Laser-Enriched Recovered Carbon Black with Improved Performance as Anode for Lithium-Ion Battery

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Introduction

Hard carbon (HC) material is thought to be a potential candidate for lithium-ion batteries (LIBs). We engineered economical HC materials as functional anode for LIBs. By way of a facile focused laser beam modification, the as-prepared anode is further engineered to achieve enhanced electrochemical performance, which are attributed to both improved structures and engineered defects. Namely, laser annealing gives rise to sample with better connectivity to facilitate charge movement and more roughened surface to present added active sites. Laser treatment generates surface defects that tend to increase Li ions adsorption by lowering Li ions diffusion barrier. As an added bonus of this discovery, the carbon materials with surface defects exhibit bright fluorescence emission when excited by UV light. In this way, we can rely on the fluorescence emission as an indicator of the suitability of the materials as anode.

Morphology and Fluorescence

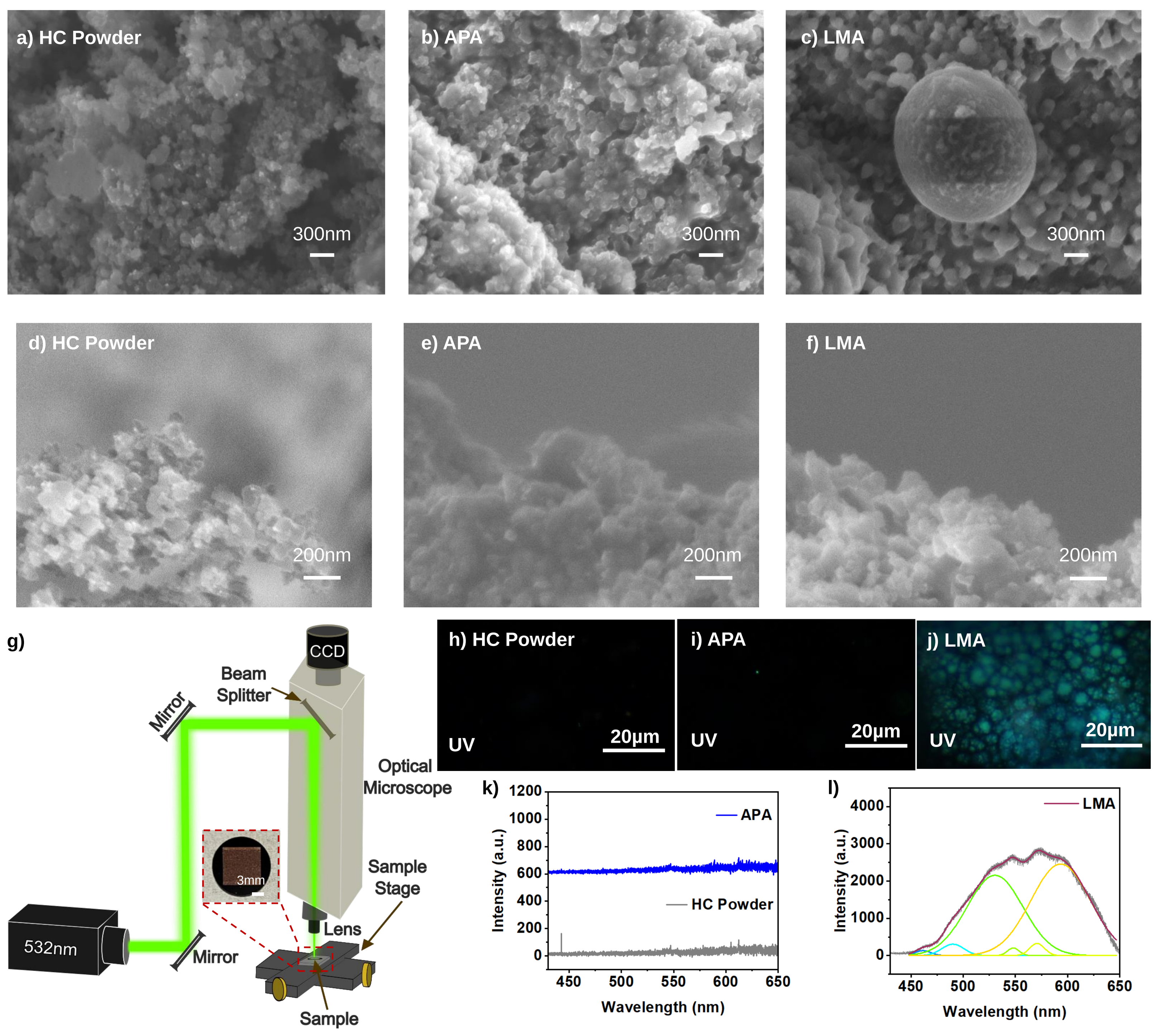


Fig 1. Morphological and optical characterization. SEM images (top view) of a) HC powder, b) as-prepared anode (APA) and c) laser-modified anode (LMA). SEM images (cross section) of d) HC powder, e) APA and f) LMA. g) Schematic of FLB setup. FM images of h) HC powder, i) APA, j) LMA under UV. PL spectra of k) HC powder and APA, and l) LMA.

Structure and Chemical Bond

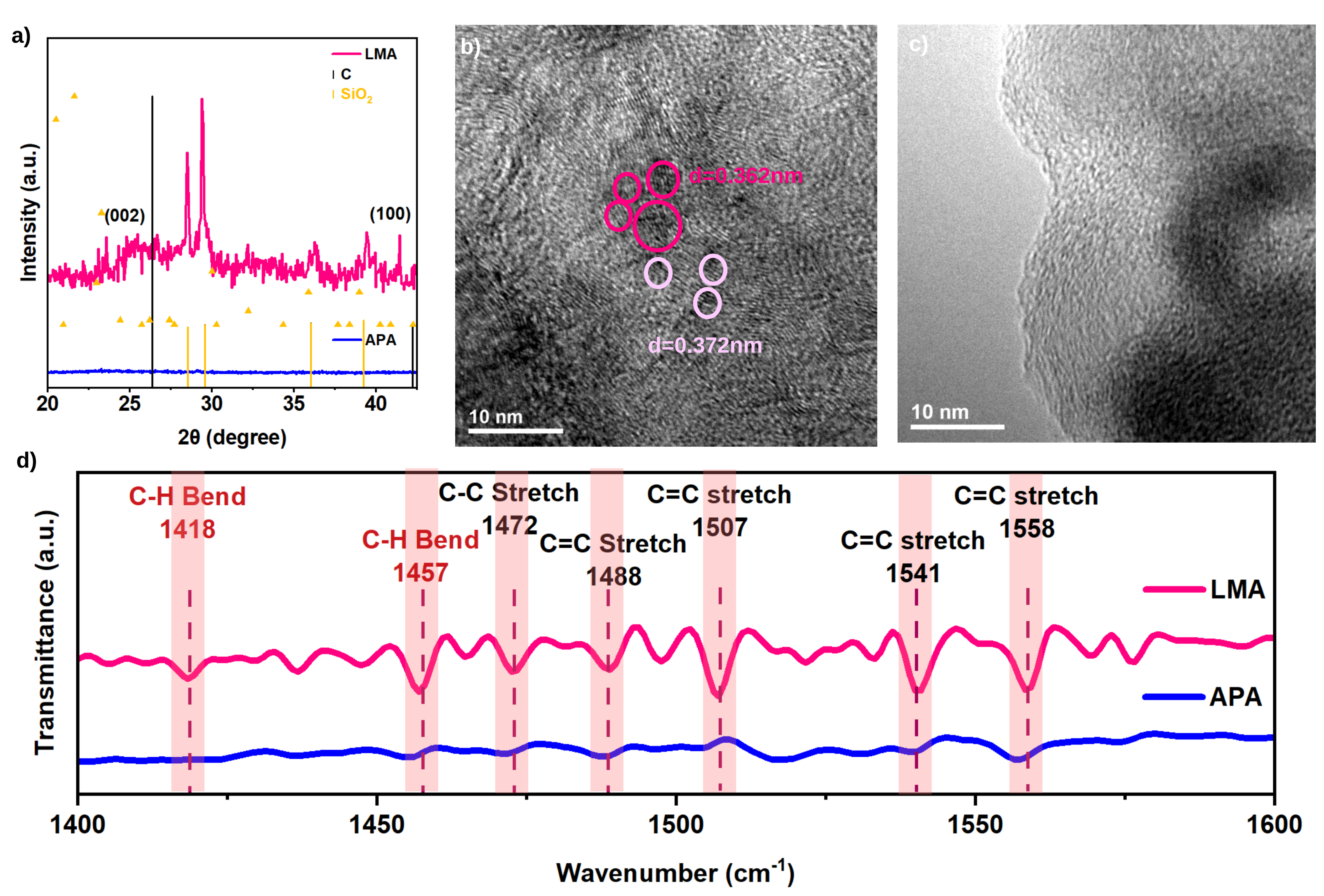


Fig 2. Structural characterization. a) XRD spectrum of LMA and APA. b) TEM images of LMA. c) TEM image of APA. d) FTIR spectra of LMA and APA.

