Broadband Dielectric Spectroscopy (BDS) Assessment of UV-C Disinfection

Brian Nablo, Darwin Hernandez, Papa K. Amoah, Yaw Obeng
NIST

Yaw.obeng@nist.gov

UV-Disinfection Works

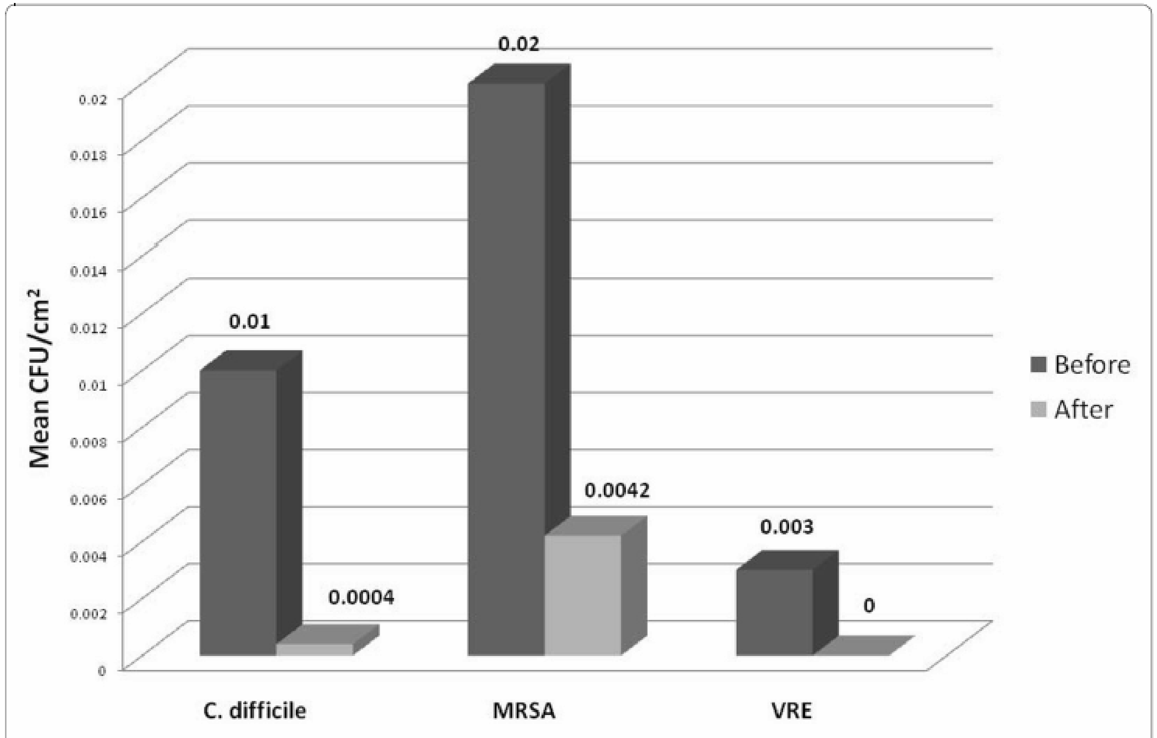


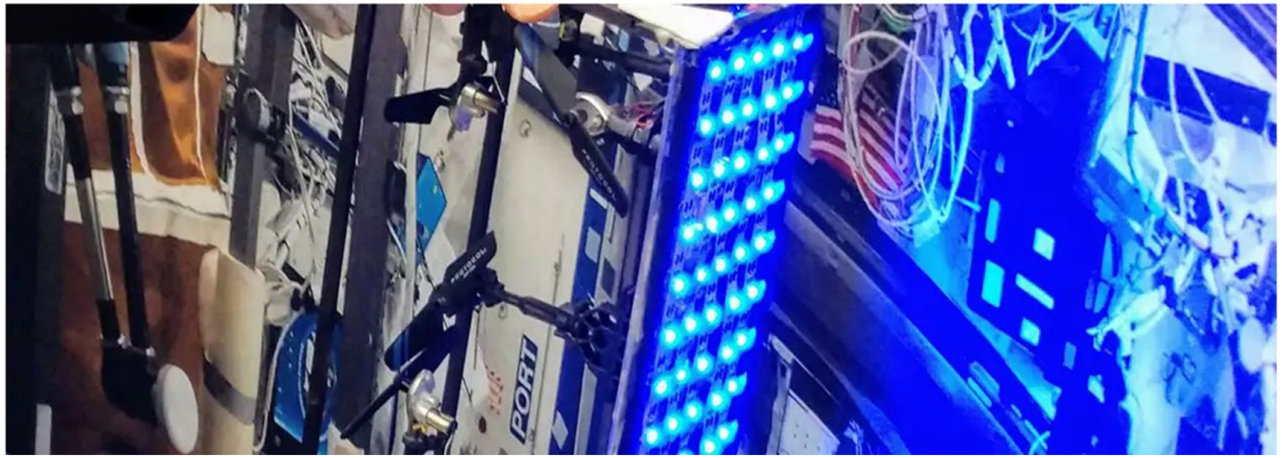
Figure 4 Mean number of colony-forming units (CFU) of *Clostridium difficile*, methicillin-resistant *Staphylococcus aureus* (MRSA), and vancomycin-resistant *Enterococcus* (VRE) recovered from contaminated surfaces in hospital rooms before and after disinfection with the Tru-D device. Two-hundred sixty-one total surfaces from 66 rooms were cultured, including call lights, bedside tables, telephones, and bed rails.

NewScientist

Zero-gravity robot cleaner could automatically sterilise the ISS

0

SPACE 19 April 2019



Why the Need for Practical Methods to Assess UV-C?

- Truth-in-advertising: comparison of different UV devices
- Training of EVS staff
- Ongoing monitoring of device efficacy
- New applications
  - Surgery, radiology, portable equipment, small devices
- Safety

Adapted from C. Donskey, "Perspectives on assessing UV efficacy by biological measurements", presented at the Workshop on Ultraviolet Disinfection Technologies & Healthcare Associated Infections: Defining Standards and Metrology Needs, NIST ,Gaithersburg, MD Jan 14-15, 2020

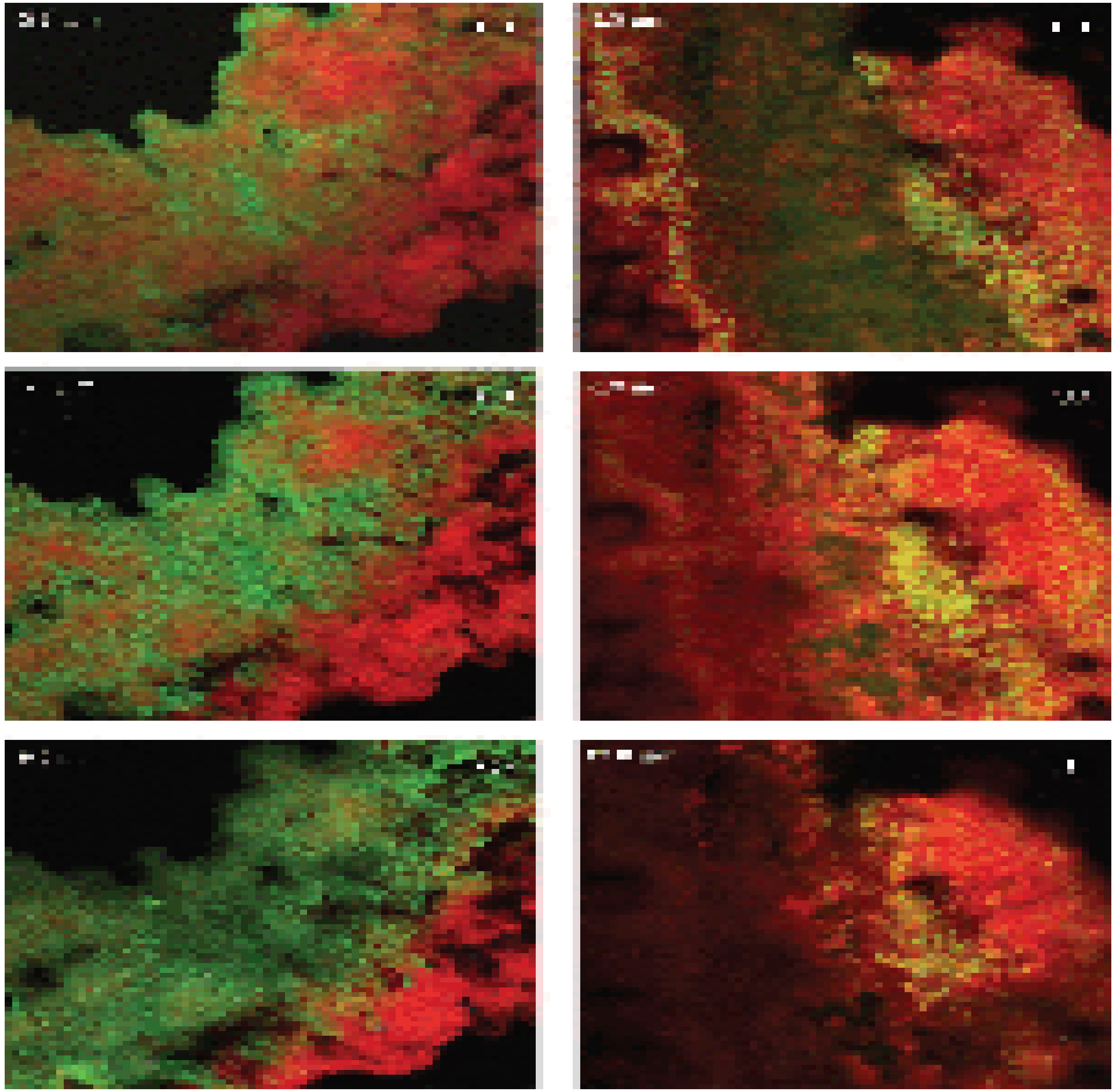
Some Current Methods For Monitoring UV-C Devices

