High-speed laser cutting of EV electrodes

Cutting-edge laser processing innovations for industrial battery manufacturing presented at LaserEmobility Workshop in Bologna

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The University of Bologna has been actively engaged for years in research in the field of high-power laser processing technologies in industrial applications. Their expertise in laser-material interactions spans from additive manufacturing (LPBF, DED, WAAM) to laser welding and cutting in battery manufacturing and assembly for the EV field. It is with great pleasure that Bologna hosts the LaserEmobility workshop from 7 – 8 October 2025, focusing on cutting-edge innovations in laser-based manufacturing technologies within the e-mobility sector.

With the dawn of third-generation electric vehicles, the demand for high-energy-density batteries has intensified, driving the need for technological innovation while reducing material and production costs. To date, lithium-ion batteries hold the lead in the automotive sector. Conventional battery designs incorporate an anode and a cathode tab (see Fig. 1a) that establish electrical contact with the battery casing. Electrodes are a sandwich composite material, where the mean layer is typically a current collector foil made of copper, for the anode, and aluminum, for the cathode, with thicknesses ranging between 8 and 30 µm. A significant innovation in battery design is the tab-less architecture, which features a full-flag configuration (Fig. 1b).

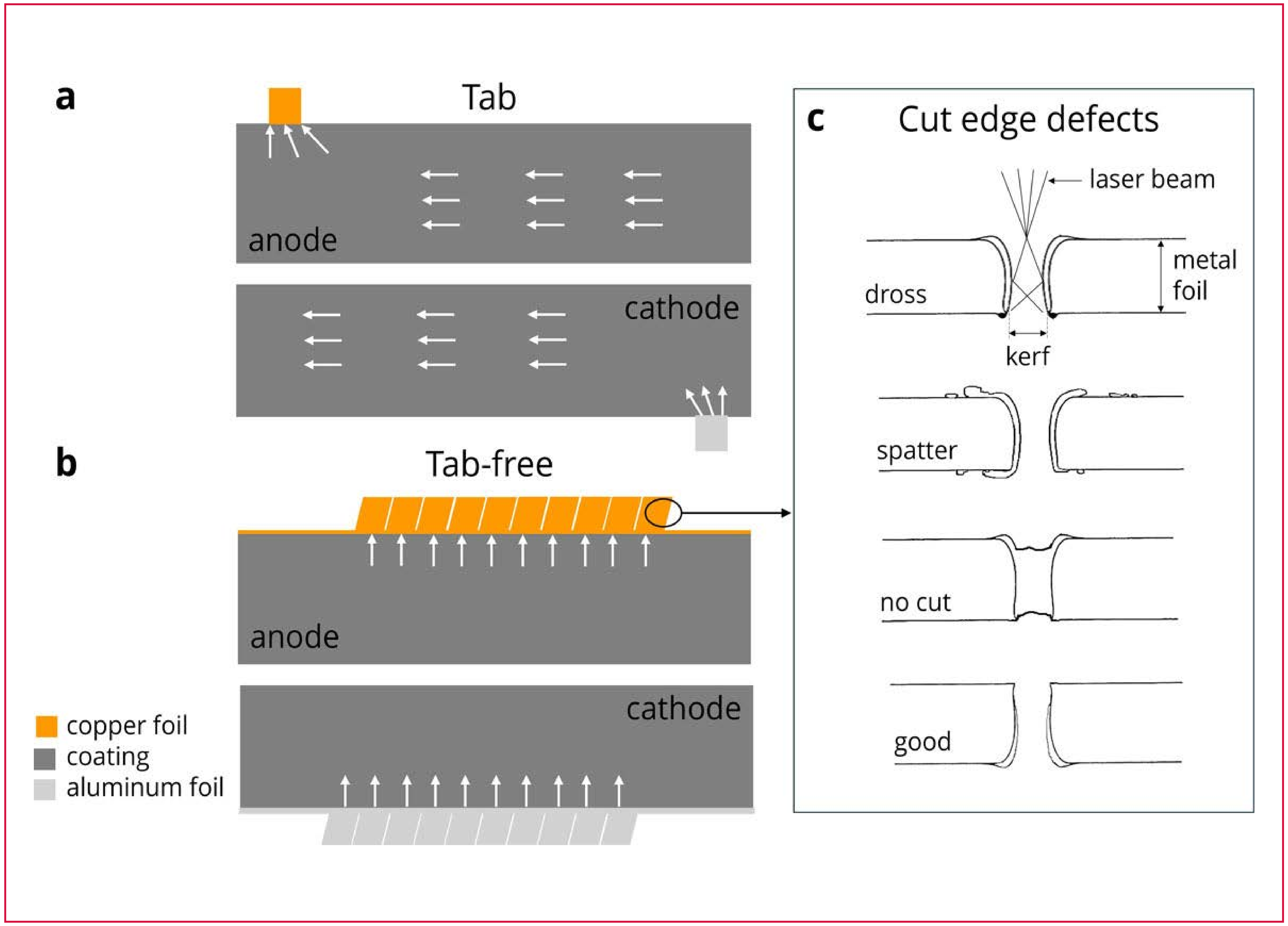

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Fig. 1 Electrode design with a (a) single-tab, where electrons travel along the entire distance; (b) tabless, where electrons travel shorter distances thanks to the full flags along the foil. Major cut edge defects are classified in (c).

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Alessandro Ascari

Alessandro Ascari is an associate professor at the University of Bologna and he got his PhD in laser joining of advanced, cellular and hybrid materials. He has been involved in studying laser-based processes for more than twenty years with particular attention to surface hardening, advanced welding and direct metal deposition.

Erica Liverani

Erica Liverani is an assistant professor at the University of Bologna. She has ten years of experience in laser materials processing, currently with a focus on laser cutting and laser welding, laser manufacturing through additive manufacturing and modeling of laser-matter interactions.

Here, the tab extends along the entire foil length, separated by slits. This design improves energy density of the battery pack in terms of reducing localized heating, improved thermal stability, and enhanced overall safety. However, it requires more complex cutting patterns, making laser technology essential for its high speed and precision.

