# Electrochemical Impedance Spectroscopy for Lithium Ion Batteries - Degradation Mechanism Analysis

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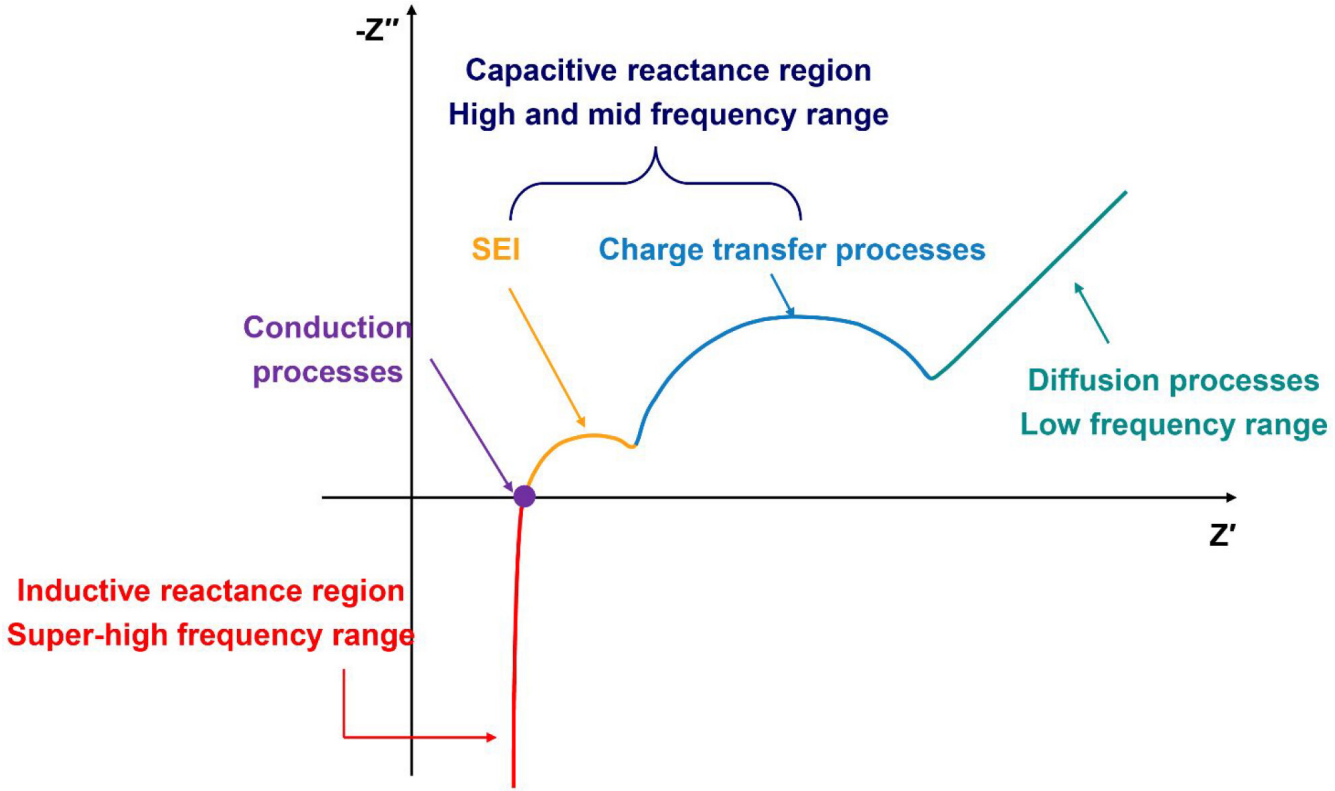
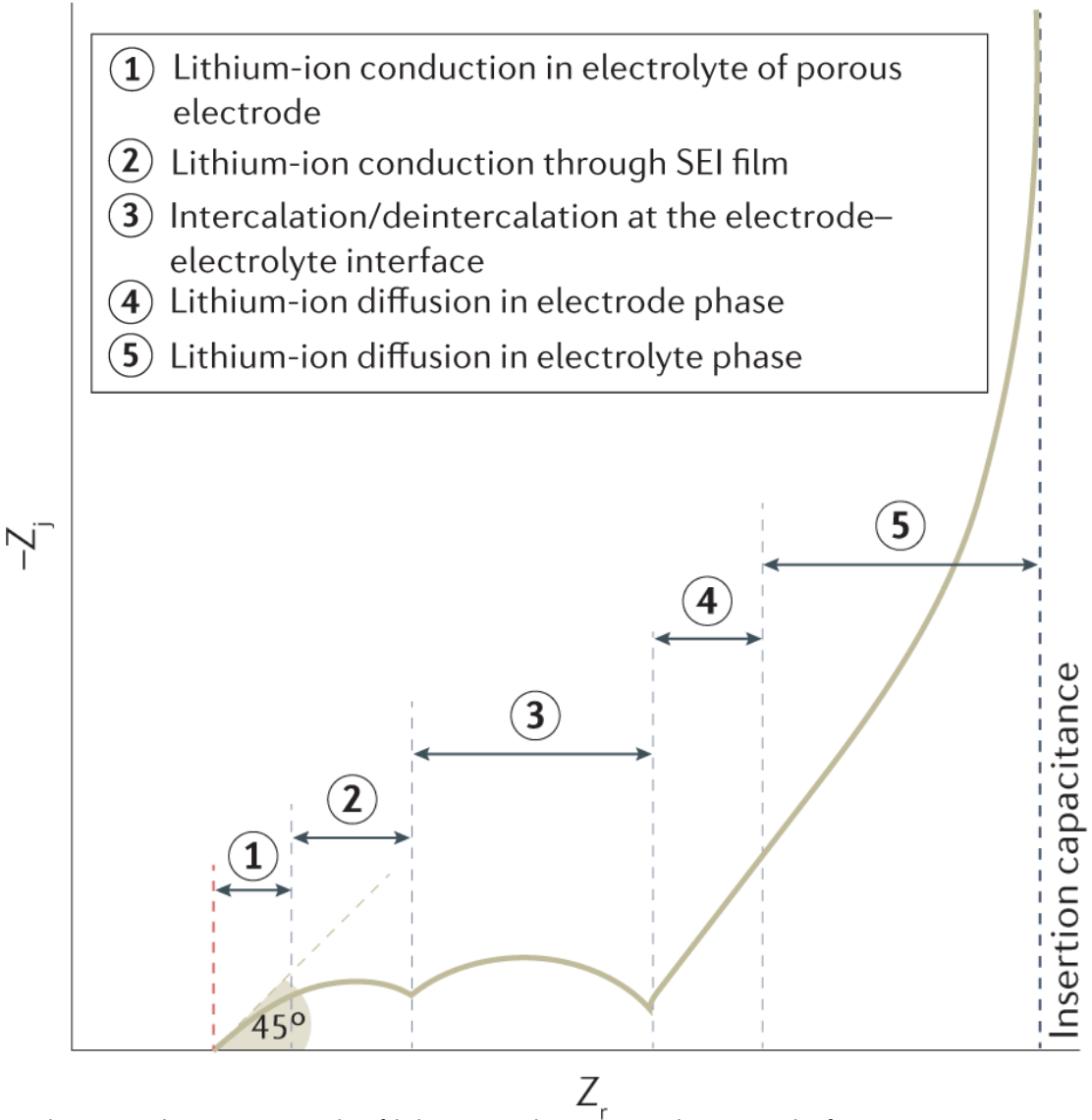
Min Jae Jung