Electrochemical Performance

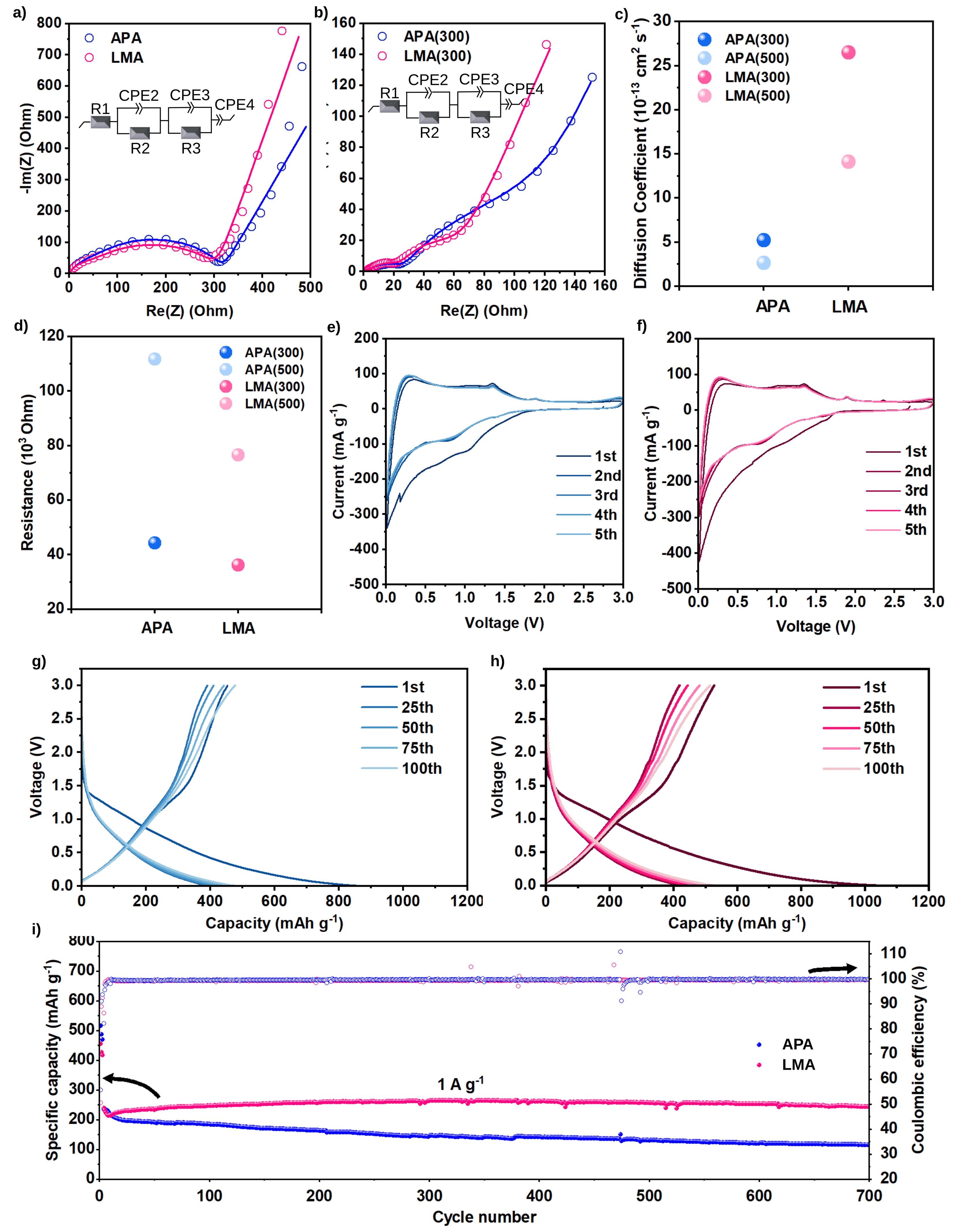