- Reductions in test organisms on carriers
- Cultures for pathogens
- Radiometric sensors
- Colorimetric indicators

ASTM E3135-18. Standard practice for determining antimicriobial efficacy of UV germicidal irradiation against microorganisms on carriers with simulated soil; Masse V, et al. Antimicrob Resistance Infect Control 2018;7:29

Cultures for Pathogens:

Survival of P. aeruginosa PA103 in Biofilms after Plasma Treatment

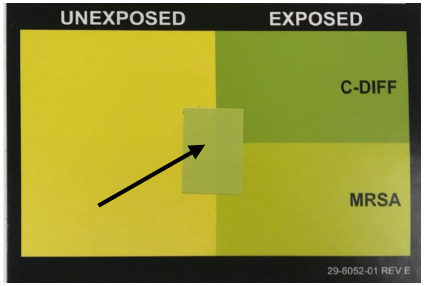


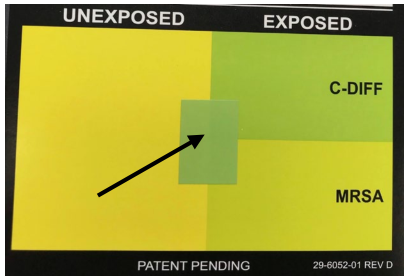
Biofilms formed on glass surfaces were treated with argon plasma or non-ionized argon for 5 min.

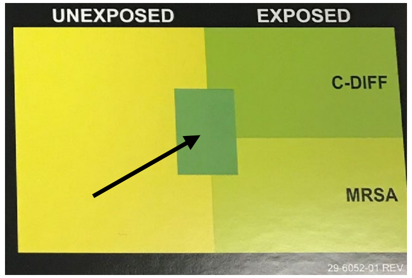
Live bacteria were stained green and dead bacteria red.

Ermolaeva et al., "Bactericidal effects of non-thermal argon plasma in vitro, in biofilms and in the animal model of infected wounds", Journal of Medical Microbiology 60, 2011 75-83, DOI: 10.1099/jmm.0.020263-0

Colorimetric Indicators





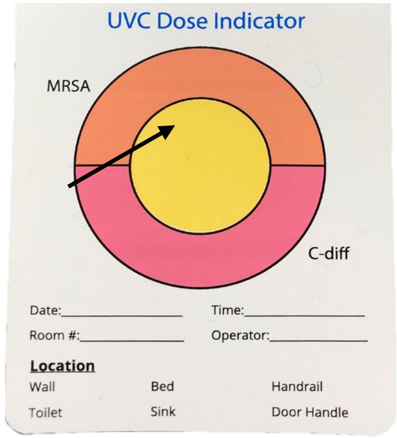


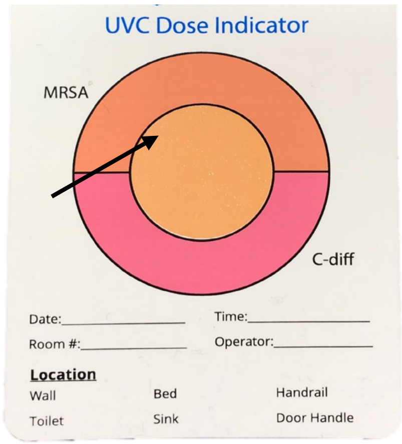
No Exposure

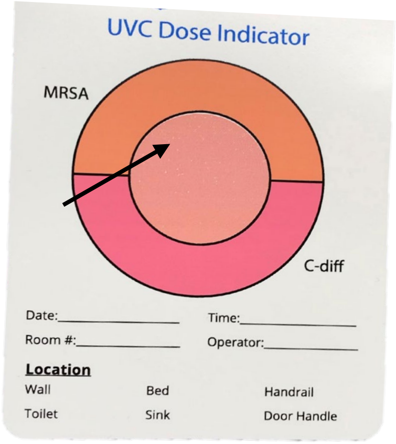
10,000 μJ/cm^2

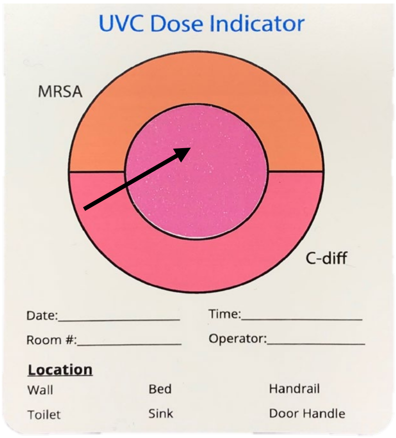
25,000 μJ/cm^2

46,000 μJ/cm^2



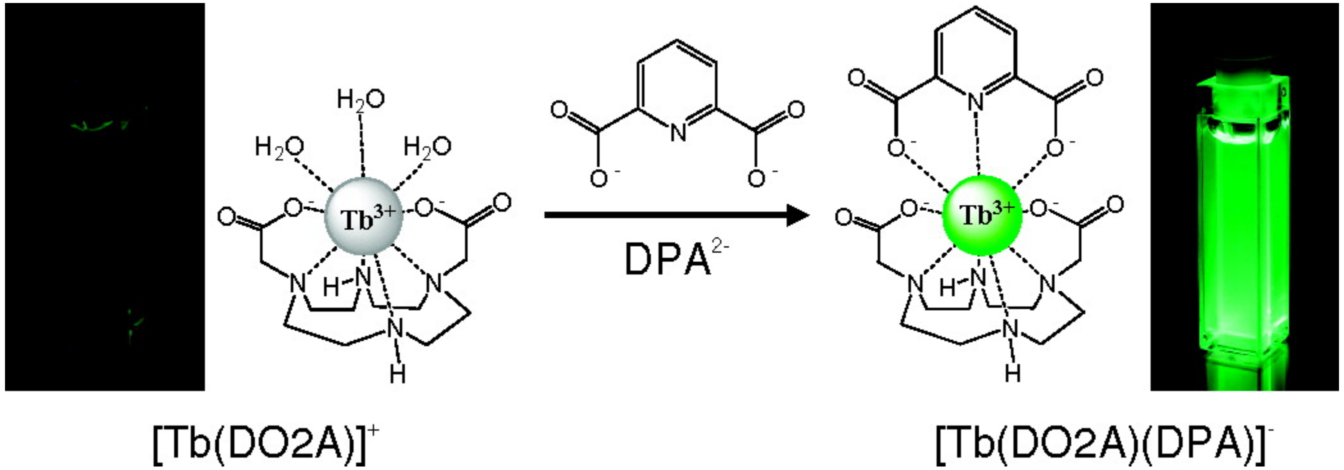


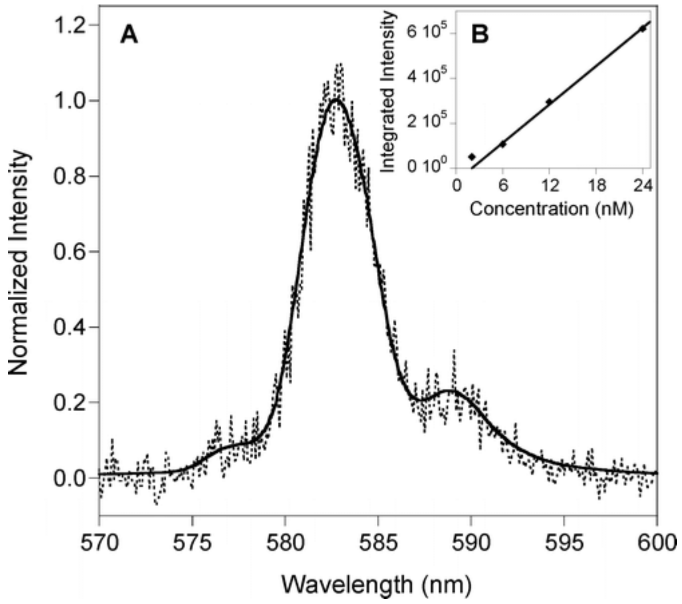




Cadnum JL. ID Week 2019.