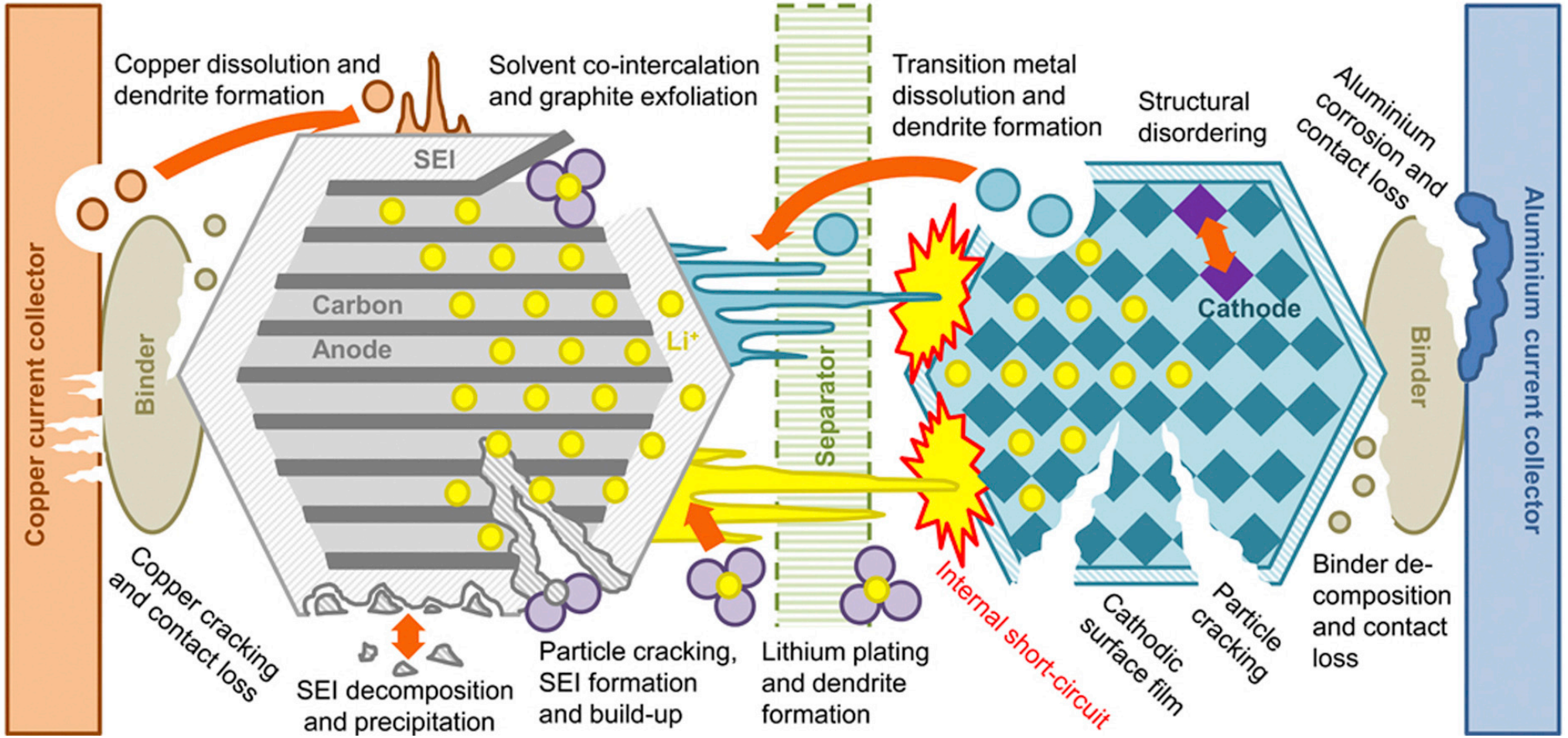
# Typical EIS of Li-ion batteries




Hu, Wenxuan, et al. "Application of electrochemical impedance spectroscopy to degradation and aging research of lithium-ion batteries." The Journal of Physical Chemistry C 127.9 (2023)
