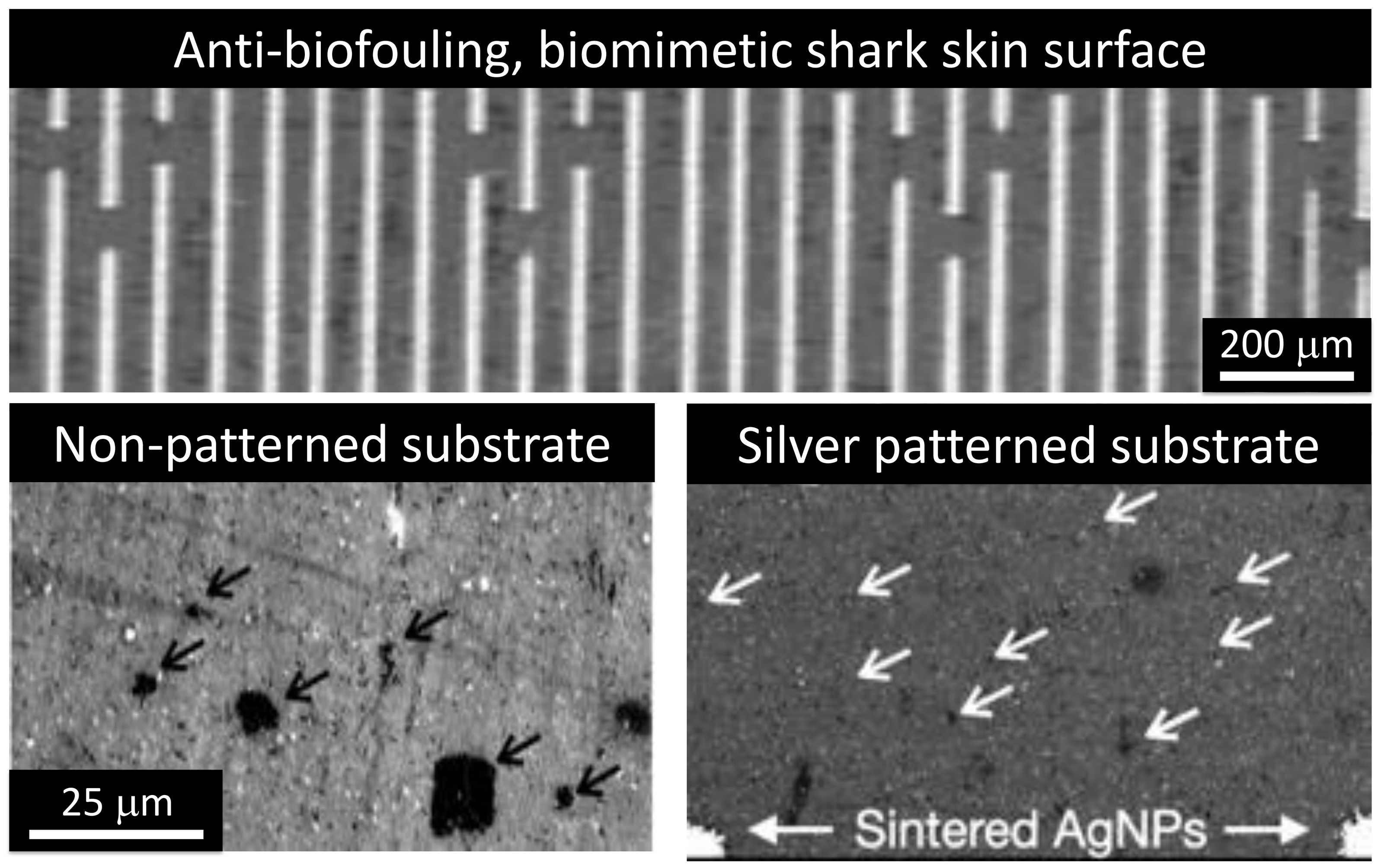
Quality Assurance in Biomaterial Aerosol Jet Printing Using Machine Learning

Samuel Gerdes[1], Srikanthan Ramesh[2], Aniruddha Gaikwad[1], Iris V. Rivero[2], Ali Tamayol[3], Denis Cormier[2], Prahalada Rao[1]

[1]Department of Mechanical and Materials Engineering, University of Nebraska-Lincoln,
[2]Department of Industrial and Systems Engineering, Rochester Institute of Technology,
[3]Department of Biomedical Engineering, University of Connecticut

Motivation: Aerosol jet printing (AJP) can create anti-biofouling and biomimetic surfaces. However, suboptimal parameters and process drifts negatively impact functionality of the construct.