Rapid Radiolytic Detection of Bacterial Spores based on Pipicolinic Acid (DPA)



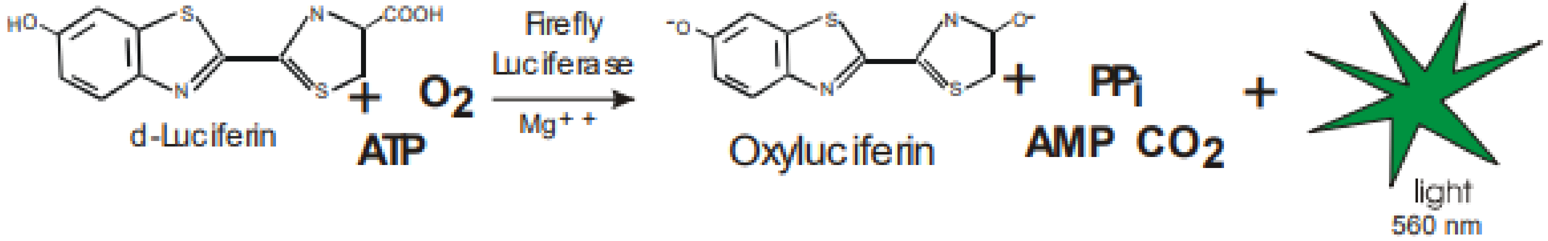


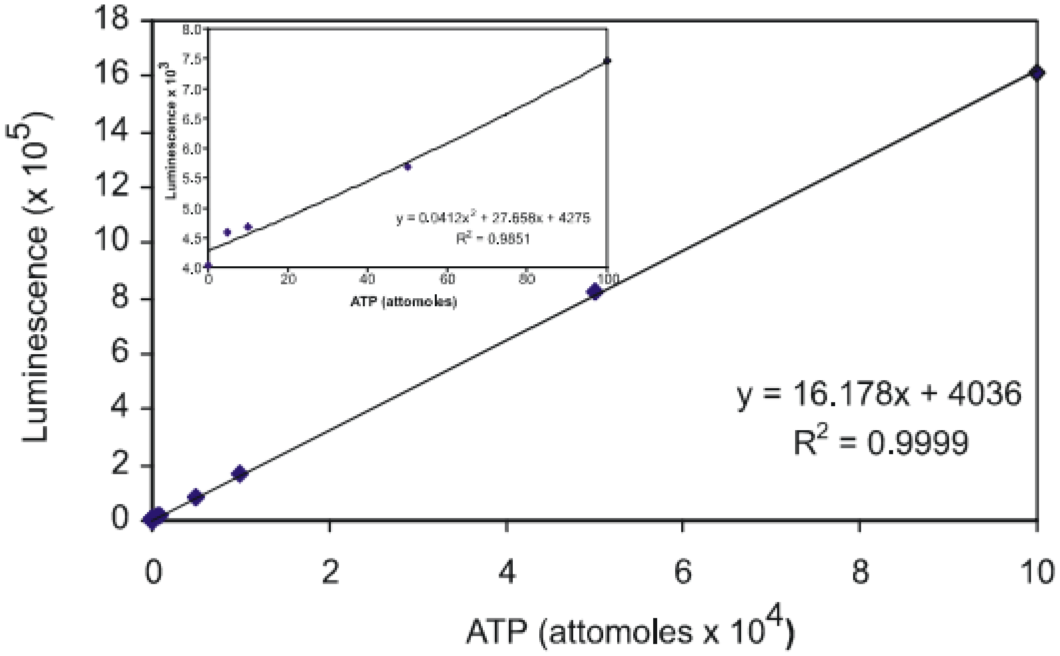
DPAa unique biomarker and major constituent of bacterial spores (>108 molecules of DPA per spore)

J. Am. Chem. Soc. **2007,** 129, 1474-1475., DOI: 10.1021/ja061831t

Luminescent Determination of ATP Concentrations

Adenosine
triphosphate
(ATP)





JoVE Science Education Database. Cell Biology. The ATP Bioluminescence Assay. JoVE, Cambridge, MA, (2020)

Broadband Dielectric Spectroscopic (BDS) Metrology in Bio Systems

Electric Equivalent Circuit Model of a Biological Cell Death: Monitor Membrane Potential Changes

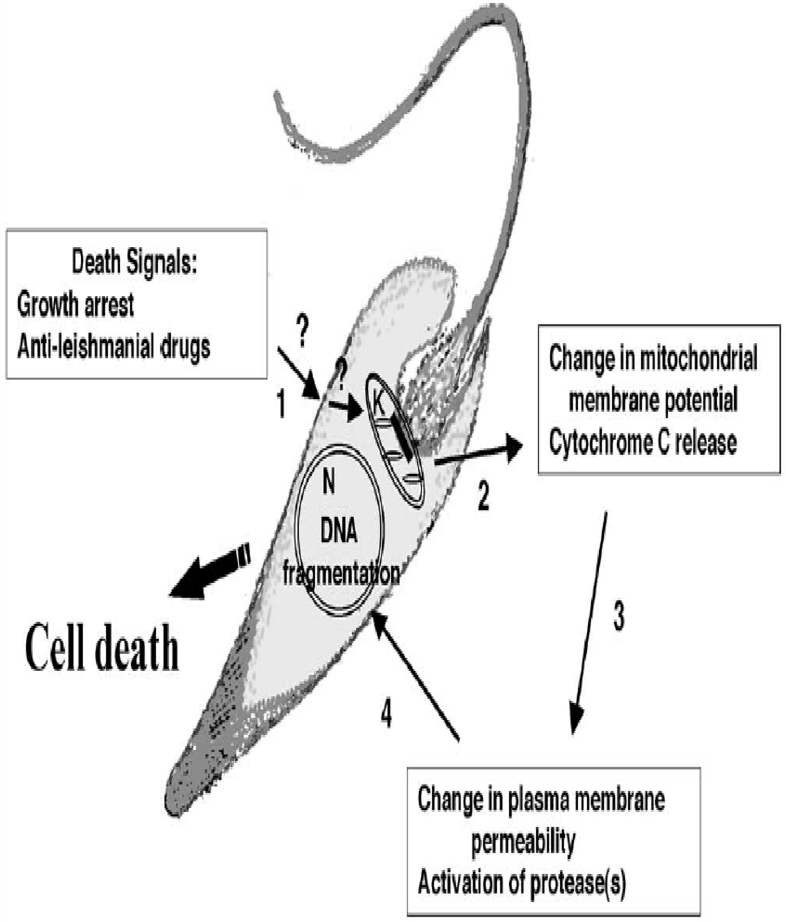
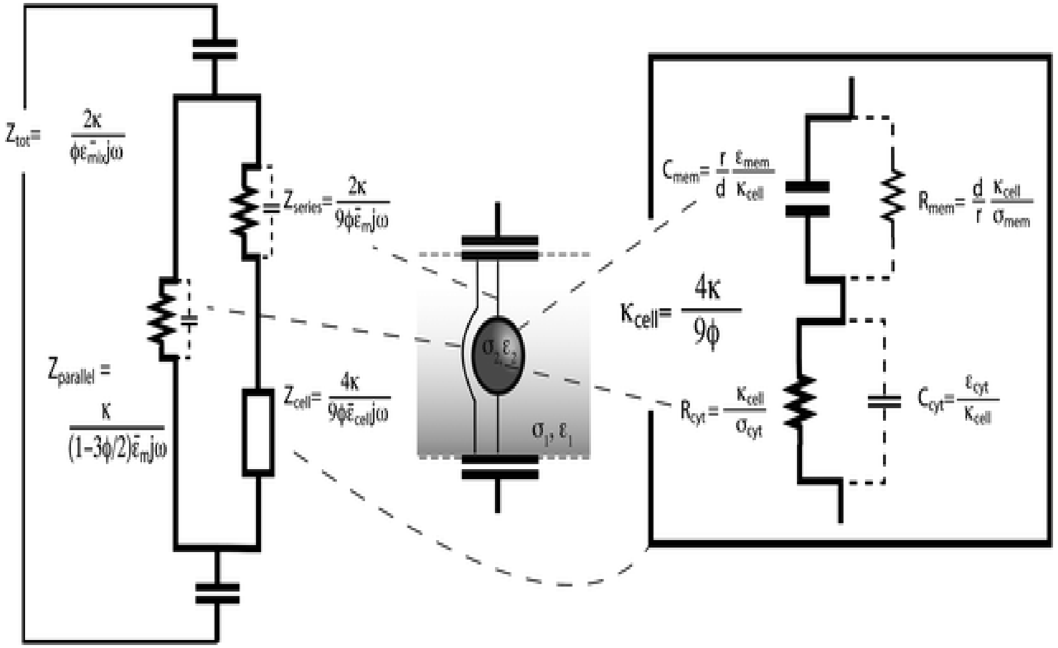


Fig. 1. Model for PCD in *L. donovani*. The model describes the various events in the induction of PCD pathway in *L. donovani* by growth arrest either due to starvation or by anti-leishmanial drugs. Arrows identified 1 → 4 depict the possible sequence of events in the Leishmania PCD pathway. N-nucleus; K-kinetoplast



International Journal for Parasitology 33 (2003) 257–267

Microwave Permittivity Extraction Of Individual Biological Cells

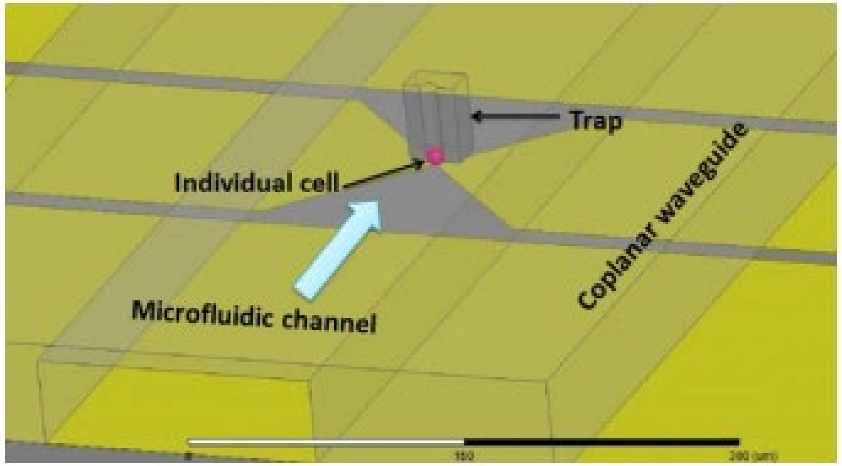


Fig. 1. Schematic view of the microwave biosensor, which includes a 5µm capacitive gap in coplanar waveguide with a microfluidic channel placed on top; the cell is blocked due to a mechanical trap.