Wang, Shangshang, et al. "Electrochemical impedance spectroscopy." Nature Reviews Methods Primers 1.1 (2021)

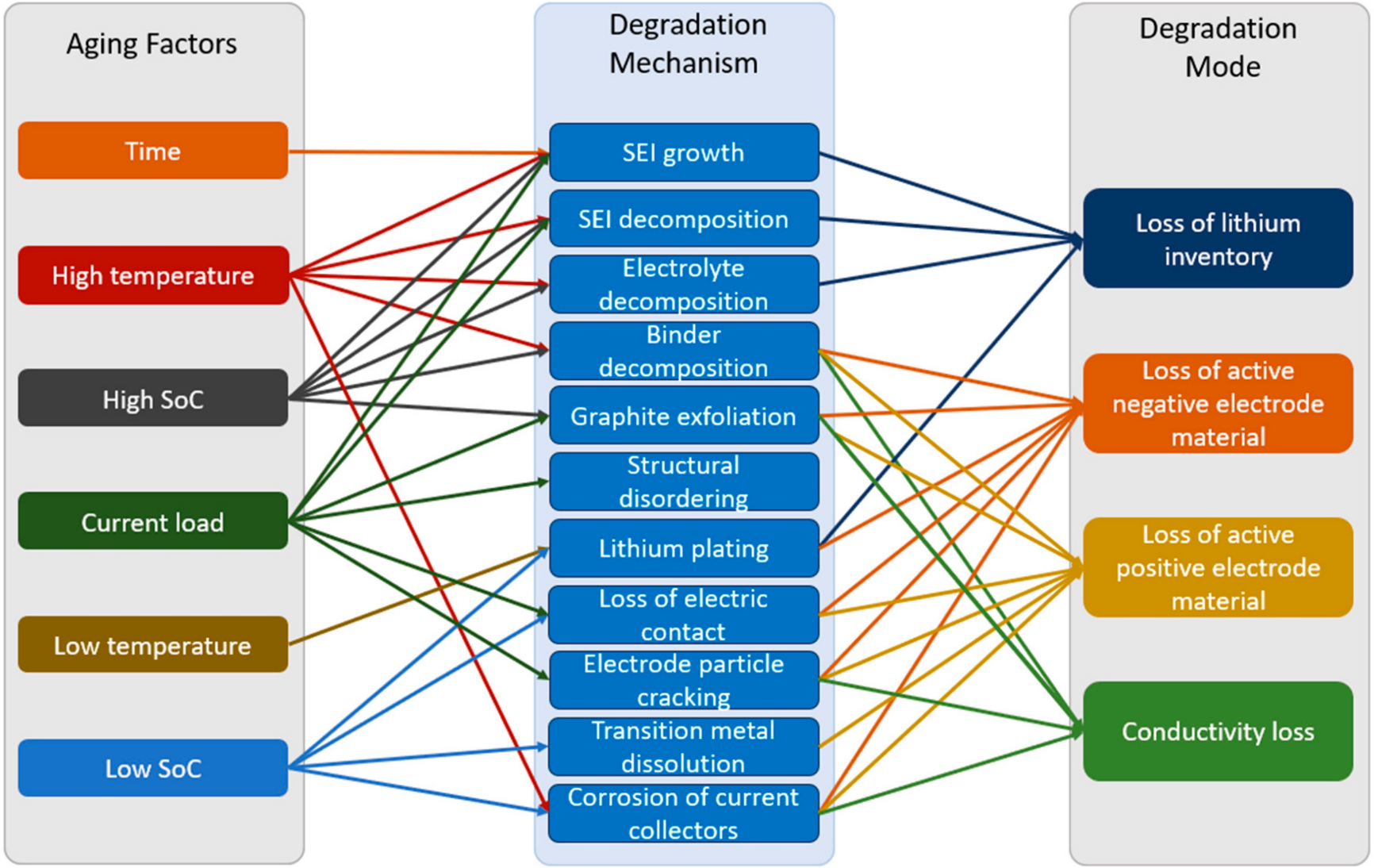
# Degradation mechanisms in Li-ion batteries