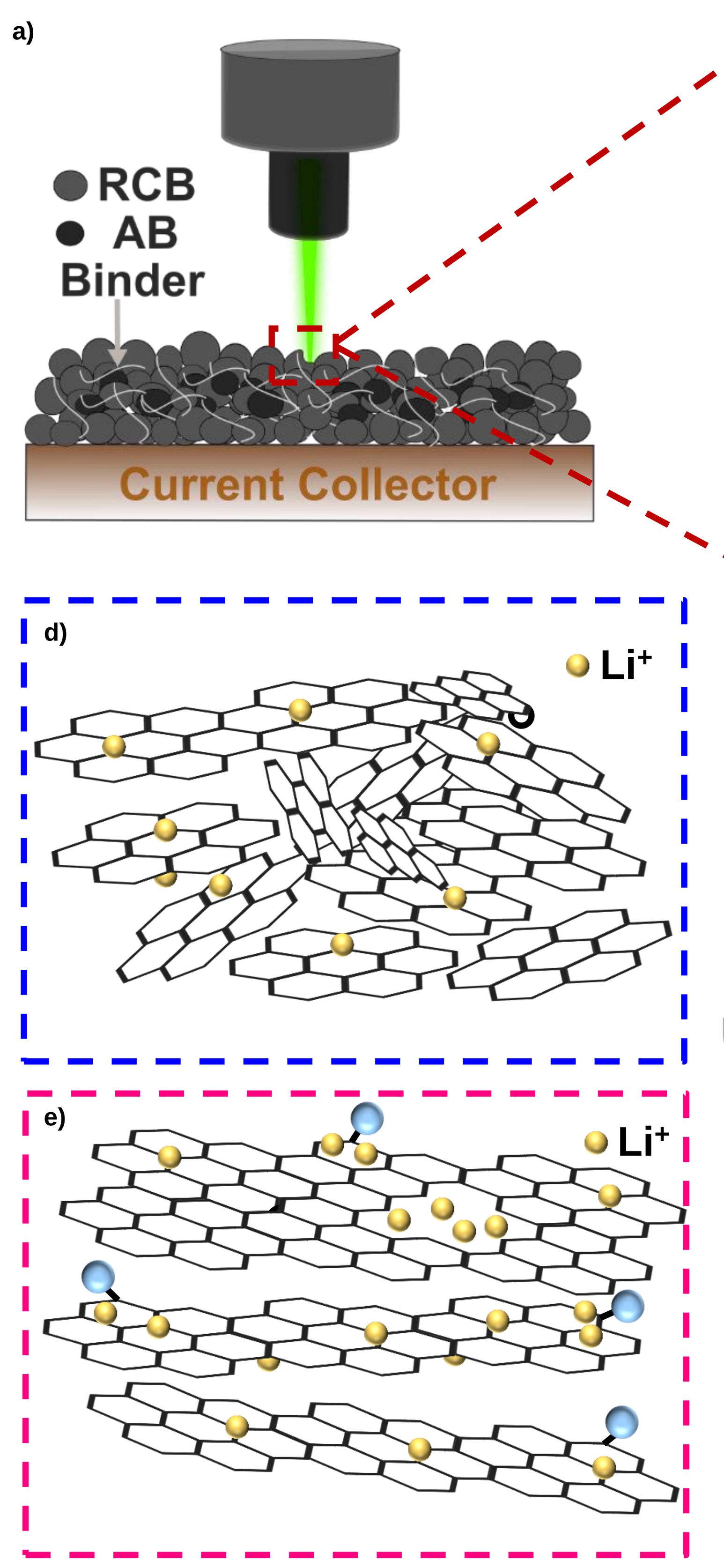