High-quality cut edges are essential to ensure reliable electric connections and prevent defects like spatter and dross (Fig. 1c), which can cause internal short circuits. Poor edge quality increases electrical stress, leading to heat generation and potential thermal runaway. Additionally, optimizing kerf width is crucial to minimizing material waste during electrode cutting and trimming. University of Bologna has conducted extensive research to define the best cutting conditions for battery foil production on both aluminum and copper. Initial static experimental campaigns compared pulsed pw and continuous-wave cw laser sources by varying key parameters such as cutting speed (up to 25 m/s), spot size, power, pulse energy, pulse duration, and repetition rate to find out how defects were affected by the latter. The key finding was that, in all studied settings, cw single mode fiber lasers allowed for improved cut quality; the only exception being low-speed (≤4 m/s) cutting of copper foils, where jagged and uneven cut edges emerged. In this instance, the pw laser produced less noticeable dross and remelted edges under low speed cutting conditions with low irradiance.

To deep dive into the physical phenomena factors affecting defects formation, a computational fluid dynamics model was used. Recoil pressure within the kerf was assessed as being the major protagonist of the melt pool dynamics. When exceeds a certain threshold, given by the local surface tension force, metal droplets are expelled as spatters. Findings with this model could serve as a guideline for selecting optimal cutting conditions when input specifications undergo slight variations, such as changes in material characteristics, spot dimensions, speed and thickness.

Ultrafast-pulsed lasers (pulse length <10 ps) have been tested as well since their ultrahigh peak power densities are highly effective in minimizing thermal effects and achieving nearly dross-free cut edges. However, the primary challenges for industrial implementation of these sources include their high cost, relatively low processing speeds and the delicate requirements of the equipment and environment – e.g., a controlled atmosphere. One way of increasing processing speed is by using multipulse burst mode, as it lowers the ablation threshold. However, the resulting quality at high speeds still does not justify the high investment required for their implementation.

Subsequently, a dedicated simulator was integrated into the university laser cell to replicate real battery foil manufacturing conditions. A key challenge at this stage was ensuring precise focal positioning of the laser beam at high processing speeds. Future studies will focus on exploring innovative materials and advanced laser strategies to enhance the performance of next-generation high-power batteries.

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Meet us at the
LaserEmobility workshop in Bologna