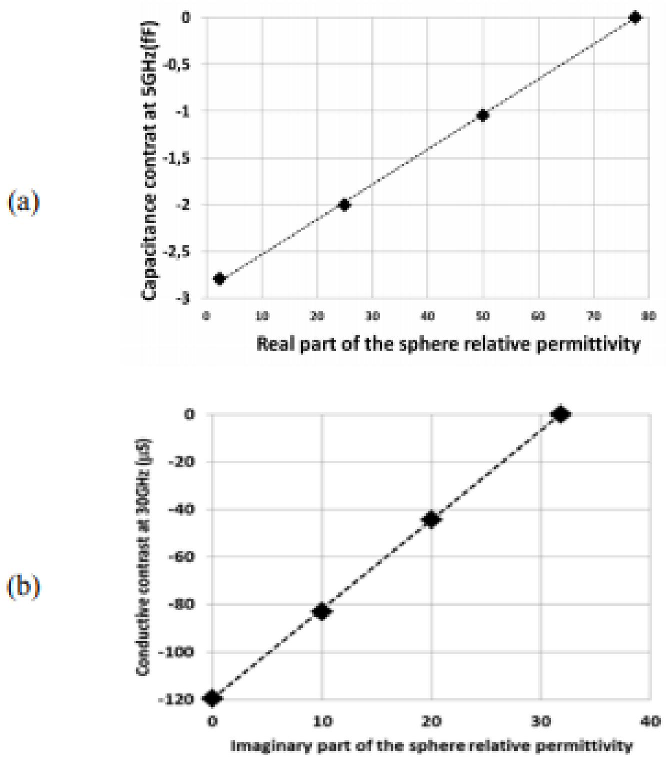
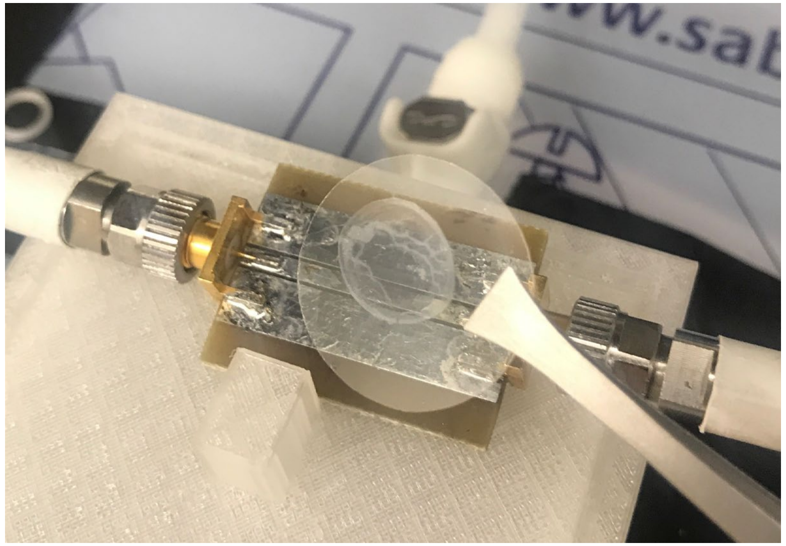


Fig. 3. Plots of (a) capacitive contrast versus ε' at 5 GHz and (b) conductive contrast versus ε'' at 30 GHz of a single sphere featuring different permittivity values.

	ε’ at 5GHz	ε’’ at 30GHz
Living cell	62.3	20.7
Permeabilized cell	69.8	25.2
Cell after heating	54.2	13.9

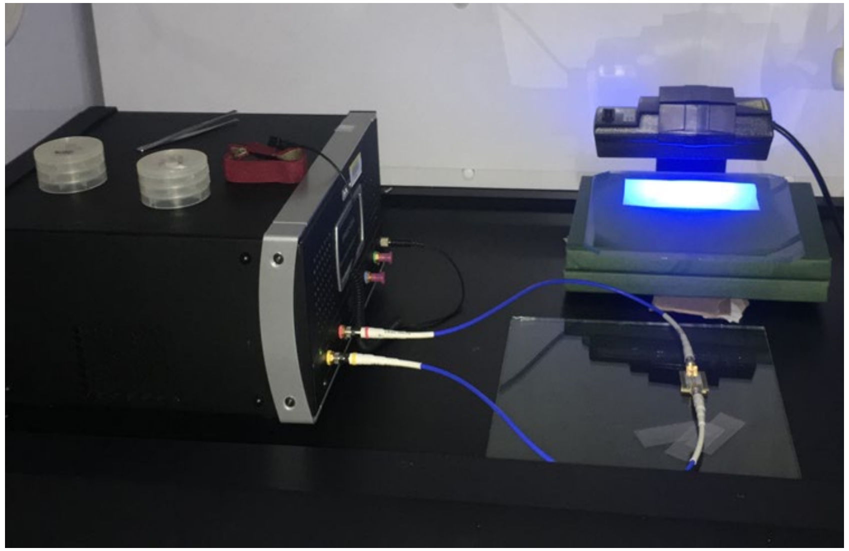
Amel Zedek, David Dubuc, Katia Grenier, “Microwave permittivity extraction of individual biological cells submitted to different stimuli”, IEEE International Microwave Symposium 2017, Jun 2017, Honolulu, United States. 4p