Fig 3. Electrochemical Measurement. a) EIS before cycling. b) EIS after 300 cycles. c) Comparison in diffusion coefficient of lithium ions. d) Comparison in lithium-ion diffusion impedance from the fitted results. e) CV curves of APA. f) CV curves of LMA. Voltage profiles of g) APA and h) LMA in the first 100th cycles at 0.1A g^{-1} and 0-3V. i) Cycling performance at 1A g^{-1} and 0-3V.

Proposed Mechanism



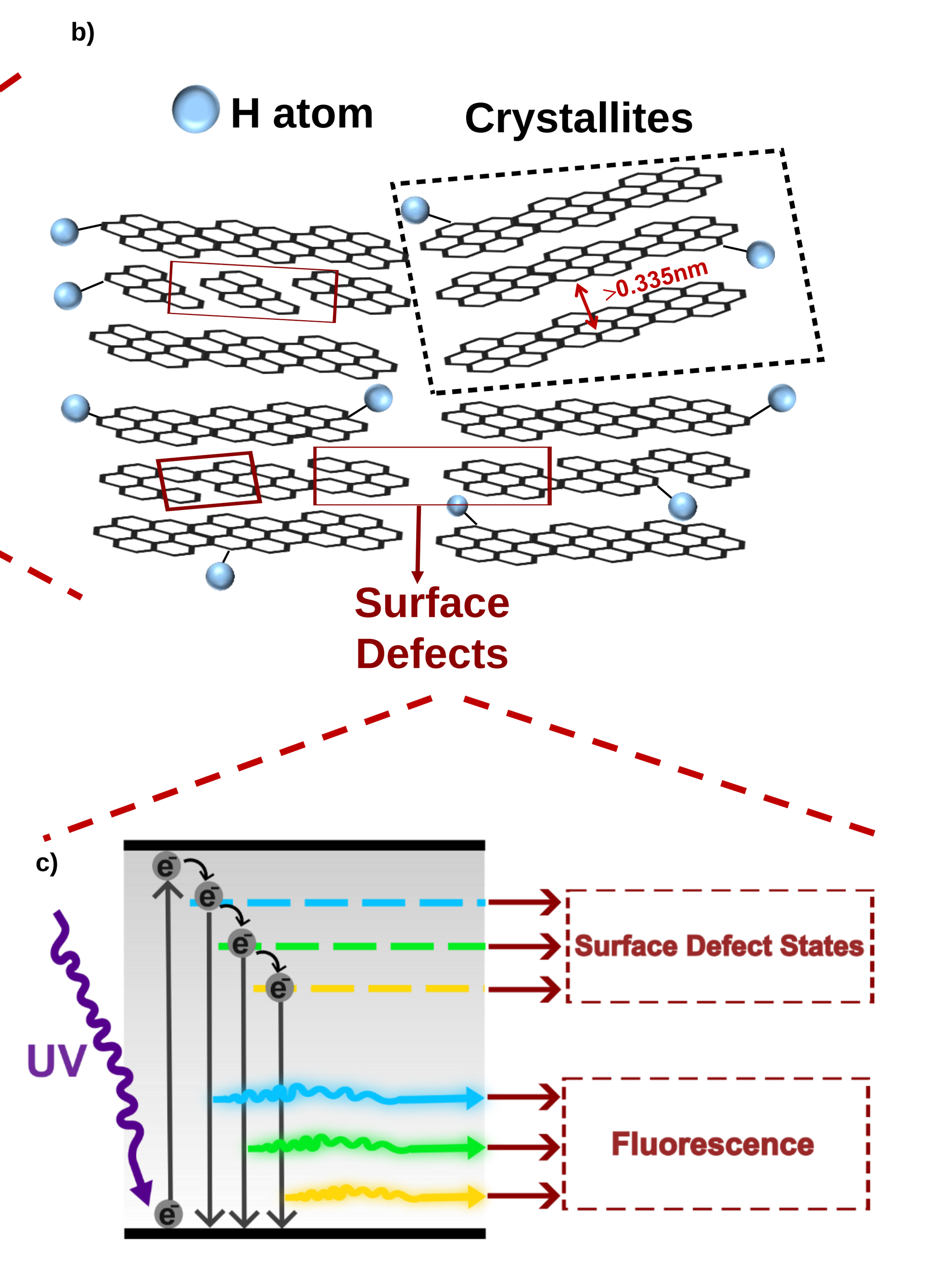


Fig 4. Schematic of mechanisms of lithium-ion storage. a) Schematic of the electrode processed by FLB. b) Schematic structure illustration after laser modification. c) Schematic of fluorescence emitted. Proposed mechanism of d) APA and e) LMA for lithium-ion storage.

Conclusion

In summary, a HC structure that readily adsorbs Li^+ is created by a one-step laser modification by lower Li^+ diffusion impedance and enhanced capacity performance. Interestingly, laser-induced surface defects indicated by fluorescence, are identified as active sites for Li^+ adsorption. Fluorescence thus could be used to provide a visual indicator of the electrochemical capacity of the HC anode material for the first time.