

I. Background

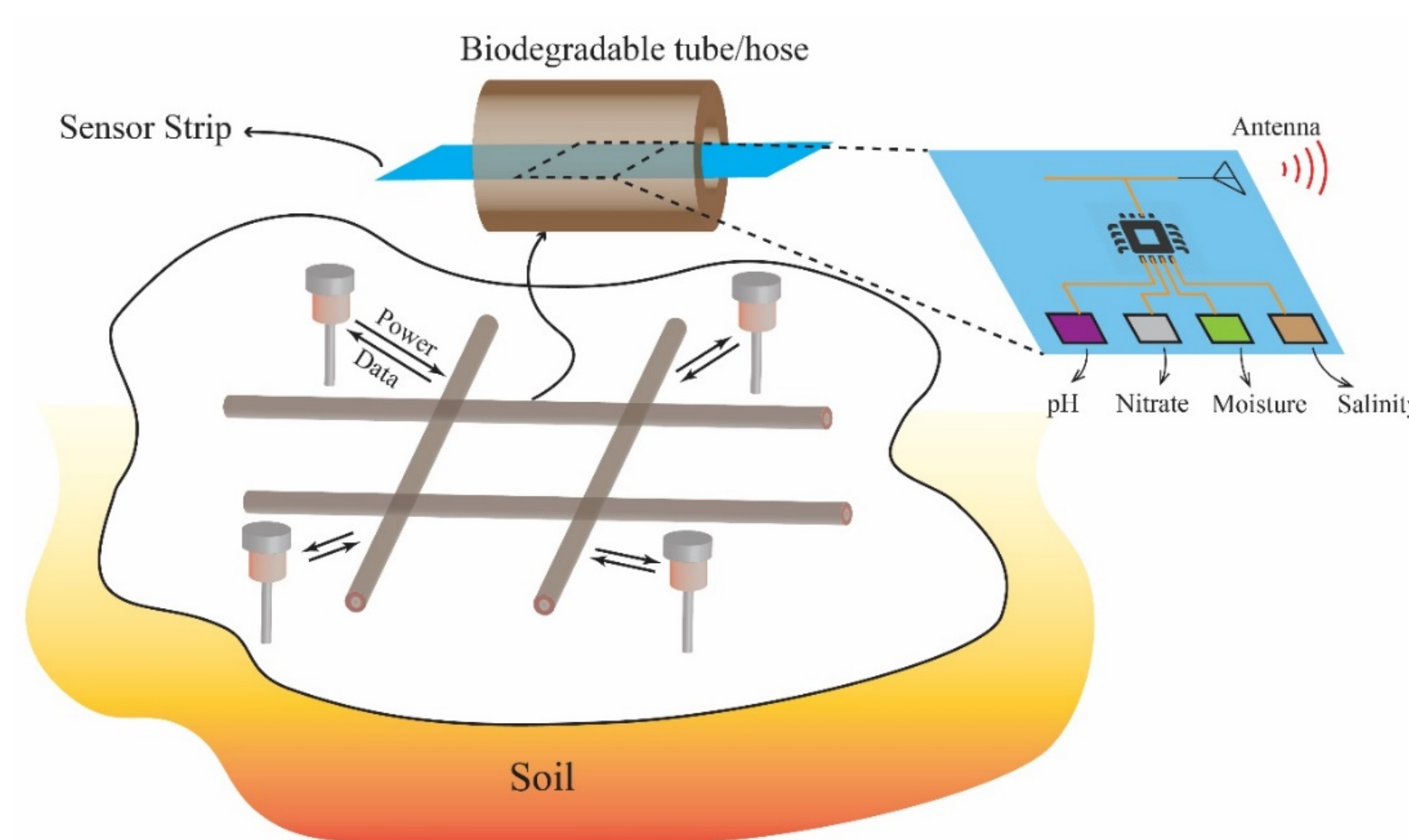
- The WHIN program seeks to create a local IoT network that feeds back data to improve outcomes in manufacturing and agriculture.
- Agricultural chemical sensors inform farmers about the chemical state of their soil.
- Accurate soil chemical data allows farmers to improve crop yield while reducing cost and environmental impact, by tuning fertilizer rates, for example.
- Current cost of agricultural chemical sensors limits widespread usage.
- WHIN project work is underway to lower the cost of ag. chemical sensors via roll-to-roll manufacturing methods for:

**Printed Flexible Electronics
Continuous Slot Die Coatings**

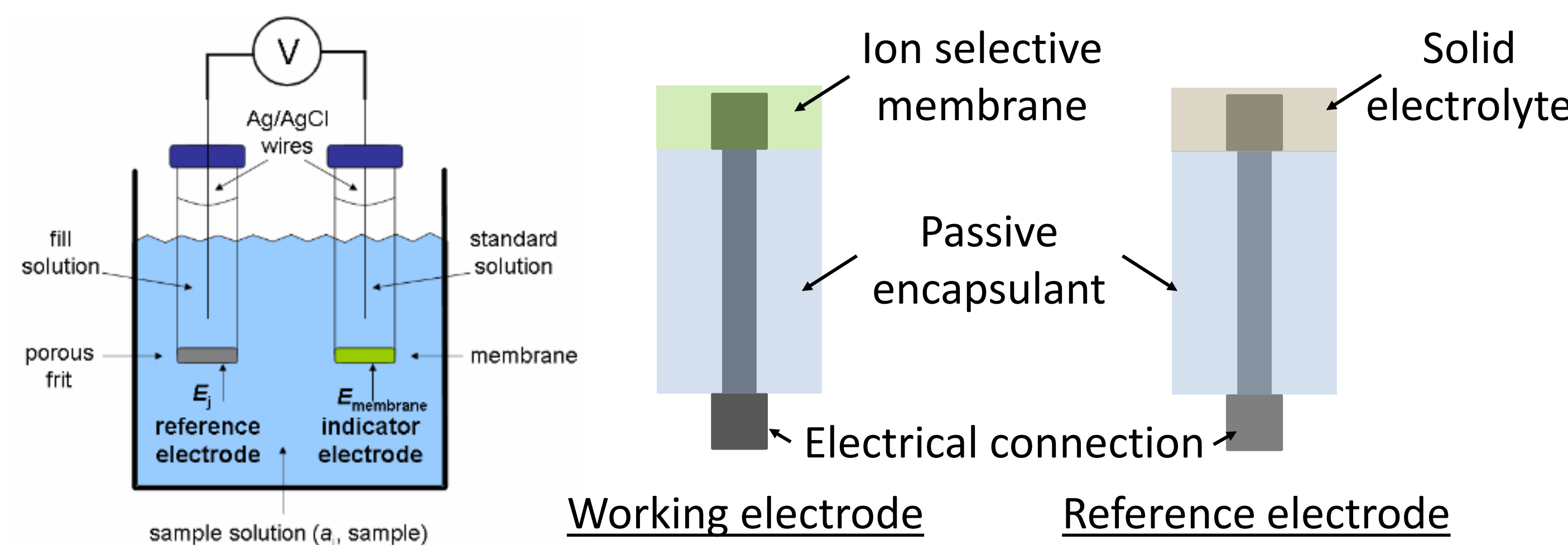
- These processes are high throughput, high reliability, and automated/not labor intensive.

II. Nitrate sensors

- Nitrate (NO_3^-) is a key plant nutrient; need to measure over 1-50 ppm range in soil.
- Real-time, in-field and non-destructive measurement
- Low cost sensors needed to measure large areas with high resolution.



