Microwave Monitoring of Microbial Degradation with UV Sources

Yaw Obeng, Dianne Poster, C. Cameron Miller, and Michael Postek

Physical Measurement Laboratory

National Institute of Standards and Technology

U.S. Department of Commerce

Creating an Index of Cell Viability

Electrical Properties of Cells –

Valuable information in the measurements of a cell's electrical resistance and impedance

1) During cell death, a sharp decline of electrical resistance is observed
   - Results from pore formation in the membranes of dead cells through which ions can penetrate
   - Leads to a change in ionic composition in the cell, water
   - Resistance is a property of a material that quantifies how strongly that material opposes the flow of electric current.
   - A low resistivity indicates a material readily allows the flow of electric current – more ions in the cell lead to readily ability to flow electric current, leading to decreased electrical resistance

- 2) Necrosis (cell death) of plant tissue
   - Leads to a change in measurements of impedance
   - 10–20% increase in high frequency conductivity

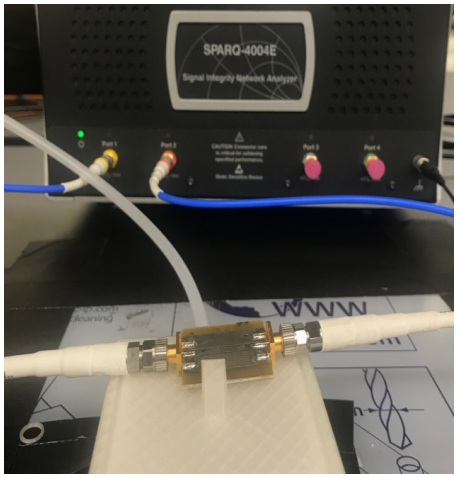
A. N. Romanov, "Changes in the Dielectric Properties of Water in Yeast Cells during Their Death ", Biophysics, 2009, Vol. 54, No. 5, pp. 607–611.

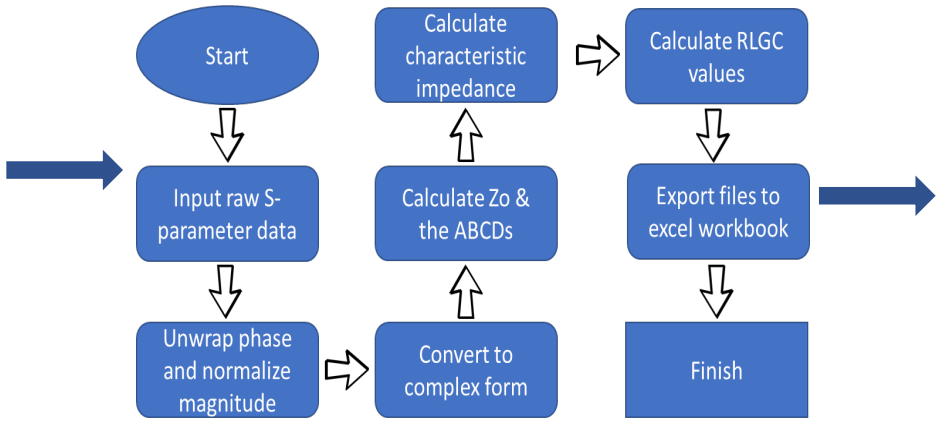
Results

Measuring a waveguide's dielectrics properties

Capturing the raw data via our module produces for microwave spectroscopy

Demonstrate Feasibility of metrology for UV-degradation of biomolecules (yogurt cultures) adsorbed on glass substrates

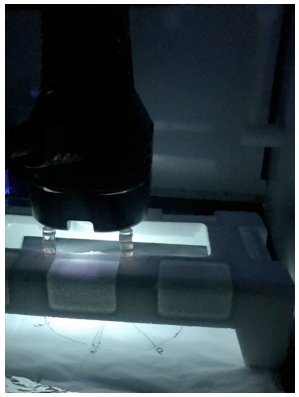




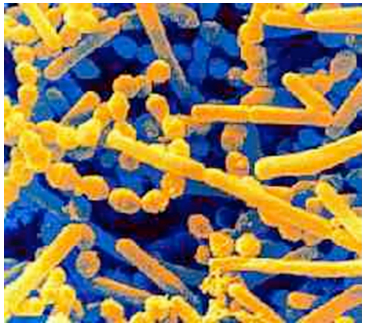
- Resistance (R)
- Inductance (L)
- Capacitance (C)
- Characteristic impedance (Zo)
- Propagation constant (Γ)

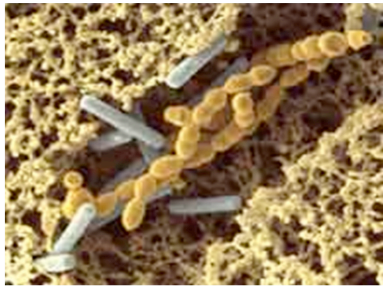
UV-degradation of Yogurt Films on Glass in Air

