly surpasses single pulse, which peaks at 1.4 m/s and 1.6 m/s for the anode and cathode respectively, versus the 2.2 m/s and 2.8 m/s achieved at 80 pulses in the burst. This represents a 57% and 75% improvement in cut speed, once again for anode and cathode respectively.

One advantage of the IceFyre FS IR200 TimeShift capability is that higher total energies are available in a burst of pulses compared to just a single pulse. For example, while a single pulse can have a maximum energy of ~200 µJ, using bursts of 5, 10, and 20 pulses enables total output burst energies of ~550, ~750, and ~900 µJ, respectively (PRF dependent). Such large "packets" of energy are evidently beneficial to improved processing speeds.

To assess cut quality, we measured the coating pull back for each cut condition on both foils (Figure 2) and took SEM images to qualitatively inspect the cut edges for metal smearing (Figure 3). Less pull back at the cut edge is more desirable, and therefore represents better cut quality.

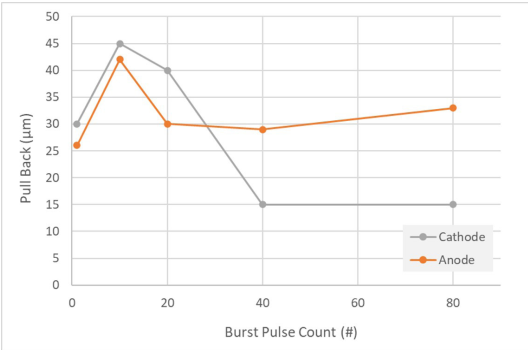

Figure 2. Coating pull back versus burst pulse count for cathode and anode foils.

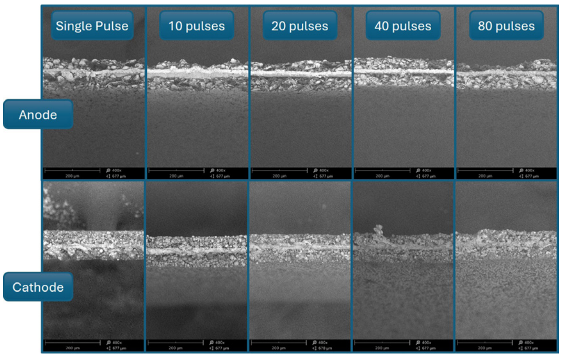

Figure 3. SEM images of the cut edges of the cathode and anode battery foils at different pulse counts from single pulse to 80 pulse burst.

For both foils we saw an initial increase in pull back for processing with a 10 pulse burst, versus single pulse processing. However, for higher burst counts pull back improved, though in the case of the anode foil the single pulse result still had the lowest pull back of the test range.

From the SEM images we can see that, in the case of the anode, there is very little smearing at any condition and looks particularly clean at the 40-pulse condition. By contrast, the quality of the cathode foil is more ambiguous. There is clear smearing for the single pulse process with improvement at 10 and 20 pulses, however 40 and 80 pulses have reduced contrast, making it difficult to assess the degree of smearing, though it appears there is a minor amount.

Expanding on our previous battery foil cutting, we further confirm the advantages of burst processing over single pulse processing, faster throughput for anode and cathode cutting, and clearly better quality for the anode. Using burst pulse output, the IceFyre FS IR200 is able to achieve single-pass cutting speeds in excess of 2 m/s with good processing quality, in most cases superior to the quality achieved with single pulse.

The IceFyre FS IR200 provides over 200 W IR femtosecond pulses at high PRF for inherently fast cutting lithium-ion battery foils. Then with the added TimeShift capability, the IceFyre FS IR200 can further increase the productivity for foil cutting while also improving cut quality.

PRODUCT

IceFyre® FS UV and IR Femtosecond Lasers

The IceFyre FS family is an extraordinary leap forward in industrial femtosecond laser technology, delivering industry-leading performance, versatility, reliability, and cost-of-ownership. The IceFyre FS femtosecond lasers are ideal for high throughput, highest-quality micromachining of critical materials, including glass, polymers, metals, semiconductors, thin films, and composites for demanding consumer electronics, clean energy, medical device, and industrial applications. Based on Spectra-Physics' *It's in the Box*™ design, IceFyre FS integrates laser and control electronics in a single, easy-to-install package.

	IceFyre FS UV50	IceFyre FS IR200
Wavelength	343 ±2 nm	1030 ± 6 nm
Power	>50 W @ 1 MHz and 1.25 MHz	>200 W @ 1-50 MHz
Maximum Pulse Energy	>50 µJ @ 1 MHz	>200 µJ @ 1 MHz
Repetition Rate Range	Single shot to 3 MHz	Single shot to 50 MHz
Pulse Width, FWHM	<500 fs	
Pulse-to-Pulse Energy Stability	<2% rms	
Power Stability (after warm-up)	<1% rms over 8 hours	
Spatial Mode	TEM_{00}, (M^2 <1.3)	
Polarization	>100:1 vertical	

Application Note_70_08/26/24