III. Science of Measuring Nitrate

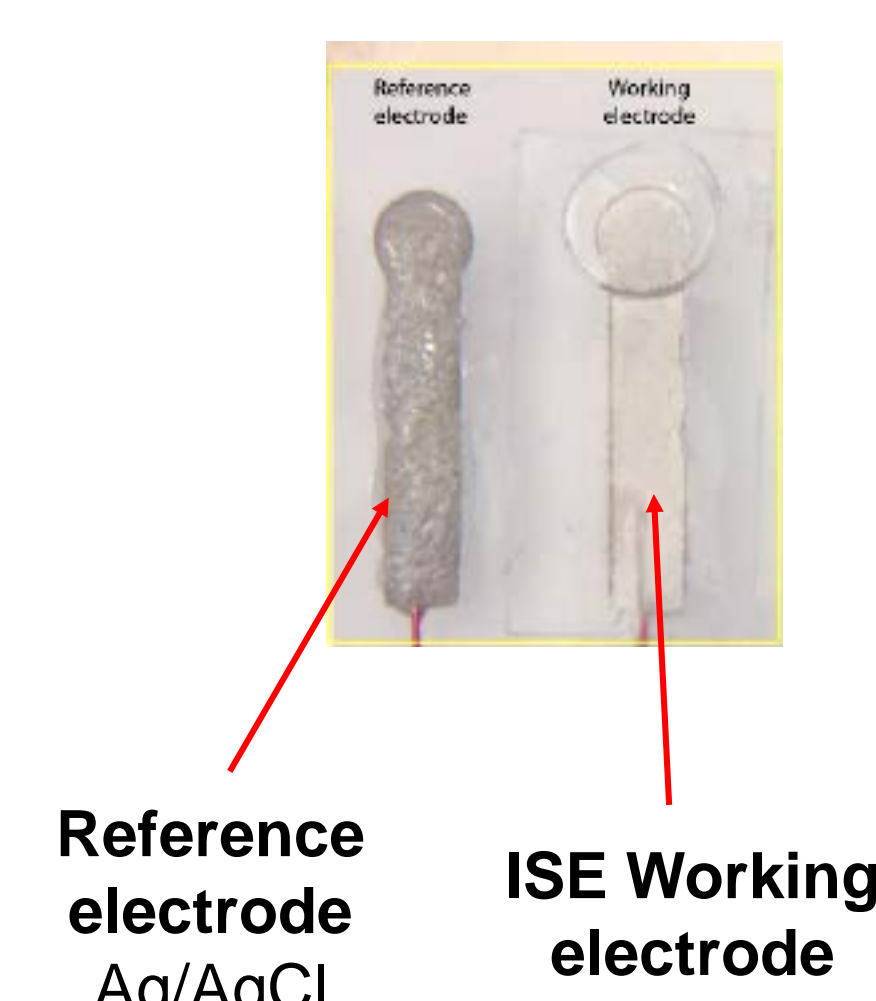
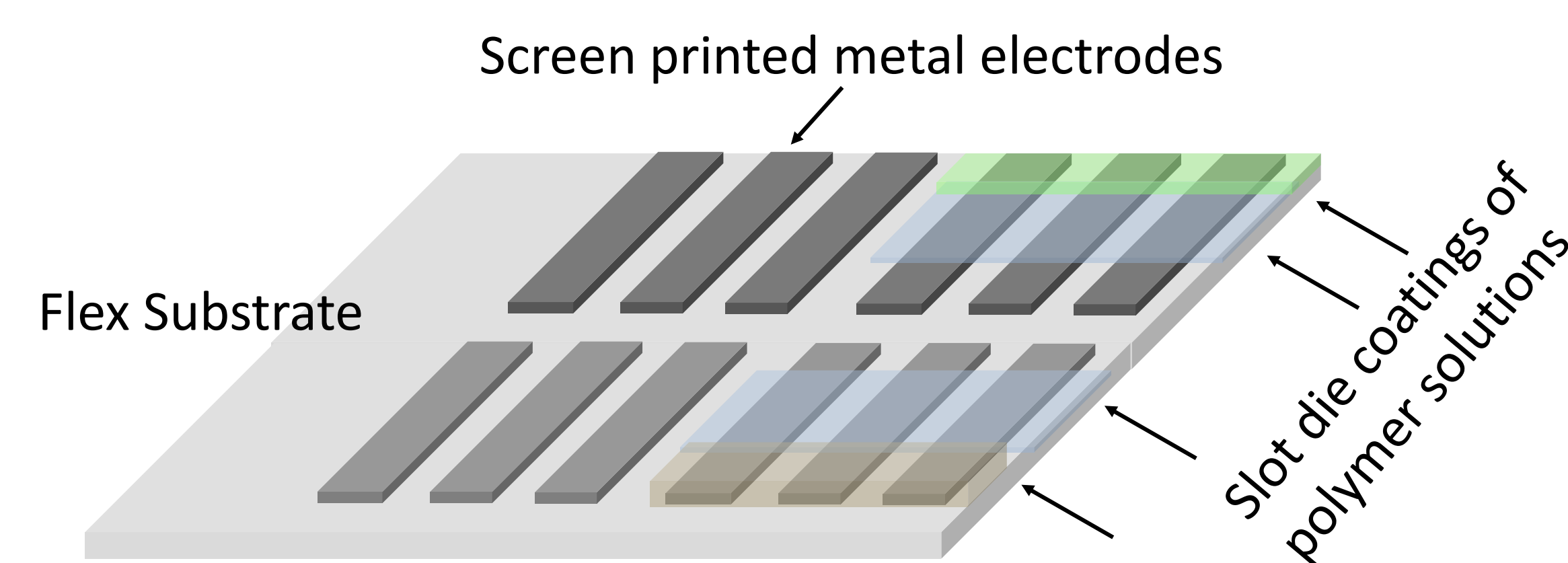