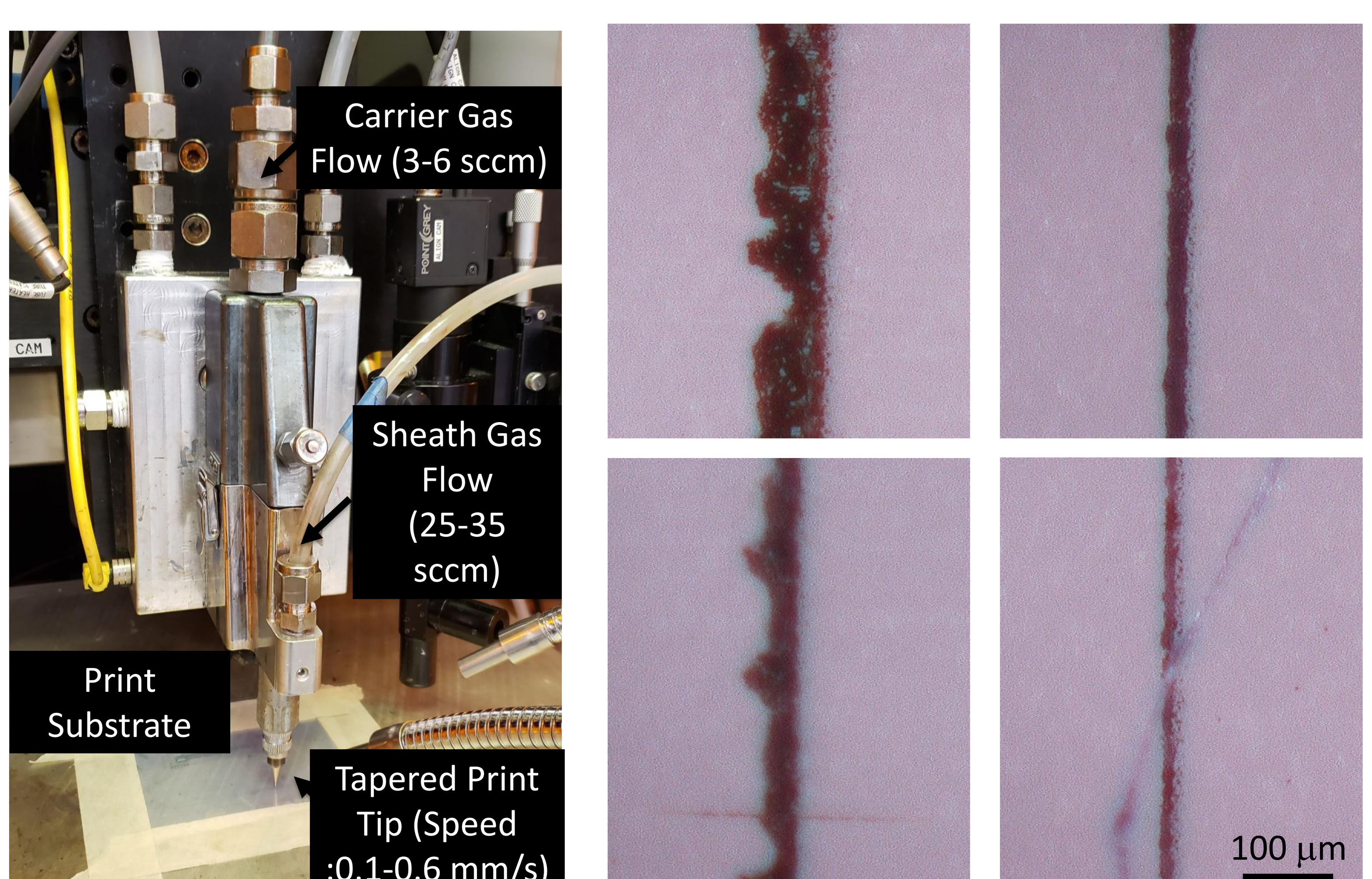


Silver nanoparticle (AgNP) patterned substrates avoid bacterial aggregation.

Goal: Detect and correct faults in AJP using in-situ sensor data.