Experimental details



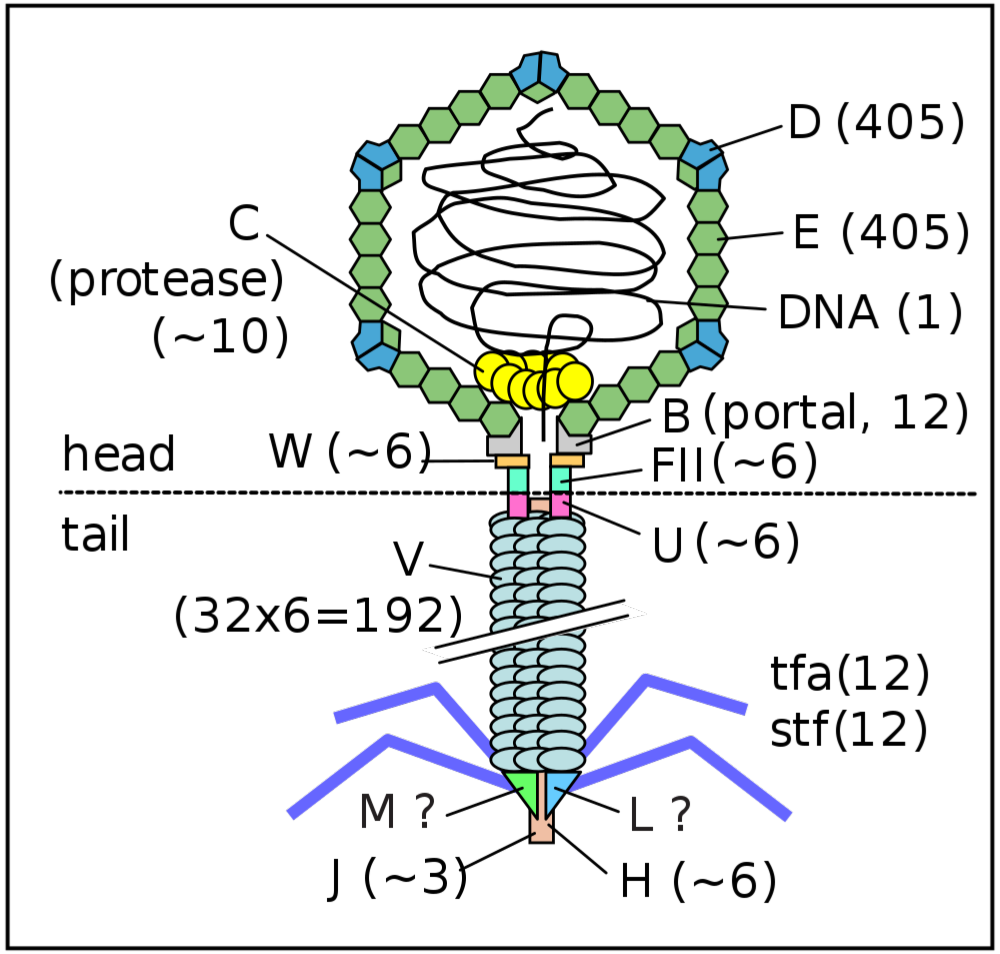
Desiccated sample on substrate

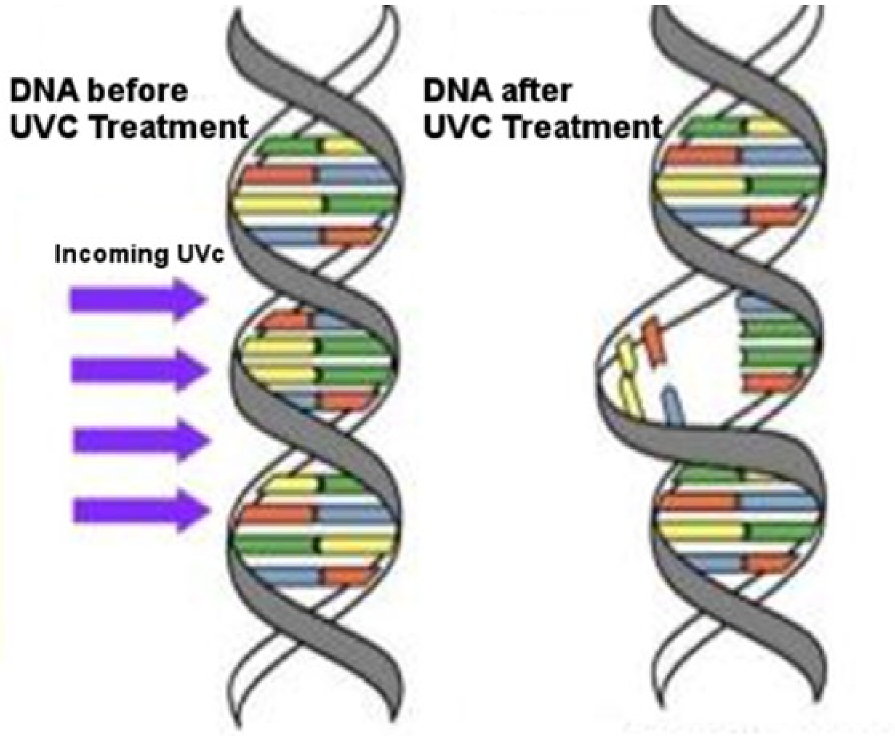
Waveguide connected to VNA



Desiccated sample with UV-Light on

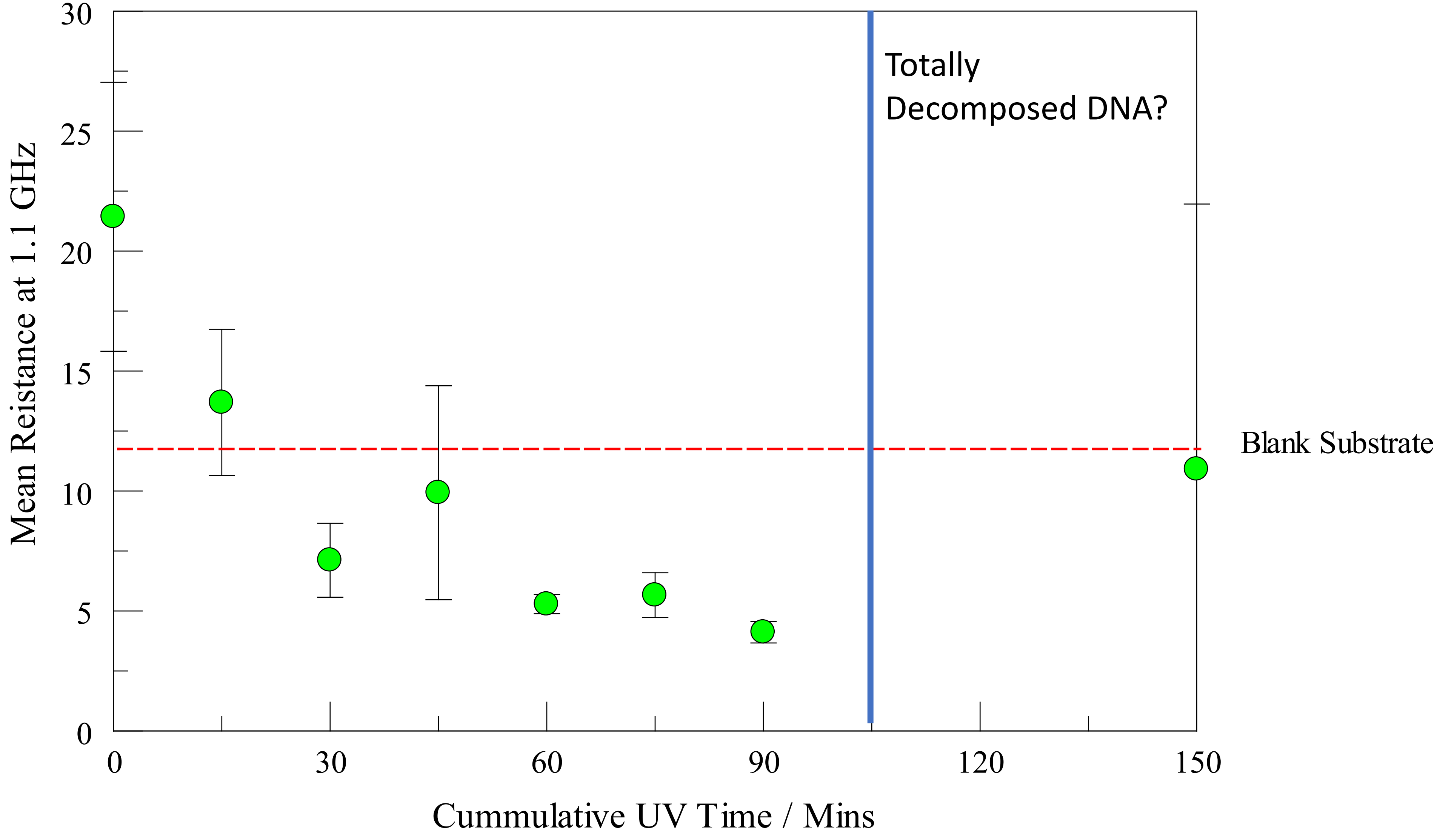
Bacteriophage lambda virion (schematic).



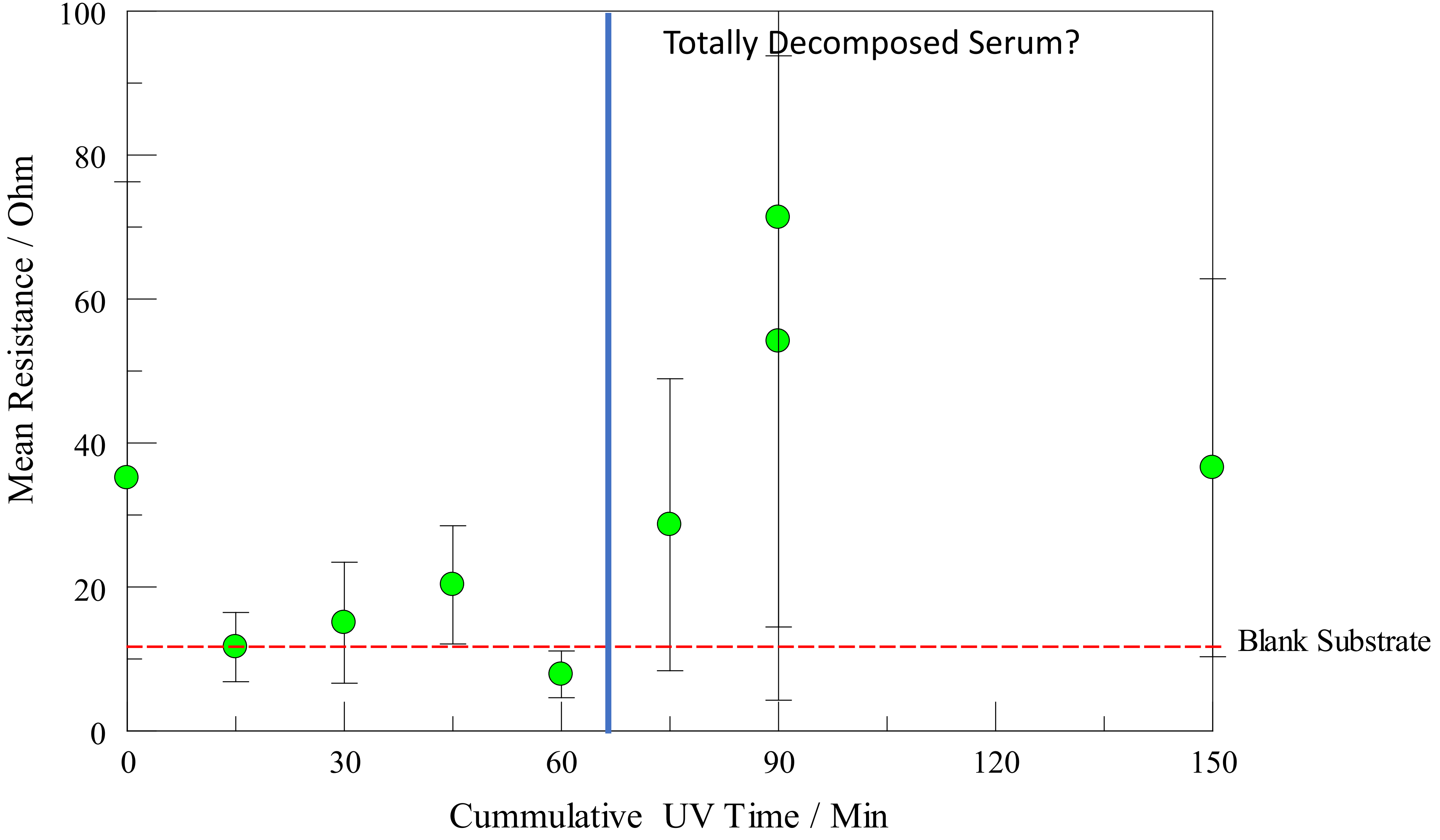


S. V. Rajagopala et al., “The protein interaction map of bacteriophage lambda” BMC Microbiol. 2011; 11: 213, doi: 10.1186/1471-2180-11-213

