# Unlocking a Tenfold Increase in Battery Performance: Poly(citric Acid) as a Novel Binder for Silicon Anode Batteries

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Silicon (Si) anodes could revolutionize lithium-ion batteries by expanding capacity eleven-fold. However, Si expansion during charging compromises battery integrity, preventing practical application. Polymeric binders can prevent this harmful expansion. Previous computational studies suggested that binders with ultra-high COOH density (33% COOH/monomer) optimized silicon stabilization, despite two opposing mechanisms: binder adhesion and electrolyte consumption. While these computational studies successfully validated high binder adhesion in ultra-high COOH density binders, the role of electrolyte consumption remained unclear. Therefore, this study aimed to clarify the chemical interactions within silicon anodes through wet-lab synthesis and validation of a particularly promising novel binder called poly(citric acid) (PCA) which has the highest known COOH density to date (43%). PCA was polymerized through repeated esterification of citric acid (CA) and characterized by Fourier Transform Infrared spectroscopy, validating successful PCA synthesis. Ion chromatography showed that PCA had 0.1% electrolyte decomposition compared with other binders, whereas NMR spectroscopy of the electrolyte solutions revealed that PCA did not produce toxic PF5 and POF3 gases found in other binders. When PCA was incorporated into physical silicon anodes and compared against poly(acrylic acid) and poly(vinylidene fluoride), PCA batteries exceeded their counterparts. PCA had 50% total capacity retention after 40 cycles compared to PAA (13%) and PVDF (1%). This study establishes ultra-high COOH-density binders as a solution for next-generation silicon anodes, demonstrating that PCA offers favorable chemical properties and superior battery performance to meet global sustainable energy demands.

**Awards Won:**

Second Award of $2,400

Chemistry and the Law: Third Award of $2,000