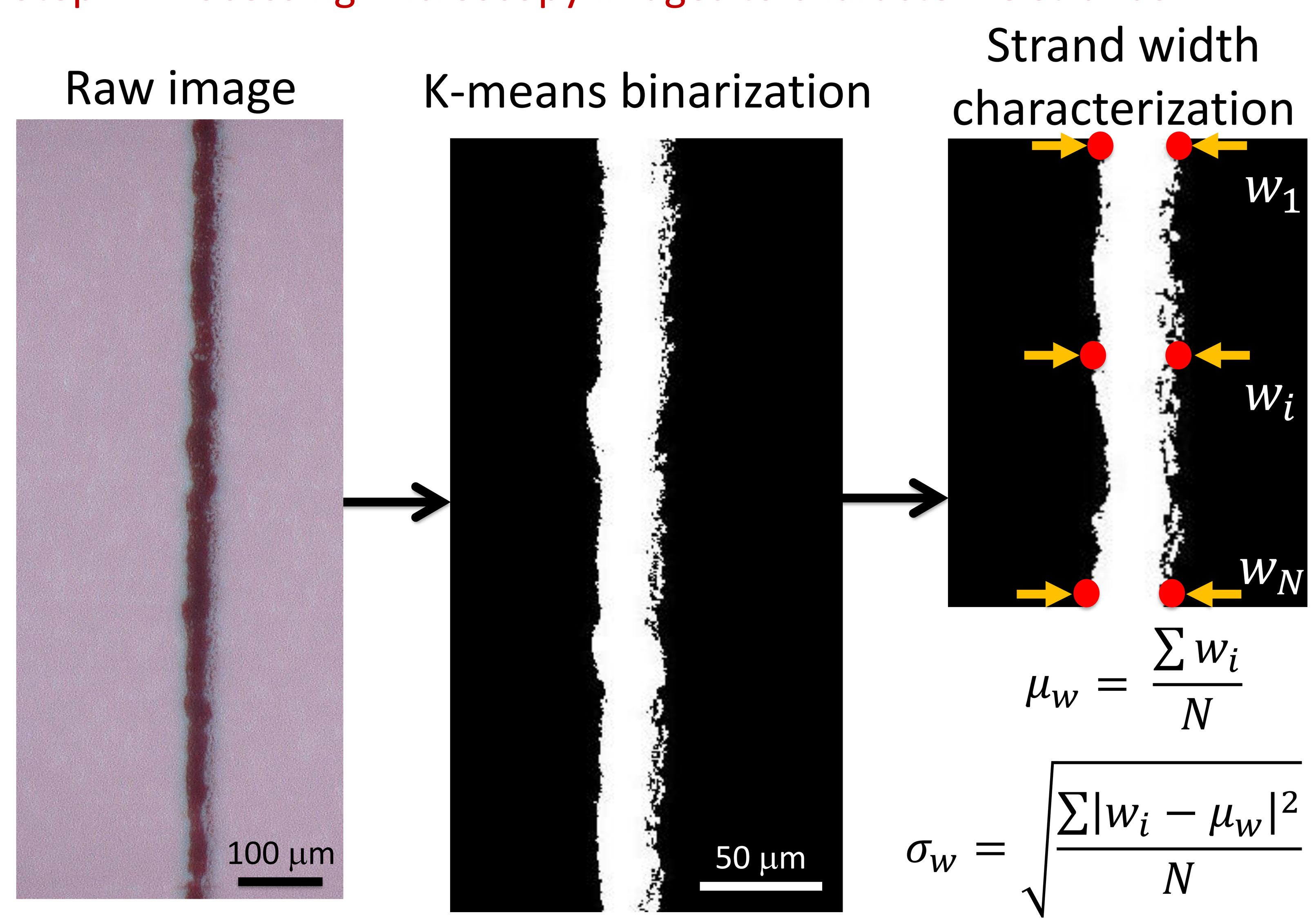
Objective: Predict strand quality, given the process parameters and phenomena, using machine learning.

Experimental Setup: (left) Printing setup for AJP. (right) Example microscopy images of varying strand qualities.