Birkl, Christoph R., et al. "Degradation diagnostics for lithium ion cells." Journal of Power Sources 341 (2017)

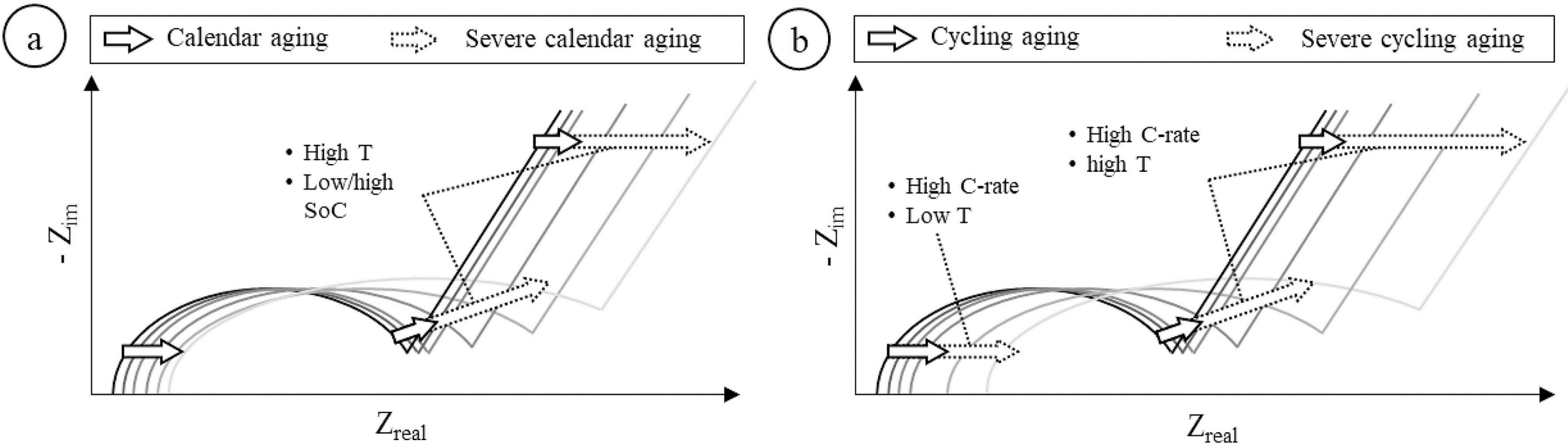
# Cause and effect of degradation mechanisms






Yarimca, Gulsah, and Erdal Cetkin. "Review of Cell Level Battery (Calendar and Cycling) Aging Models: Electric Vehicles." Batteries 10.11 (2024)

