Accelerating Low-temperature Processing of Printed Nanoinks Using Machine Learning and Bayesian Optimization of Non-thermal Plasma Jet Sintering

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Motivation
- Rapid processing of emerging nanomaterials on flexible and thermosensitive substrates for applications in wearable electronics and in situ sensors
- Non-thermal plasma jets enable simple and low-temperature sintering of printed thin films on delicate substrates
- Machine learning Bayesian optimization (BO) approaches optimize multi-dimensional experimental problems in a low-cost and efficient way

References

Optimization Workflow & Results

Step 1. Determine plasma jet operating envelope ($Q_{\text{max}}, U_{\text{max}}, f_{\text{max}}$)

Step 2. Maximize SEI ($Q, U, f$)

Step 3. Maximize $\sigma$ and minimize $T_{\text{max}}$ ($d, n, t_{\text{on}}, t_{\text{off}}$)

Objectives:
- maximize electrical conductivity ($\sigma$) of ITO thin films
- minimize the peak substrate temperature ($T_{\text{max}}$)

• Decision variables: $Q, U, f, d, n, t_{\text{on}}, t_{\text{off}}$
• BO increases SEI by 2.4x
• Pareto front indicates the best trade-off between $\sigma$ and $T_{\text{max}}$

Summary
• Bayesian optimization method optimized 7-dimensional variable space to maximize the electrical conductivity of ITO films and control the substrate temperature under a relatively low value
• Non-thermal plasma jet sintering of ITO produced a conductivity of 7.6 S m$^{-1}$ with a substrate temperature below 47 °C in 1 hour
• Achieved 81.4% of furnace sintering with a temperature 250 °C lower and 3x faster

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