Methods

Step 1: Processing microscopy images to characterize strands



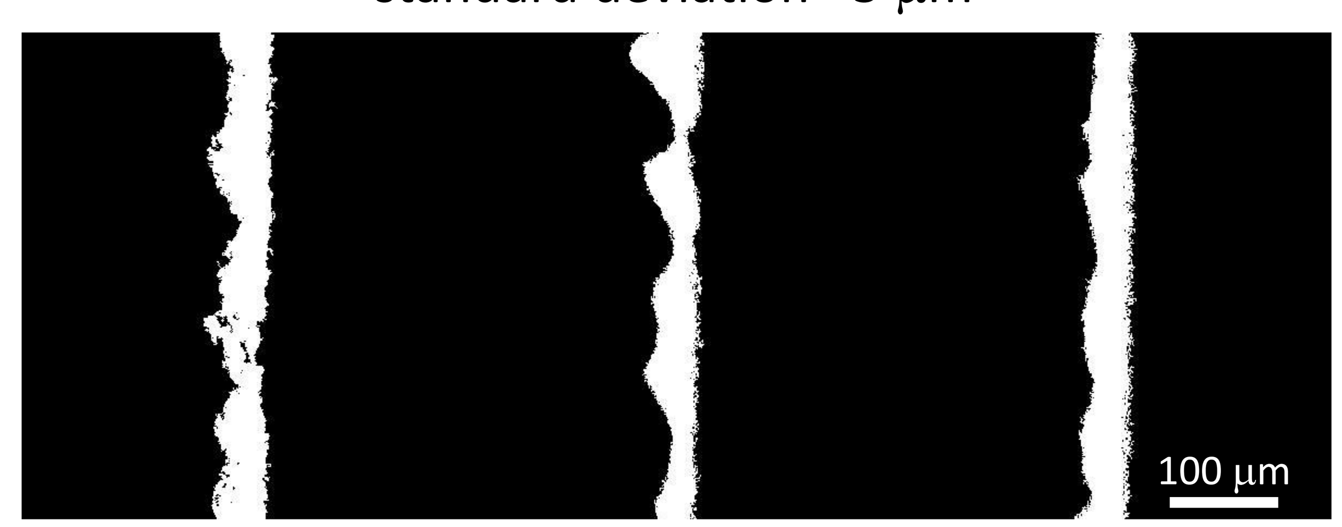
$$\mu_w = \frac{\sum w_i}{N}$$

$$\sigma_w = \sqrt{\frac{\sum |w_i - \mu_w|^2}{N}}$$

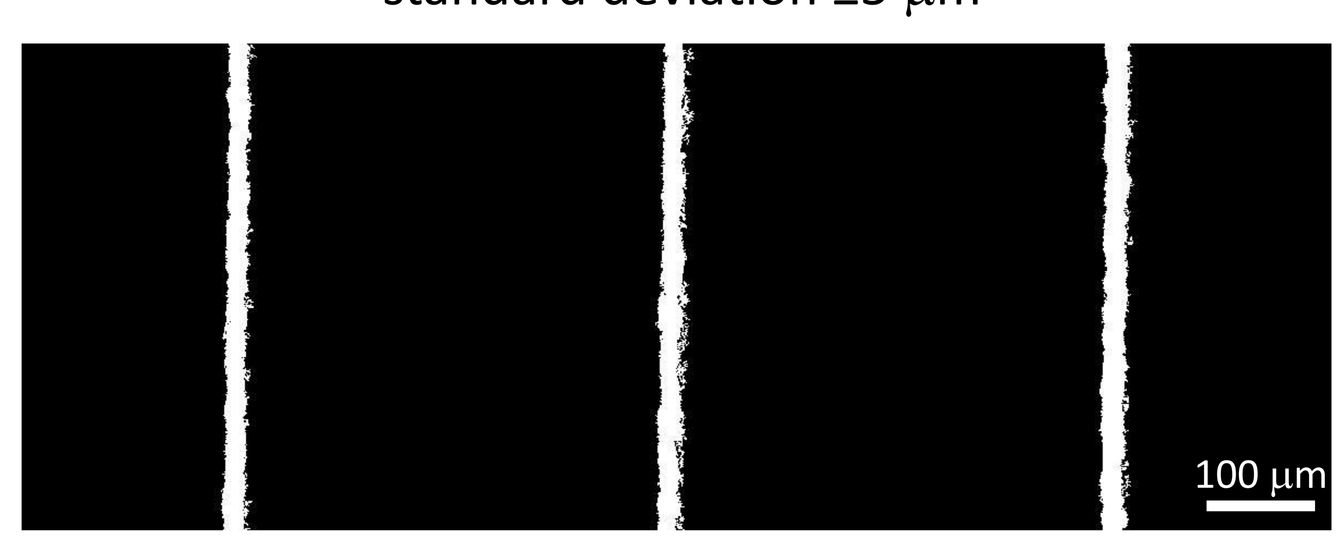
Strand measurements are indicators of their quality.

