Biosensor for in-situ Measurement of Microbial Activity in Soil

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I. Motivation

As industrial agriculture continues to expand, it is clear that we need to address the negative impacts that the use of heavy pesticides and fertilizers have in the environment. As we begin to look for alternatives to these practices, we realize that our understanding on how the microbiome, which already exists in all soils, can be used to enhance crop yields without the damages is very limited.
Monitoring microbial activity will become crucial as we strive to achieve sustainability and developing a cost-effective sensor which allows in-situ measurements of microbial activity will serve as the first steps towards painting a full picture.

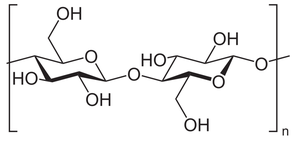
II. Measuring Microbial Activity with Cotton

Shirley Soil Burial Test Fabric, used traditionally to measure microbial activity, before and after burial. Threads on the cloth mark areas with standard thread counts, e.g. 36 threads across 1 cm of cloth bounded by two blue threads. This ensures that an equal number of threads are broken in a tensometer during measurement of tensile strength across different soil treatments.

- **The Soil Burial Test has been reportedly used since 1945 as a measurement of microbial activity**
- **It consists in burying a piece of cotton fabric in soil for a period of time and performing tensile testing on the material after**
- **High levels of microbial activity would be indicated by a loss in tensile strength as the bacteria degrade the fabric**

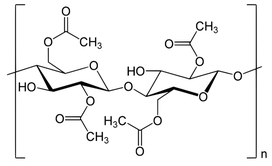
Cellulose, The Key to Microbial Activity Sensing

Cellulose



- **Cellulose is a naturally occurring polymer composed of the monomer glucose**
- **The cotton films are made of 96% cellulose which enables degradation**

Cellulose acetate

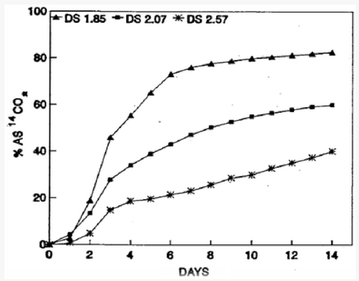


- **Cellulose acetate consists of the same cellulose backbone with acetate groups along the chain**
- **It has been used to create films and coatings**

Potential for Microbial Activity Sensor

Degradation of cellulose acetate films due to microbial biomass presents the opportunity to create sensors which measure degradation and relates it to bacterial activity. The ability to form cellulose acetate films makes this substrate especially attractive

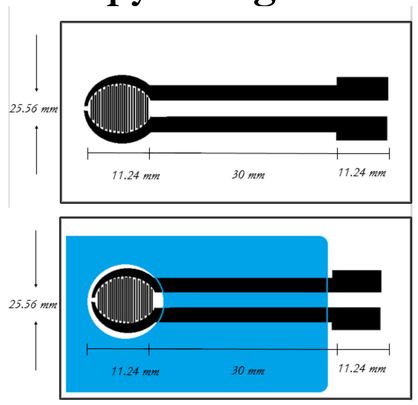
III. Sensor Designs and Applications



Biodegradation of cellulose acetates with different Degrees of Substitution (DS: 1.85, 2.07, 2.57) as indicated by the percent of labeled carbon metabolized to 14CO2. The materials were exposed to biologically active laboratory aerobic test vessels at 53 °C.

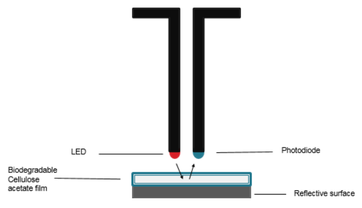
Bacteria	Mostly found in:
Neisseria sicca	Mucosal surface of many animals
Alcaligenes xylosoxidans	Soil, water, and some cases in saline solution (CDC outbreak case)
Pseudomonas (various strains)	Soil, water, plants, and on the skin

Impedance Spectroscopy Using Interdigitated Electrodes (IDE)



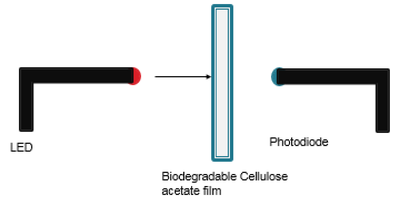
- **Copper based Interdigitated Electrodes are created through photolithography using a positive photoresist**
- **All exposed areas are covered with a passivation layer using SU-8 photoresist**
- **The exposed IDE's are covered with a cellulose acetate film. Changes on the film (degradation) are measured by quantifying the change in impedance**
- **This gives a direct measurement for microbial biomass**

Optical Approaches based on Staining and Degradation of the Material



LED – Photodiode system to measure changes in light intensity as the cellulose acetate films degrade/stain

- **Left. A reflecting surface is covered with a biodegradable cellulose acetate film. As the film degrades, the intensity of the reflecting light increases**
- **Right. A cellulose acetate film is placed between an LED and a photodiode. The amount of light that goes through the material with change as the material stains or degrades**



IV. Limitation and Future Work

- Testing the IDE based sensor under a full spectrum is necessary to establish the relationship between degradation and microbial biomass
- Optical and Impedance approaches are limited by the rate of degradation and rate of staining
- Optical approach can be more sensitive to interference (noise) when placed in the field