Colorimetric Leaf Sensors: Fabrication and Optical Detection

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We have developed: (i) a custom imprint tool for passive optical sensors, (ii) camera mount for a forward-facing RGB (FLIR) camera with two degrees of freedom (iii) algorithm to determine sensor angle relative to the FLIR camera

Introduction

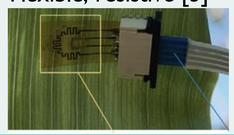
Drought can lead to decreased crop yield and plant increased stress. Heightened leaf temperature and wet leaf surfaces can be used to isolate stressed individuals [1-2]. Low-cost, colorimetric sensors are being developed to measure leaf temperature and surface moisture. Interrogation of these sensors will be done by observing the visible/near IR light reflect from the sensors utilizing ground/aerial imaging systems.

Current leaf sensors are typically battery powered and expensive which limits the #sensors/acre that can be deployed

Apogee IR Radiometer

Implexx Sense

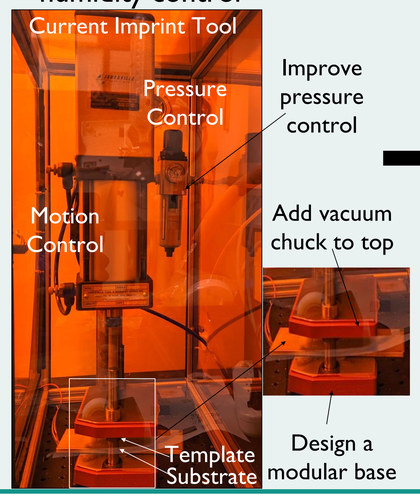
Flexible, resistive [3]



Objectives

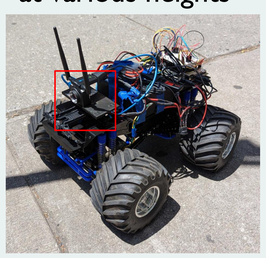
Leaf Sensor Fabrication:

- Design a custom imprint tool that incorporates pressure, temperature, and humidity control



Leaf Sensor Detection:

- Design a mount to allow FLIR camera to capture sensors located at various heights

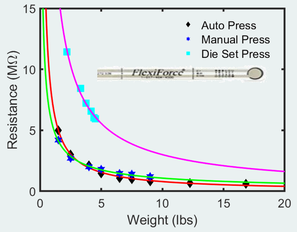


- Determine the angle at which the sensors are relative to the camera

Custom Nanocrystal Imprint Tool For Sensor Fabrication

Miniaturization of Imprint Tool:

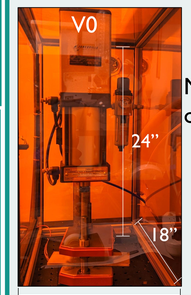
Design Specifications	V0	V1	V2
Fine Pressure Control	×	✓	✓
Compact	×	✓	✓
Heating	×	×	✓
Vacuum Chuck	×	×	✓
Auto Z-Plane Control	×	×	✓
Optical Metrology	×	×	✓



Calibration curve created for the pressure sensor used in imprints

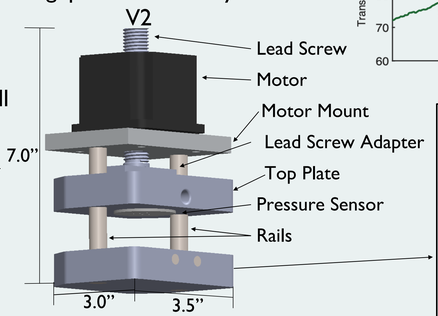
Current design flaws
- Needs shims to achieve pressure control
- Bulky
- Only have one to use for imprinting

Improvements made:
- Enabled fine tuning of pressure
- Small enough to use inside a glove box
- Increase throughput of sensors by 3x

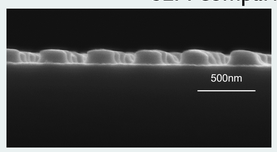


Miniaturization of imprint tool

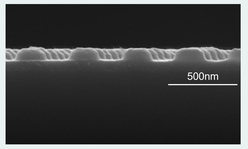
Incorporate all specifications



SEM comparison of sensors:

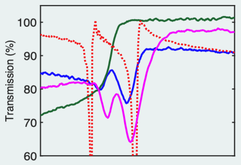


Old imprint tool



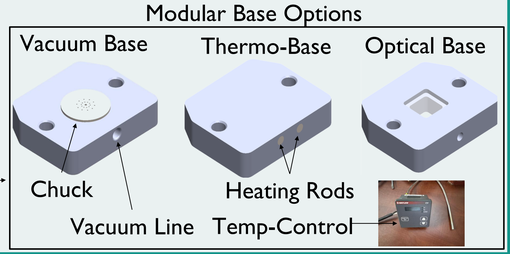
V1 imprint tool

- Same pillar heights and spacing
- New imprint tool was able to produce similar results

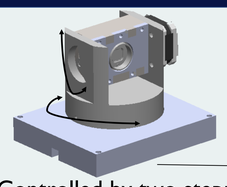


- Achieved resonance peaks with V1 imprint tool

Modular Base Options

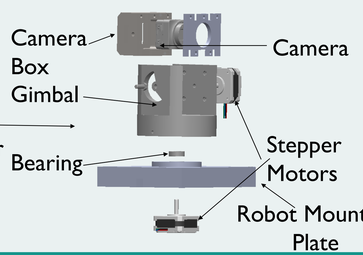


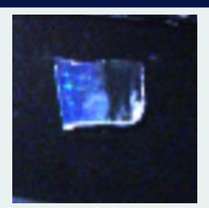
Custom Camera Mount for Sensor Detection



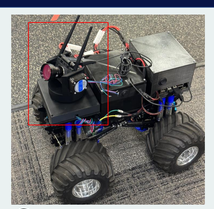
- Controlled by two stepper motors
- 2 degrees of freedom (Pitch and Yaw)

Exploded View:





Picture of the sensor taken by the FLIR camera



Camera mount on ground robot

Used Hough Transform to detect lines to estimate leaf angle

Future Work

- Decrease sensor fabrication time by controlling temperature around the substrate
- Control separation of template through the use of the vacuum chuck
- Integrate real-time leaf angle detection and calculation
- Modify leaf angle detection algorithm to better estimate the sensor's location relative to the camera

1 - Weather and climate extremes, 10, 4-10.
2 - American Journal of Botany, 90(6), 857-864.
3 - Adv. Mater. Technol. **2021**, 6 (6), 2001246.

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