Evolution of the Resistance of Double-stranded Bacteriophage Lambda Thin Film on Glass during UV Photolysis in Open Air



Evolution of the Resistance of Fetal Bovine Serum (Protein) Thin Film on Glass during UV Photolysis in Open Air



Ultraviolet (UV)/ozone Cleaning for Removing of Contaminants from Surfaces

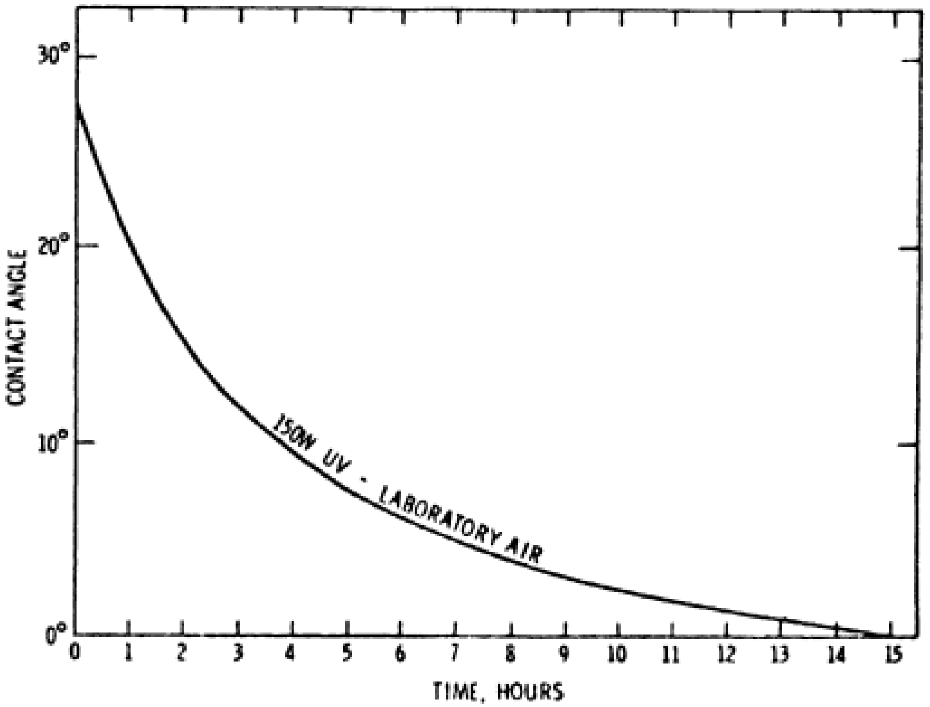
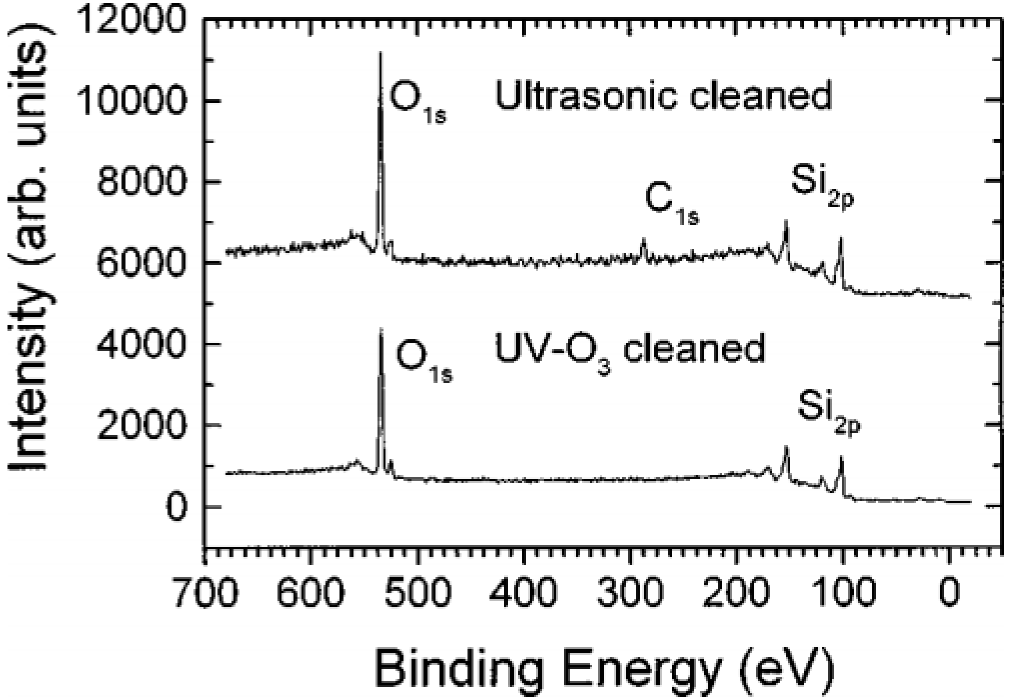


Figure 1. UV/ozone cleaning of a glass surface. (Ref. 2)

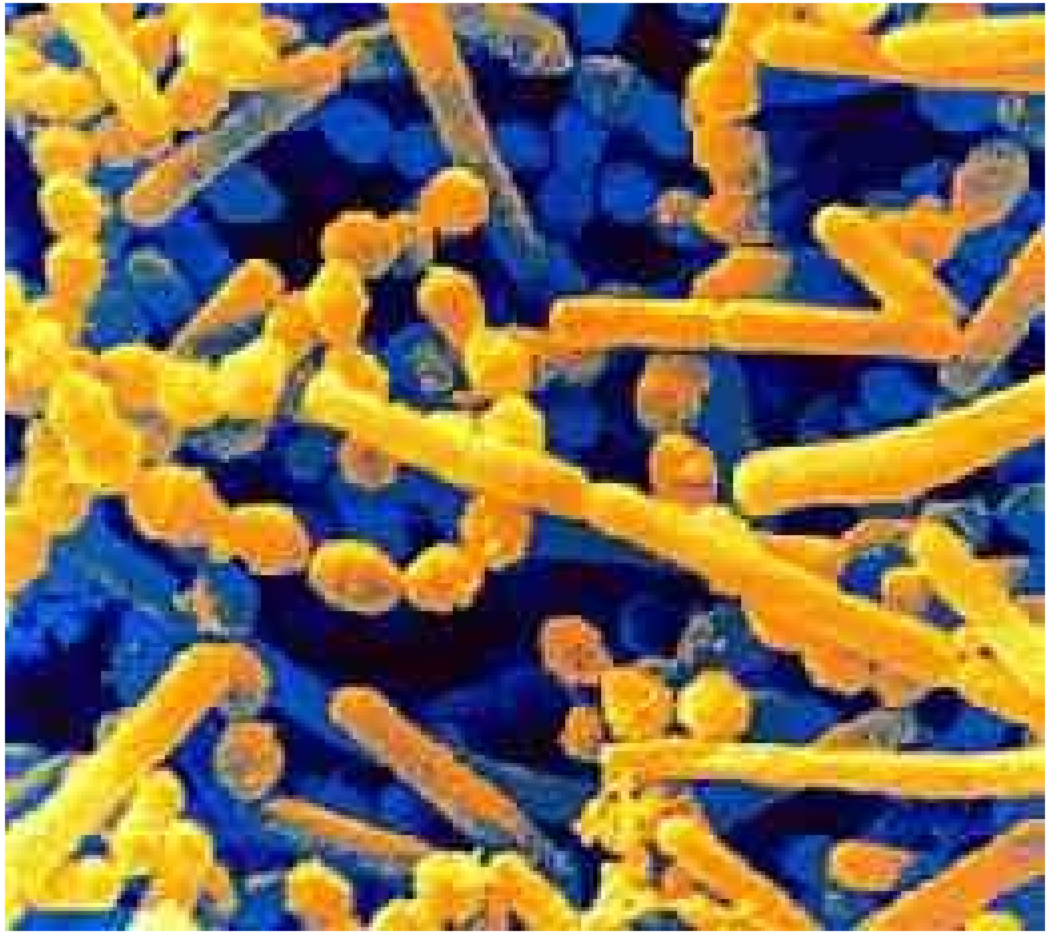


Survey XPS spectrum for adventitious hydrocarbon on Si before and after the UV-ozone jet cleaning process for 30 min.