Potentiometric sensors:

- Signal measured: potential difference between working electrode (WE) and reference electrode (RE).
- WE potential depends on nitrate ion concentration.
- Ion selective membrane coating ensures only the nitrate ion impacts the WE potential.
- RE provides defined reference potential via solid electrolyte coating.

IV. Prototyping the Sensor

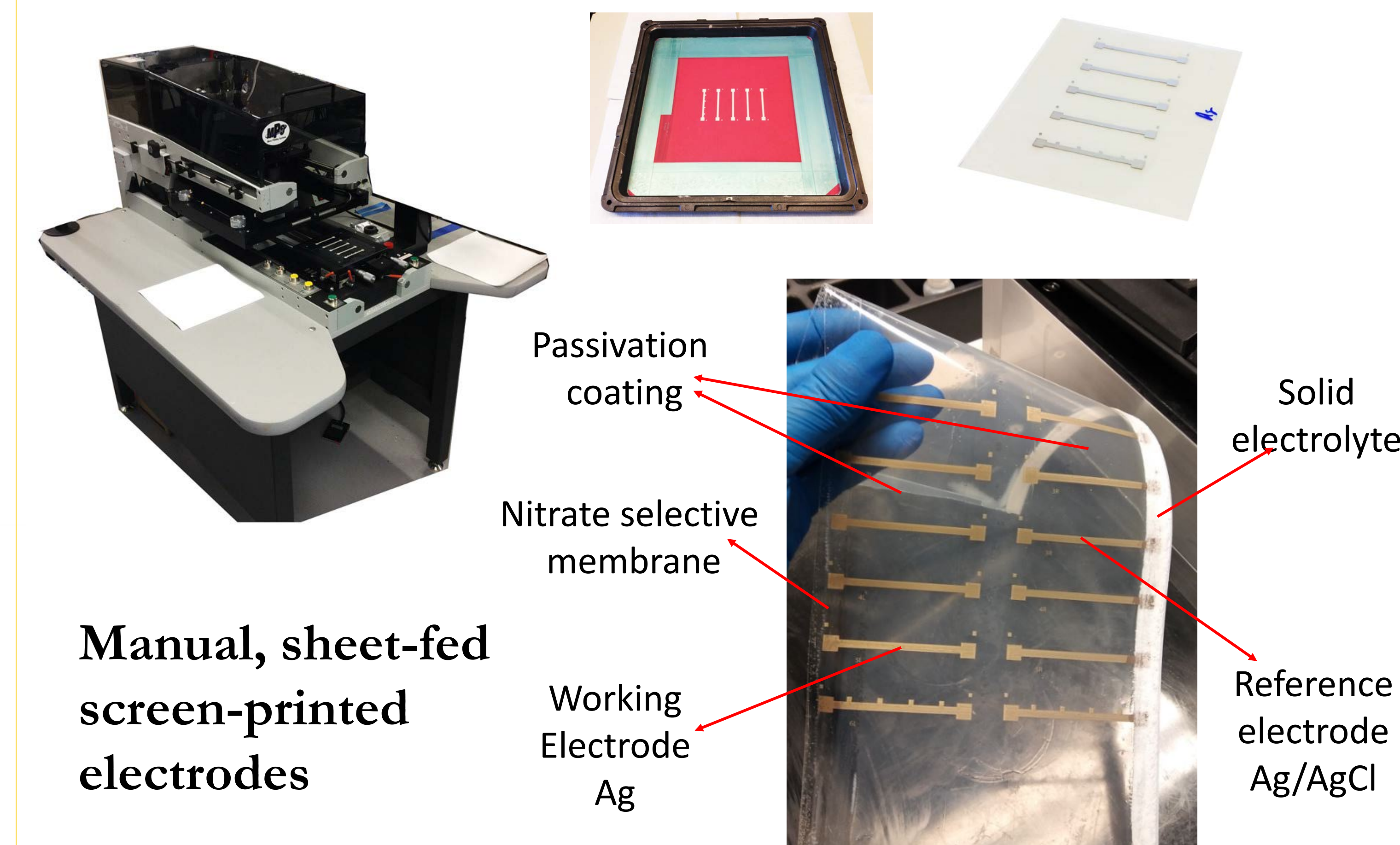
- R&D fabrication methods developed to be compatible with scalable roll-to-roll manufacturing.