Step 2: Labelling print regimes

Regime 1 (R1): Undesirable, mean width >21 µm or standard deviation >5 µm



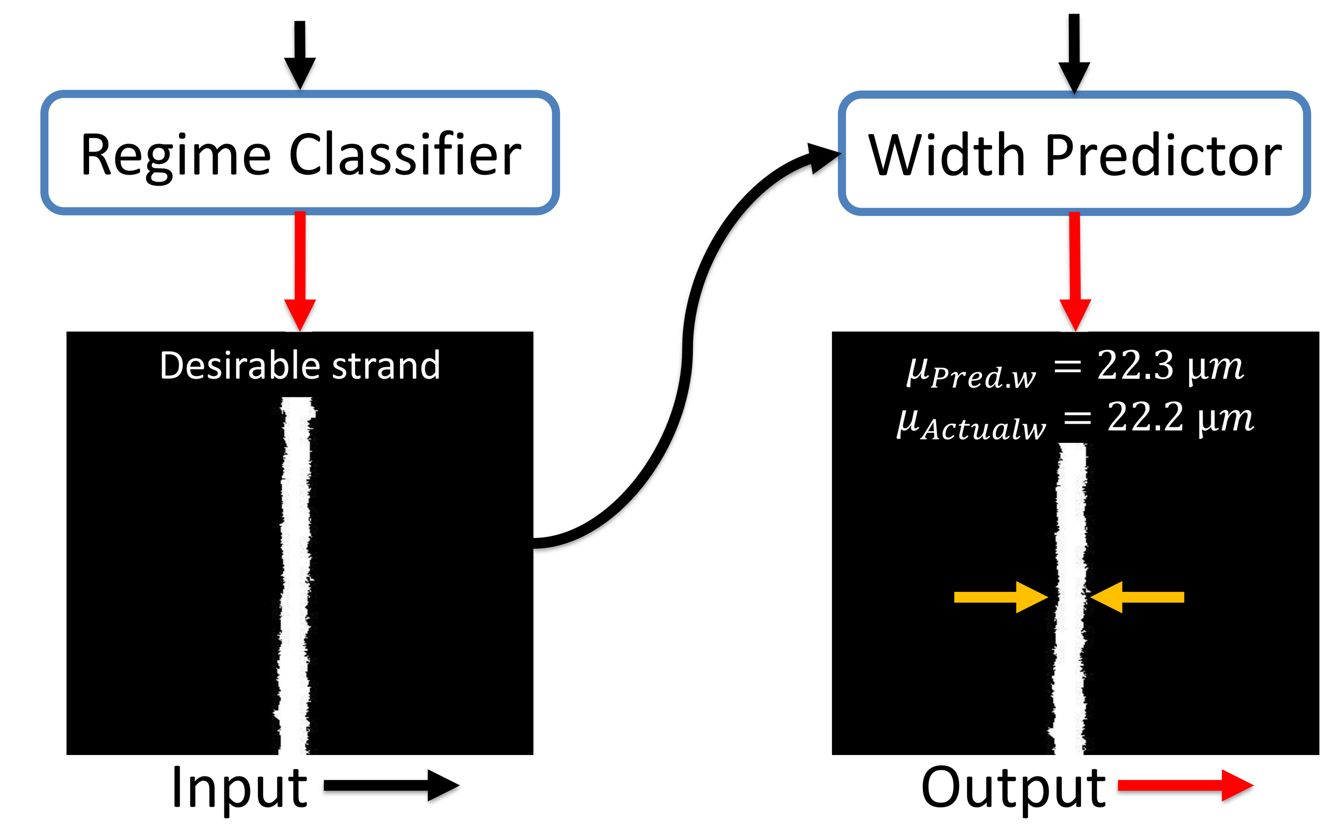
Regime 2 (R2) : Desirable, mean width ≤21 µm and standard deviation ≤5 µm



Step 3: Correlating process parameters and theoretical simulations to print quality using machine learning