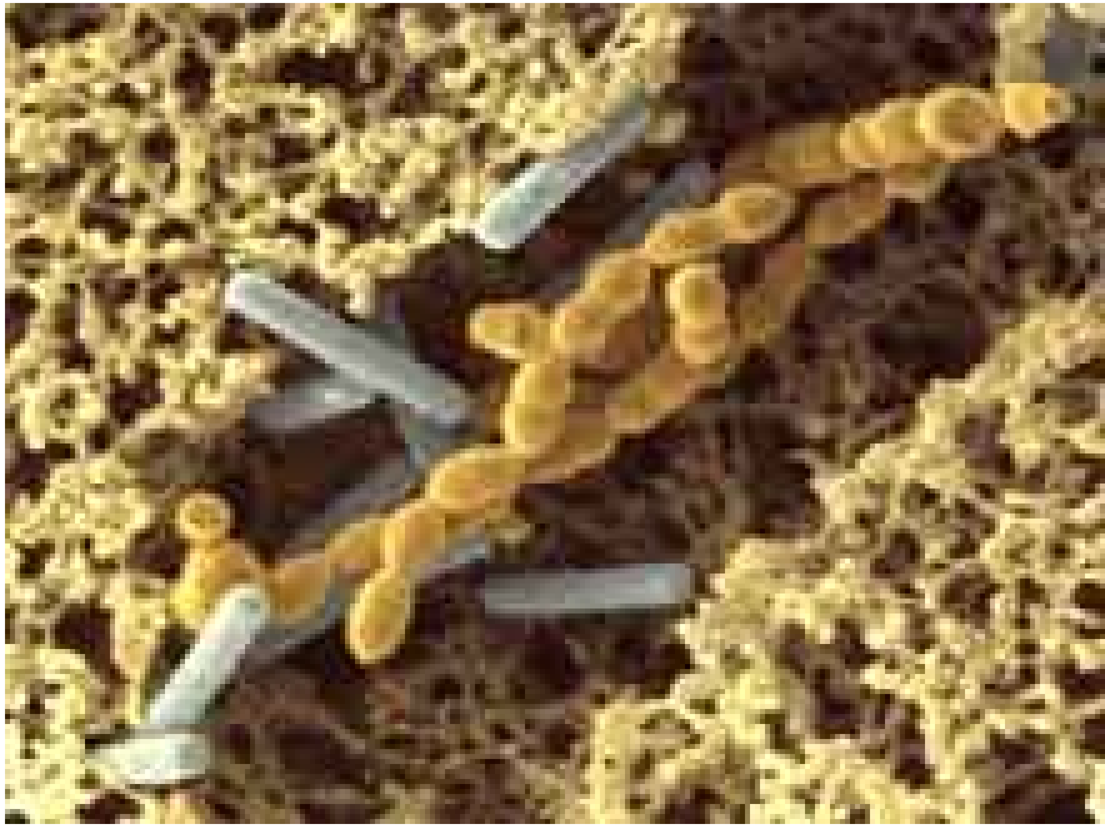
Vig J.R. (1979) UV/Ozone Cleaning of Surfaces: A Review. In: Mittal K.L. (eds) Surface Contamination. Springer, Boston, MA, DOI: https://doi.org/10.1007/978-1-4684-3506-1_16

D. W. Moon et al., “Ultraviolet-ozone jet cleaning process of organic surface contamination layers”, Journal of Vacuum Science & Technology A 17, 150 (1999); doi: 10.1116/1.581565

SEM of Yogurt



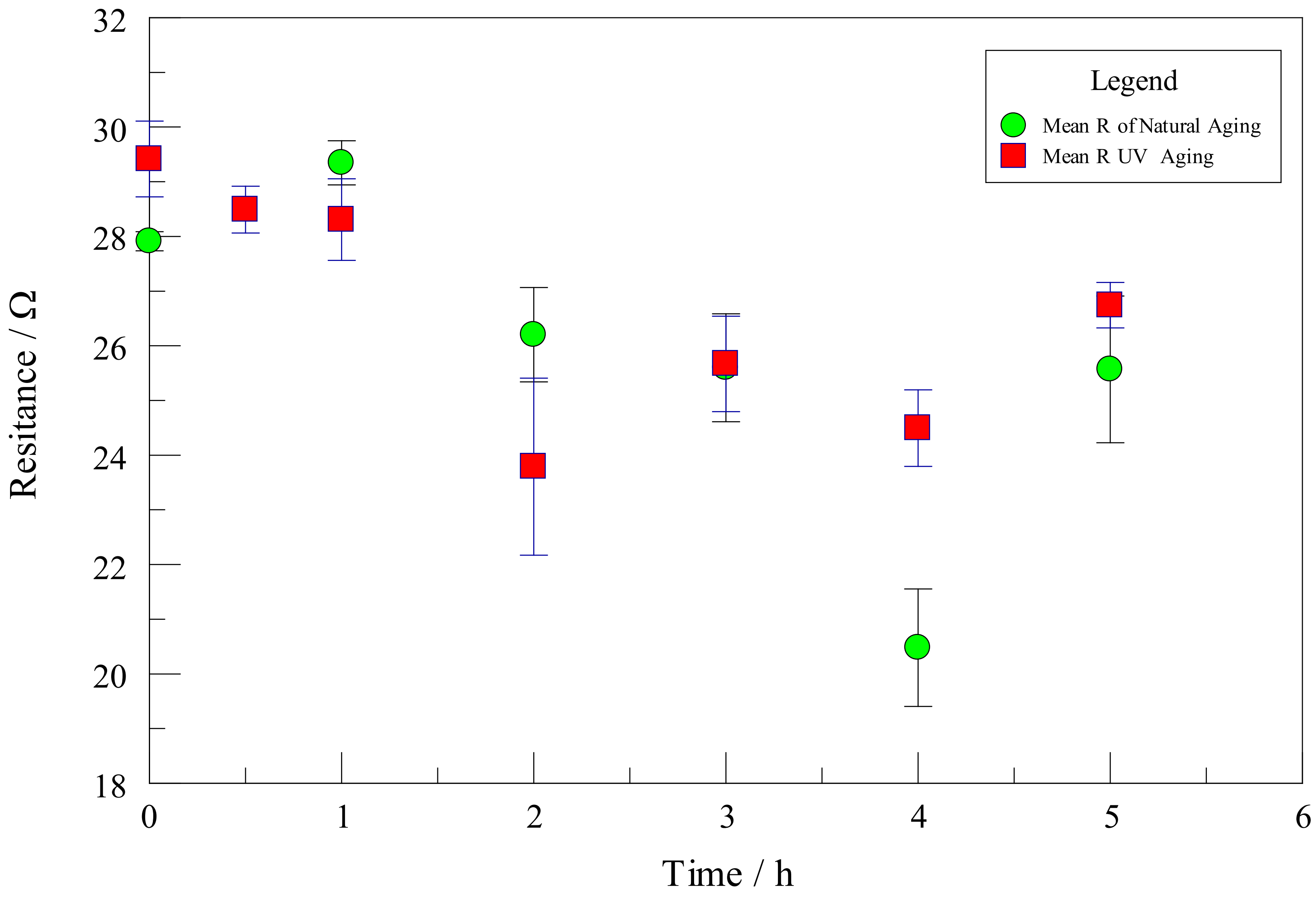
Yogurt bacterial culture consists of thermophilic streptococci (globules) and lactobacilli (rods) (SEM).



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

UV-degradation of Yogurt Films on Glass in Air :
The competition between monitoring UV damage and UV-decomposition