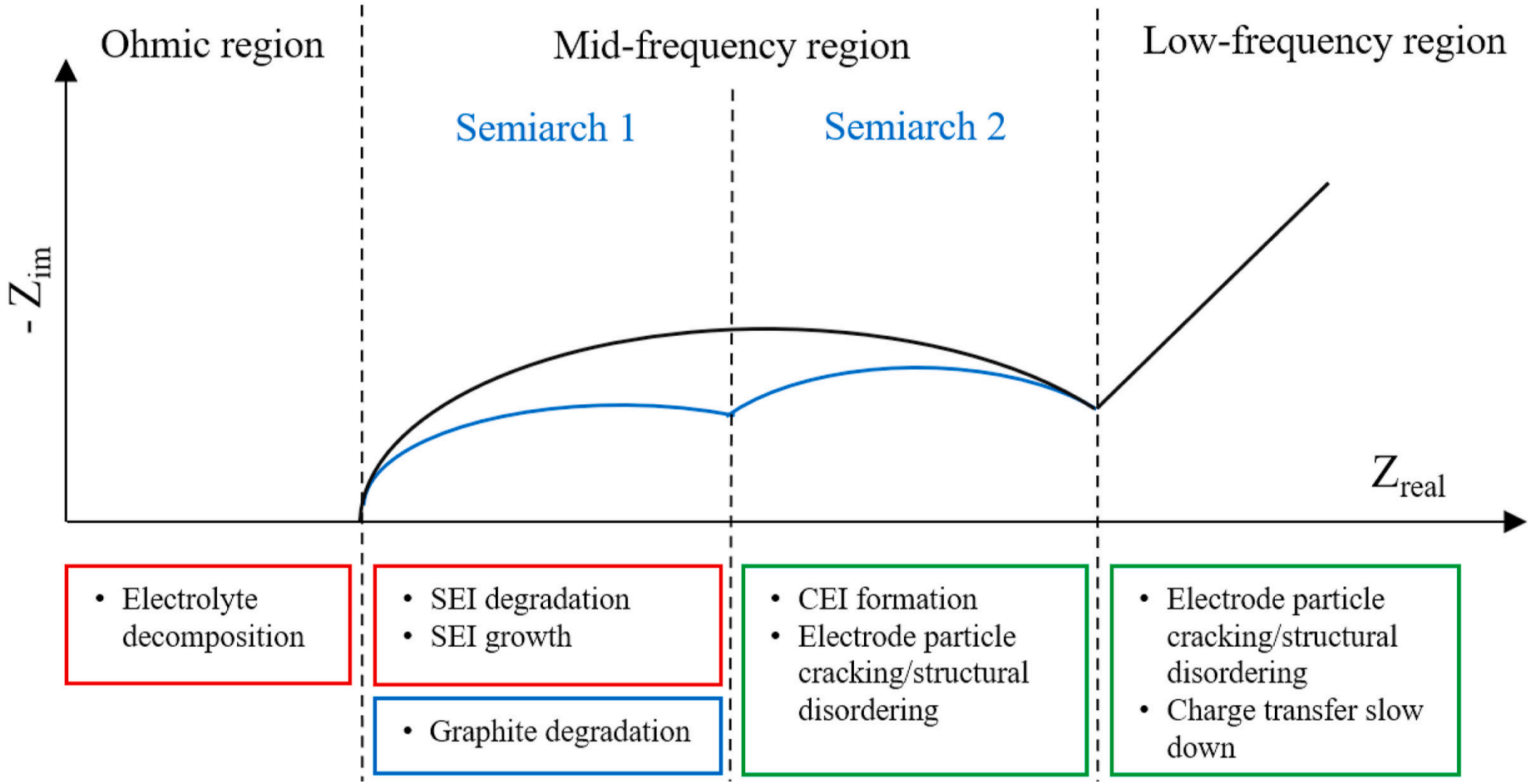
# Typical EIS variation with aging experiment






Iurilli, Pietro, Claudio Brivio, and Vanessa Wood. "On the use of electrochemical impedance spectroscopy to characterize and model the aging phenomena of lithium-ion batteries: a critical review." Journal of Power Sources 505 (2021)