Experimental Setup



SEM of Yogurt





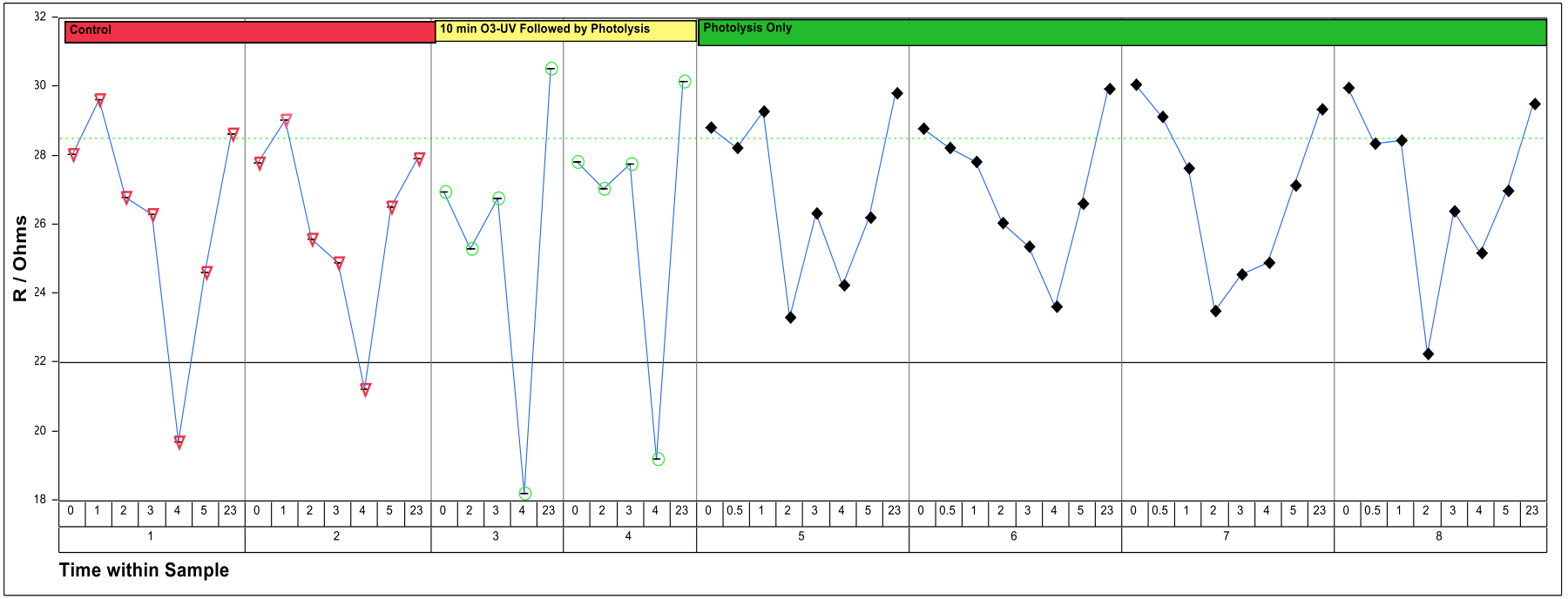
SEM (scanning electron micrograph) of Streptococcus thermophilus (yellow)and Lactobacillus bulgaricus cells (blue) in yogurt. Streptococcus thermophilus is a lactic acid bacterium found in fermented milk products, used in the production of yogurt

http://www.magma.ca/~scimat/FoodStruct_1982-93.html

Electrical Resistance as Index of Cell Viability

Death of biological cells → Reduced Electrical Resistance

- (as a result of pore formation in the membranes of dead cells and change in water content)
- BDS detects change in electrical properties biomolecules in thin film



Fresh Samples

Dead Samples

- Cells die by (i) starvation (out of substrate in about 4 hrs.)
- (ii) UV-Ozone (O3) does not kill all the bacteria in the Yogurt Film
- (iii) or (ii) by photolysis (in about 2 hours) - cell death is accelerated by UV-photolysis from 4hrs to 2 hrs.
- Cells that survive UV-irradiation eventually will die by starvation.

Gaps and Limitation

- Use modern calibrated light sources
- Light monitor to determine how much light is hitting the samples
- Uniformly irradiate samples in a controlled environment (atmosphere, temperature, humidity)
- Sample-to-sample reproducibility (i.e., uses cell culturing wells)
- Serial Measurement time overhead for samples in a batch

Next Steps

- Comprehensive Chemical analyses of intermediate and final products
- Test theory and concepts on with Bakers' Yeast
- Define parameters for HAI mitigation efficacy
- Distance and angular dependence of irradiation efficacy
- Predictive models for UV-photolysis (e.g., COMSOL models)

Dr. Yaw Obeng
yaw.obeng@nist.gov