- Print velocity
- Combination chamber Re #
- Focusing Ratio

- Sheath flow
- Carrier flow
- Print velocity
- Strand half

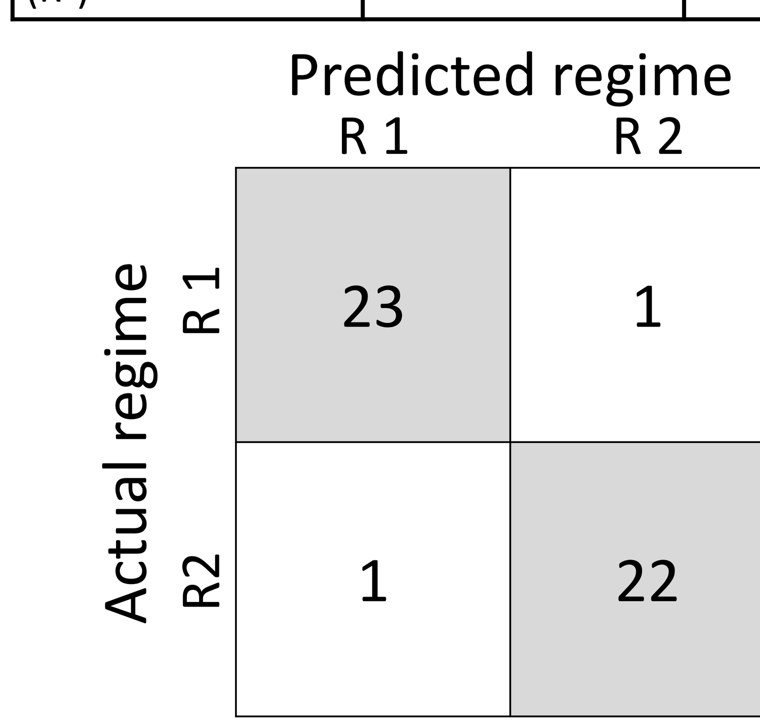


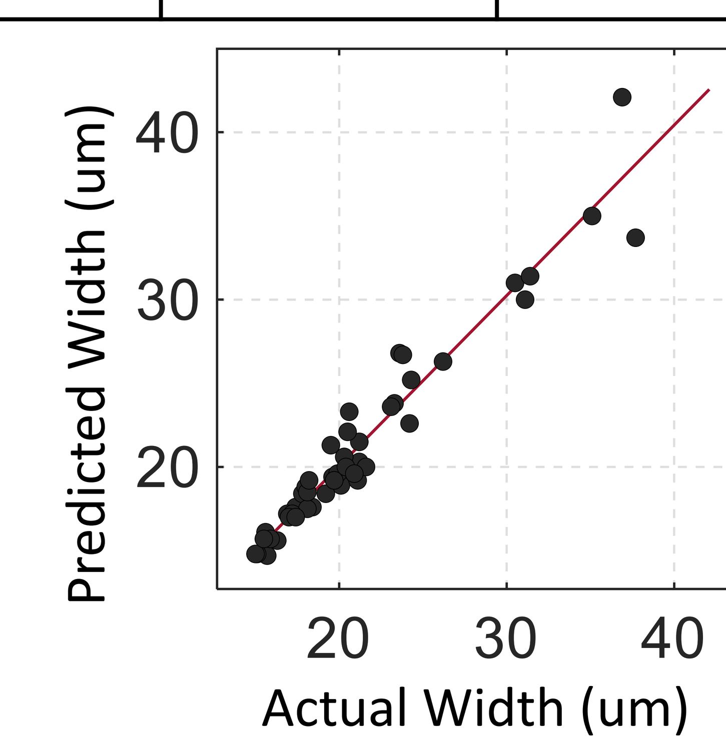
Sequential machine learning approach schematic utilizing process parameters coupled with theoretical CFD simulation results.

Results

- Desirable/undesirable classification performed with accuracy approximately 90% (2 misclassifications in 45)
- Strand width prediction accuracy ≈ 80% (264 train/46 test)

	Support Vector Machine	K-Nearest Neighbor	Random Forest	Artificial Neural Network
Regime Classifier (F1-score)	0.85	0.86	0.89	0.82
Width Predictor (R^2)	0.62	0.62	0.82	0.52





Broader Impacts: Establish pre-print, process parameter screening, avoiding wasted time and effort on failed prints. Further, the results highlight machine learning's versatility in small dataset applications, reducing the experimental burden to produce sufficient machine learning networks.