# Typical EIS with degradation mechanisms



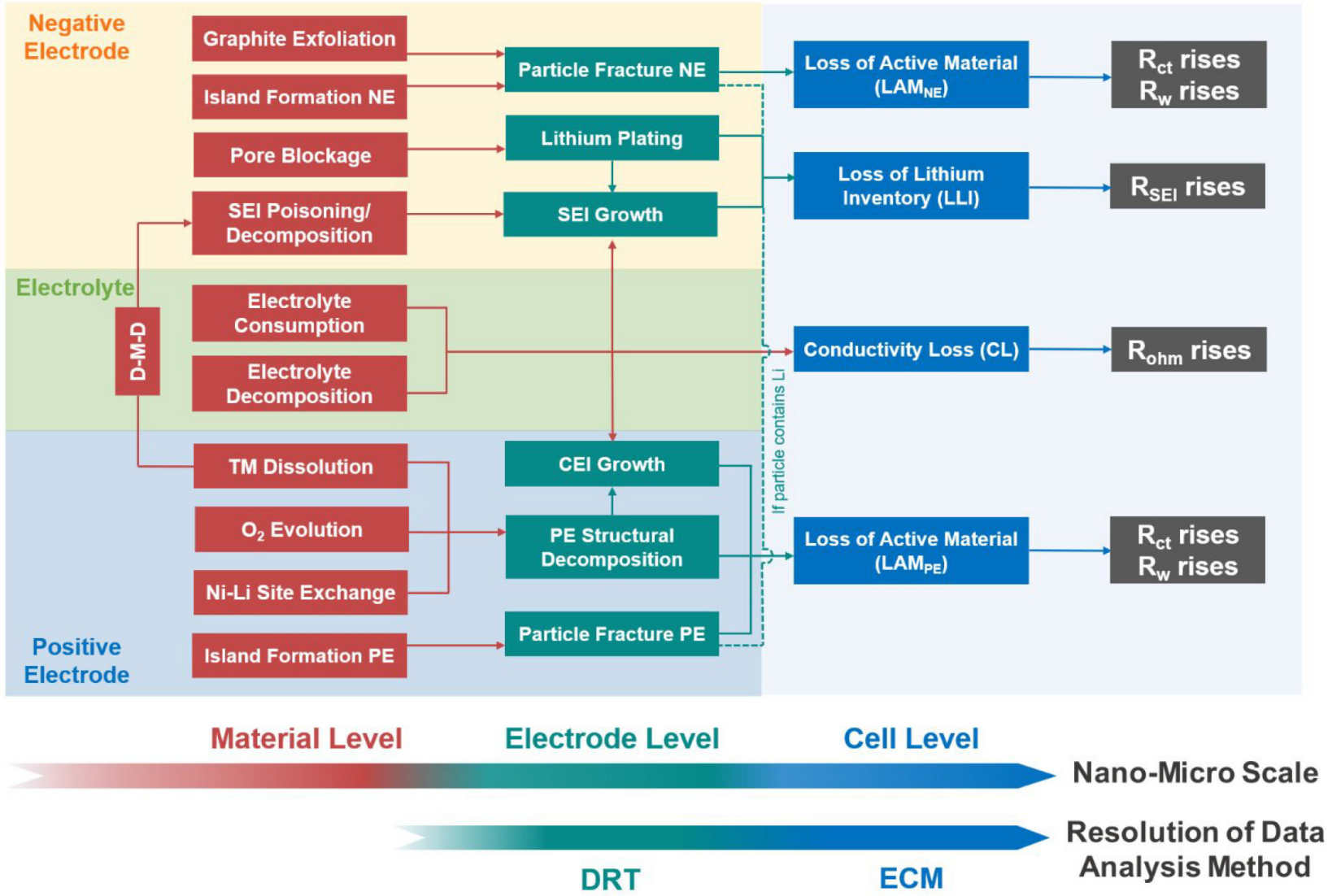

Legend:

- Loss of lithium inventory
- Loss of anode active material
- Loss of cathode active material



Iurilli, Pietro, Claudio Brivio, and Vanessa Wood. "On the use of electrochemical impedance spectroscopy to characterize and model the aging phenomena of lithium-ion batteries: a critical review." Journal of Power Sources 505 (2021)

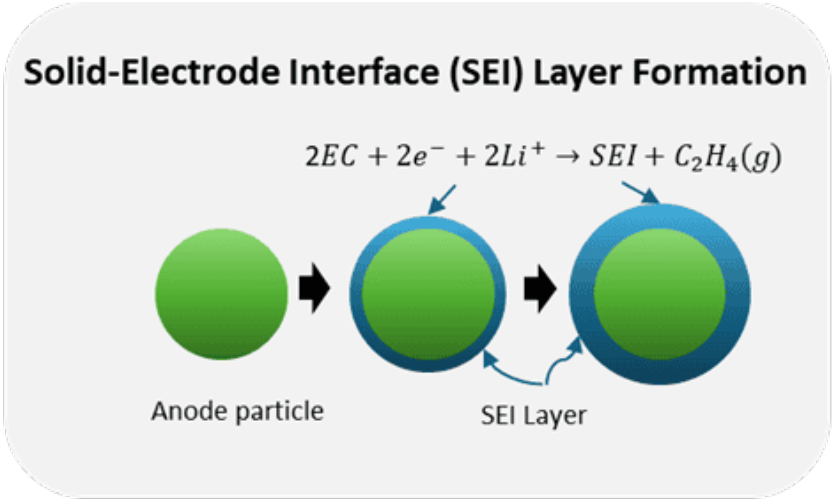
# Typical degradation mechanisms and EIS evolution