Early Prototype:
Hand-painted electrodes,
Pipetted coatings.
(courtesy R. Rahimi)

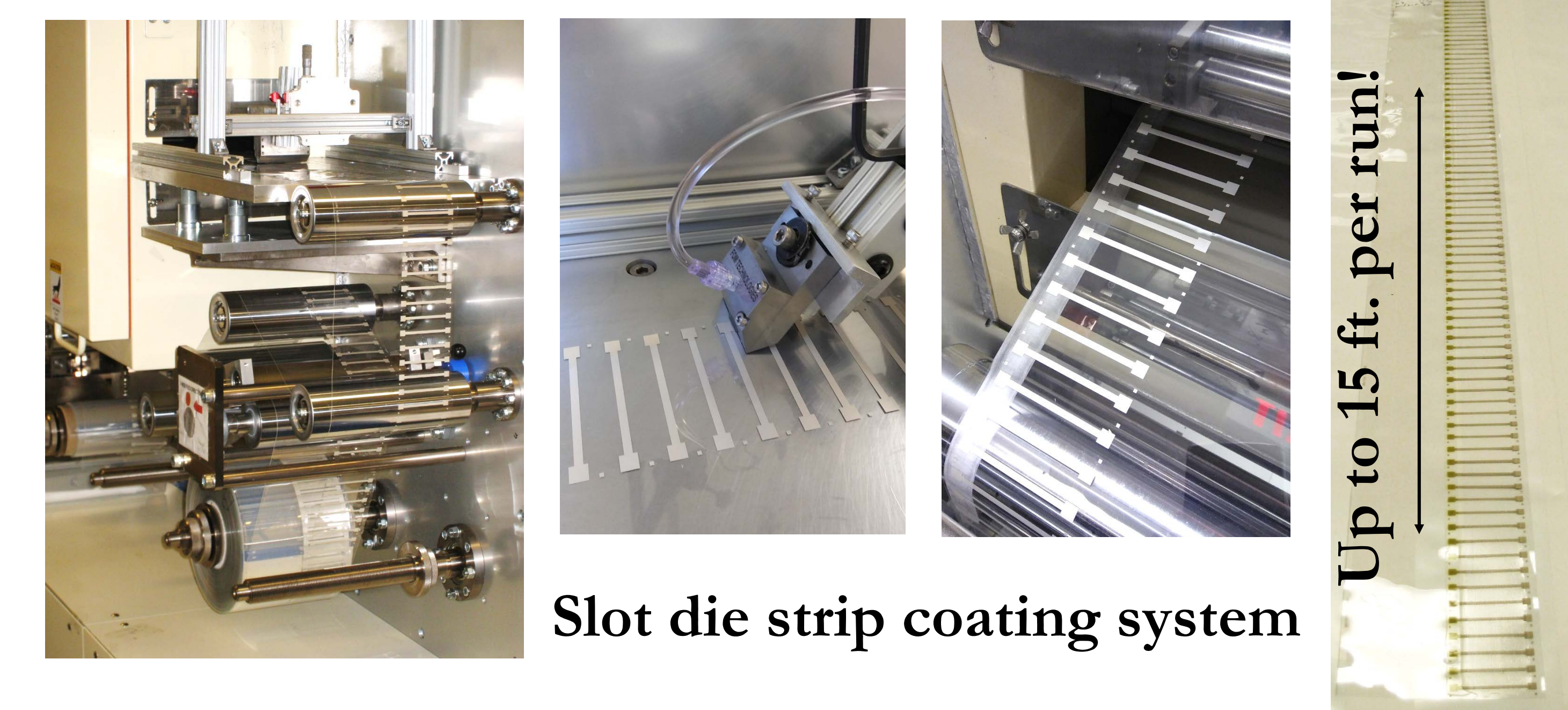
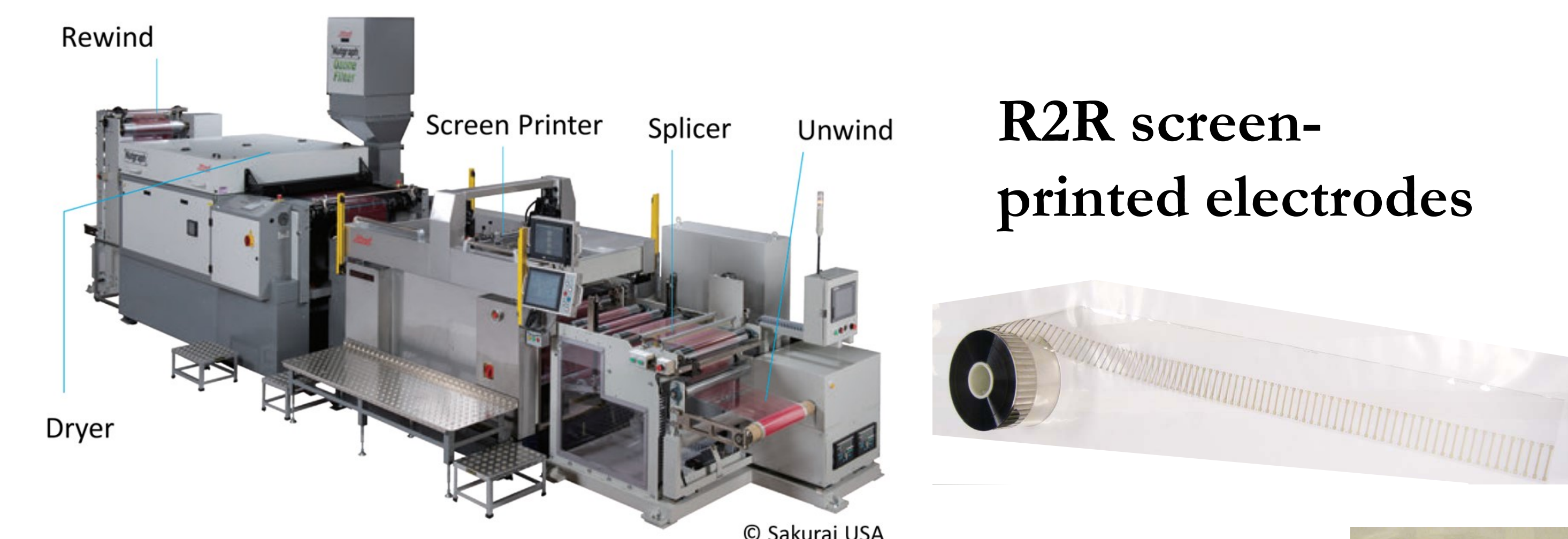
V. Sensor Manufacturing

- First scale-up steps involve single sheet printed electrodes, coated with customized doctor blade.



Manual, sheet-fed screen-printed electrodes

- Sheet-fed samples successfully demonstrated materials and layout compatible with roll-to-roll (R2R) processes.



Slot die strip coating system

- Successful demonstration of R2R sensor manufacturing.