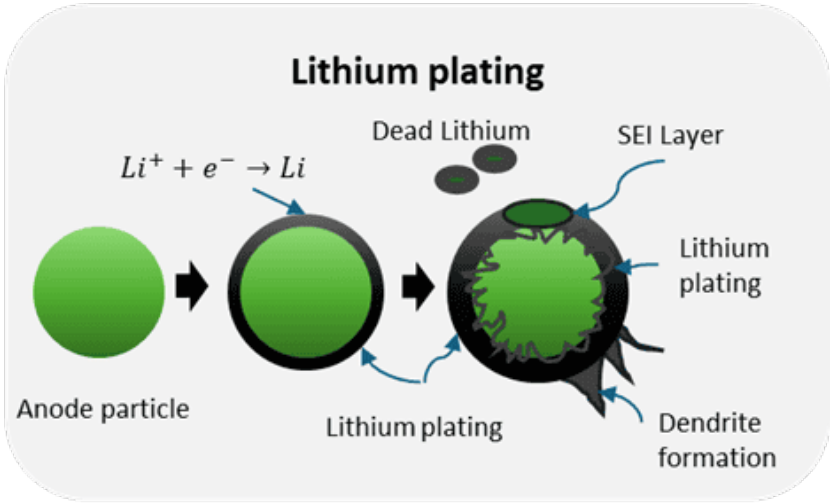


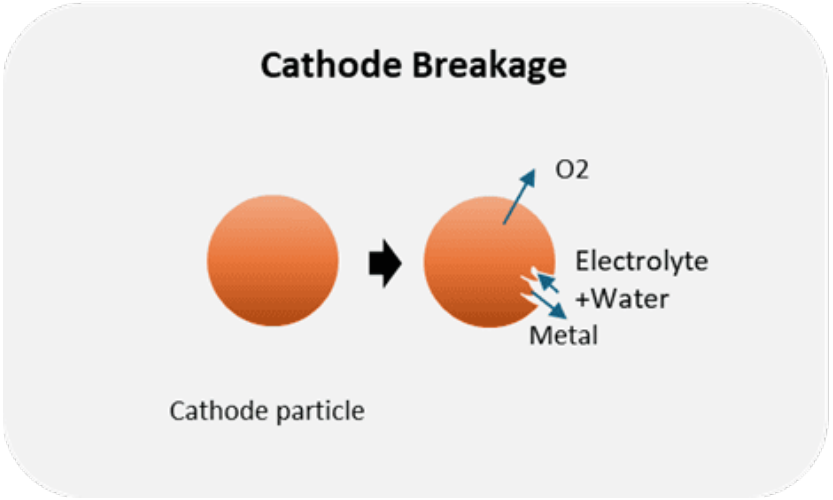


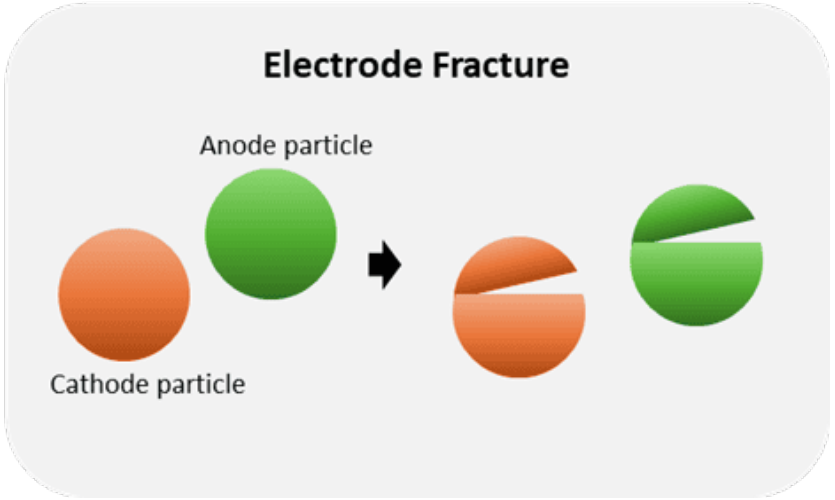

Hu, Wenxuan, et al. "Application of electrochemical impedance spectroscopy to degradation and aging research of lithium-ion batteries." The Journal of Physical Chemistry C 127.9 (2023)

# Major degradation mechanisms

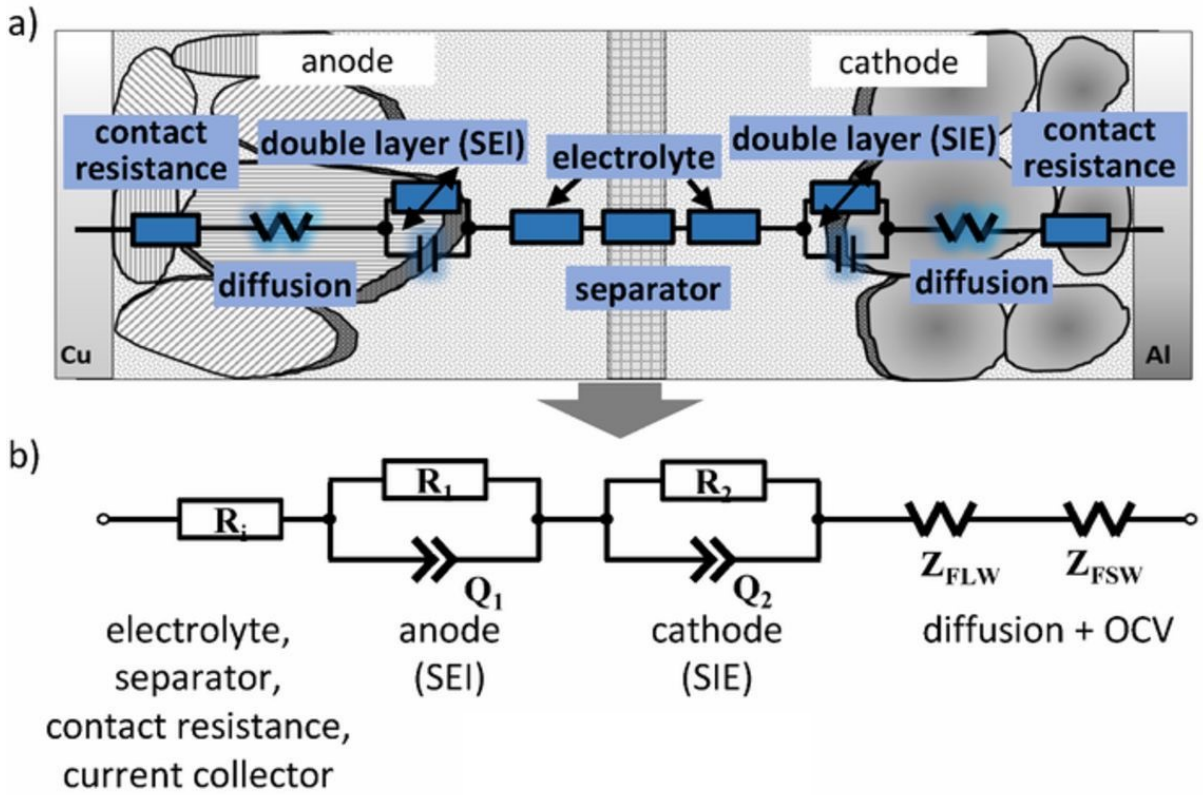


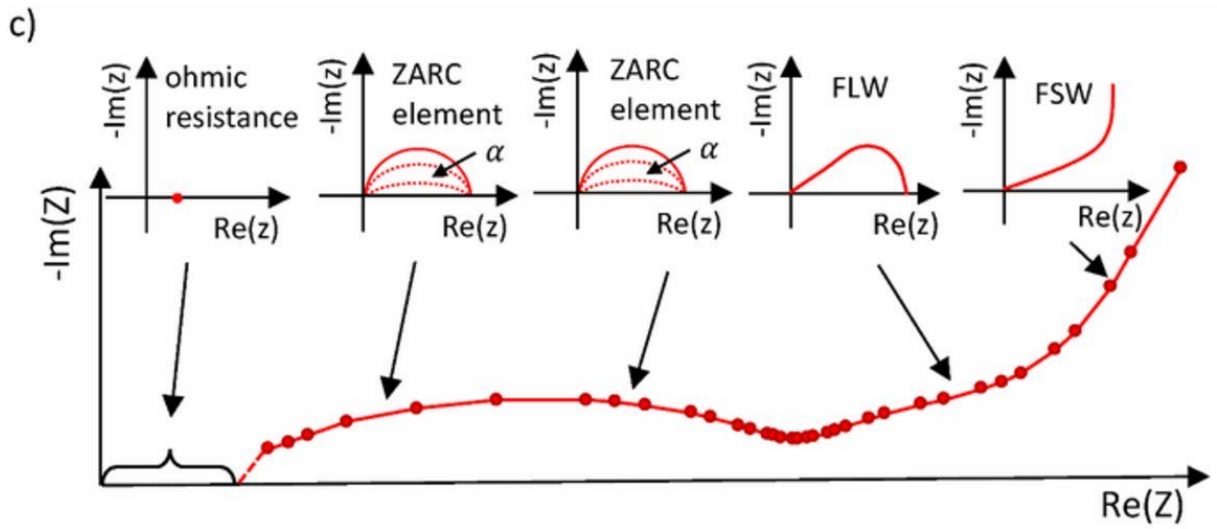



# Example of ECM and physical equivalence



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