Minimum Resistance Times

Natural Aging: 4 hours

UV Aging: 2 hours

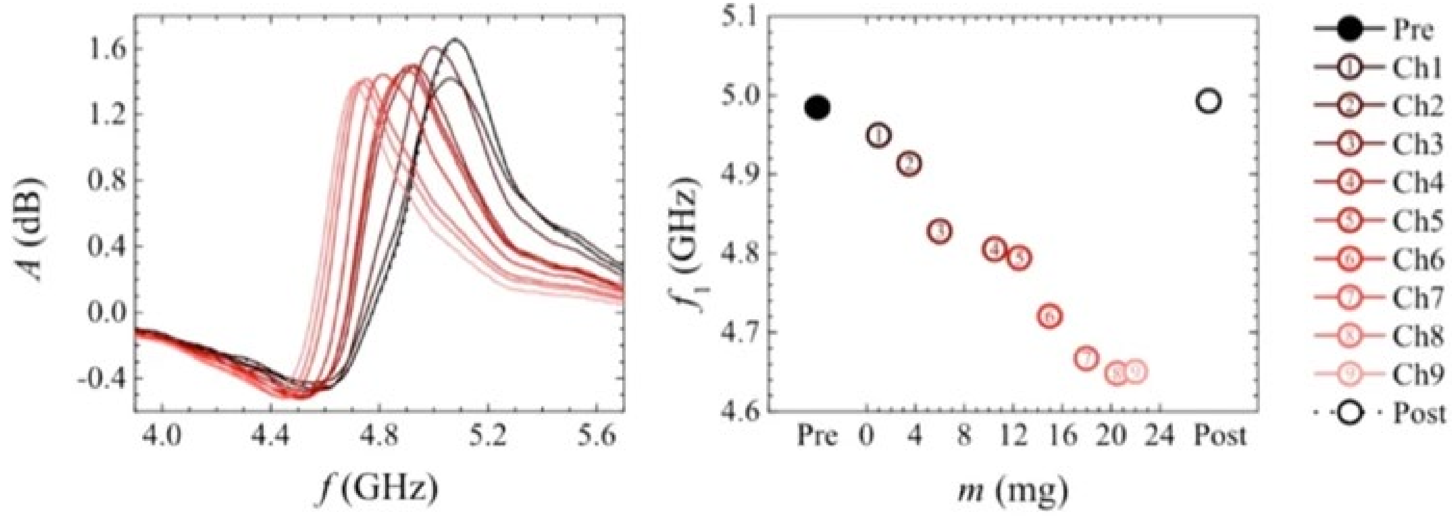
Main Conclusions

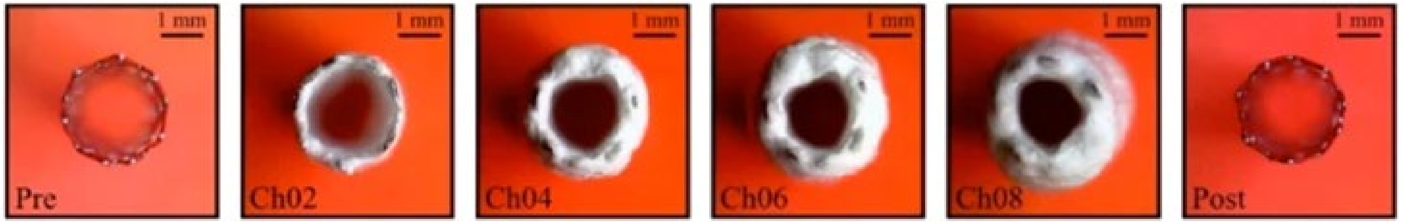
1. BDS is a viable metrology for decontamination efficacy:
   - BDS can electrically detect cell vitality
   - BDS can distinguish DNA damaged cell from just protein damage
2. BDS is a rapid and non destructive
3. More work in needed to make BDS based techniques standard

Other Biological Applications of BDS

Microwave Monitoring of In-stent Neoatherosclerosis

(Evolution of the fundamental resonant frequency with an increasing cholesterol depot in Stents)





Test performed on a Medtronic Driver Sprint BMS (12 × 2.75 mm):Axial sequential imaging illustrates the evolution of the cholesterol crust (from left to right: m = 0.0 ± 0.5 mg, 3.5 ± 0.5 mg, 10.5 ± 0.5 mg, 15.0 ± 0.5 mg,

UNIVERSITAT DE BARCELONA

C. Gálvez-Montón et al., "Ex vivo assessment and in vivo validation of non-invasive stent monitoring techniques based on microwave spectrometry", Scientific Reports , Volume 8, Article number: 14808 (2018), https://doi.org/10.1038/s41598-018-33254-9.

RF Monitoring of Vascular Stent Reliability

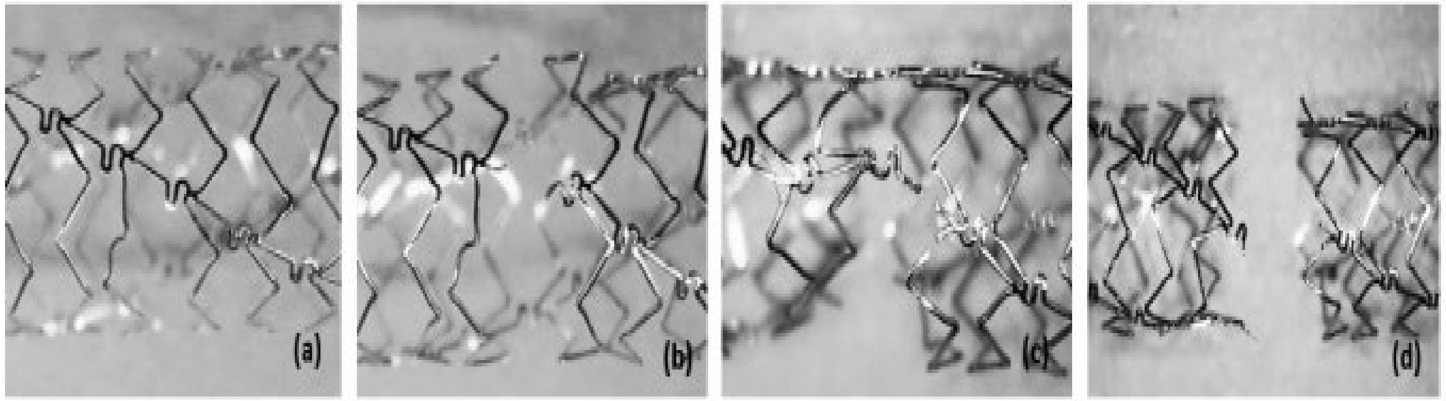


FIG. 1: Images of the different types of fractures performed in the stent. (a) no fracture stent (b) strut fracture (Type I); (c) half-crown fracture (Type II); (d) complete fracture (Type III).

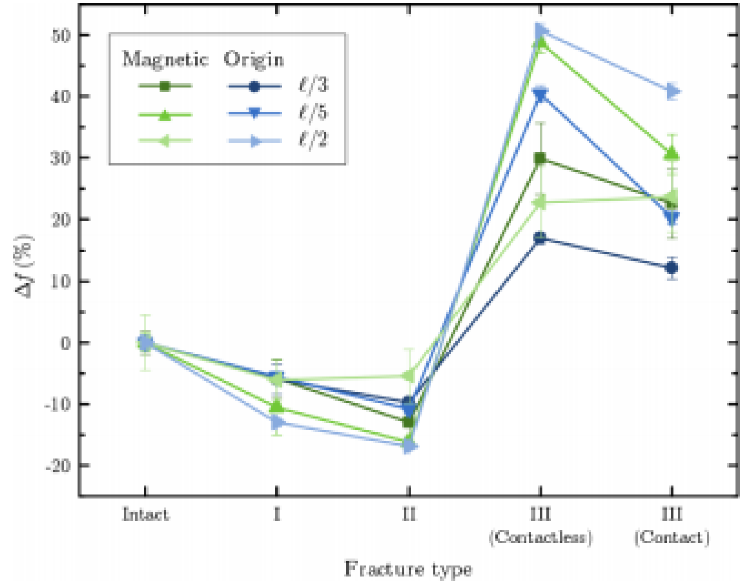
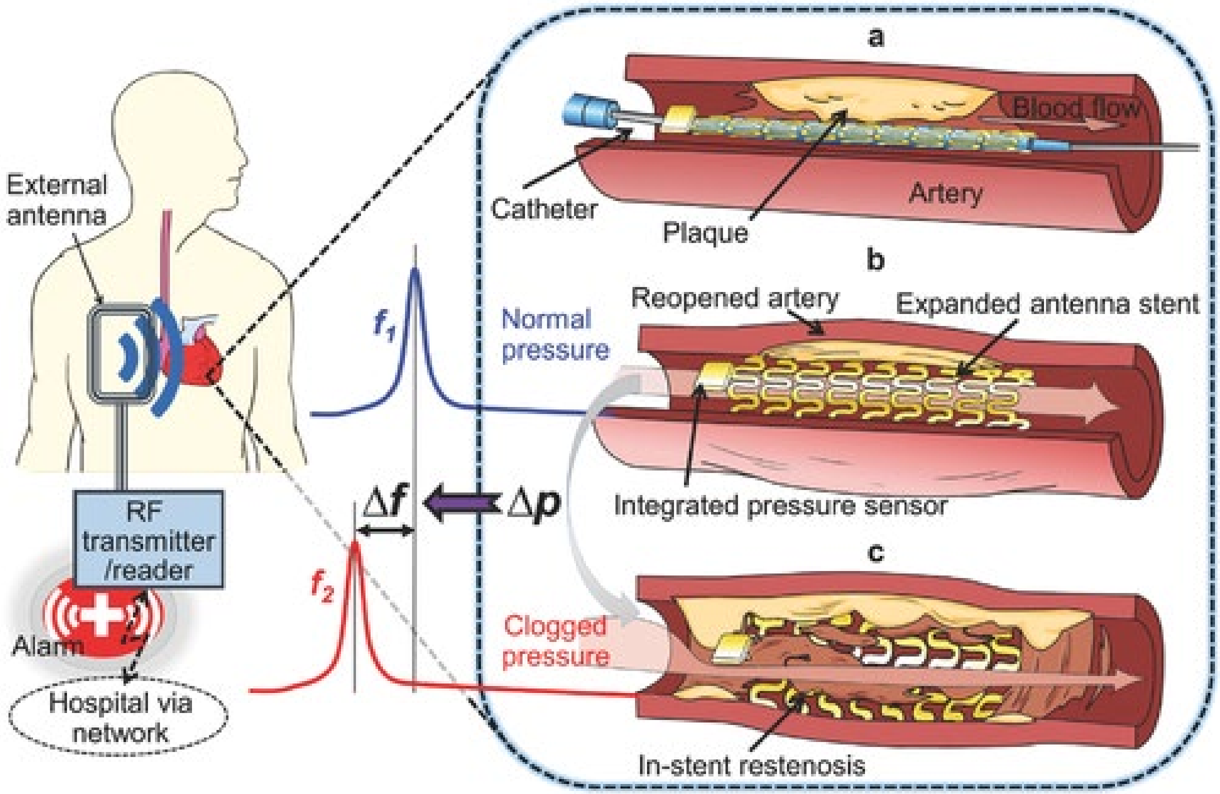


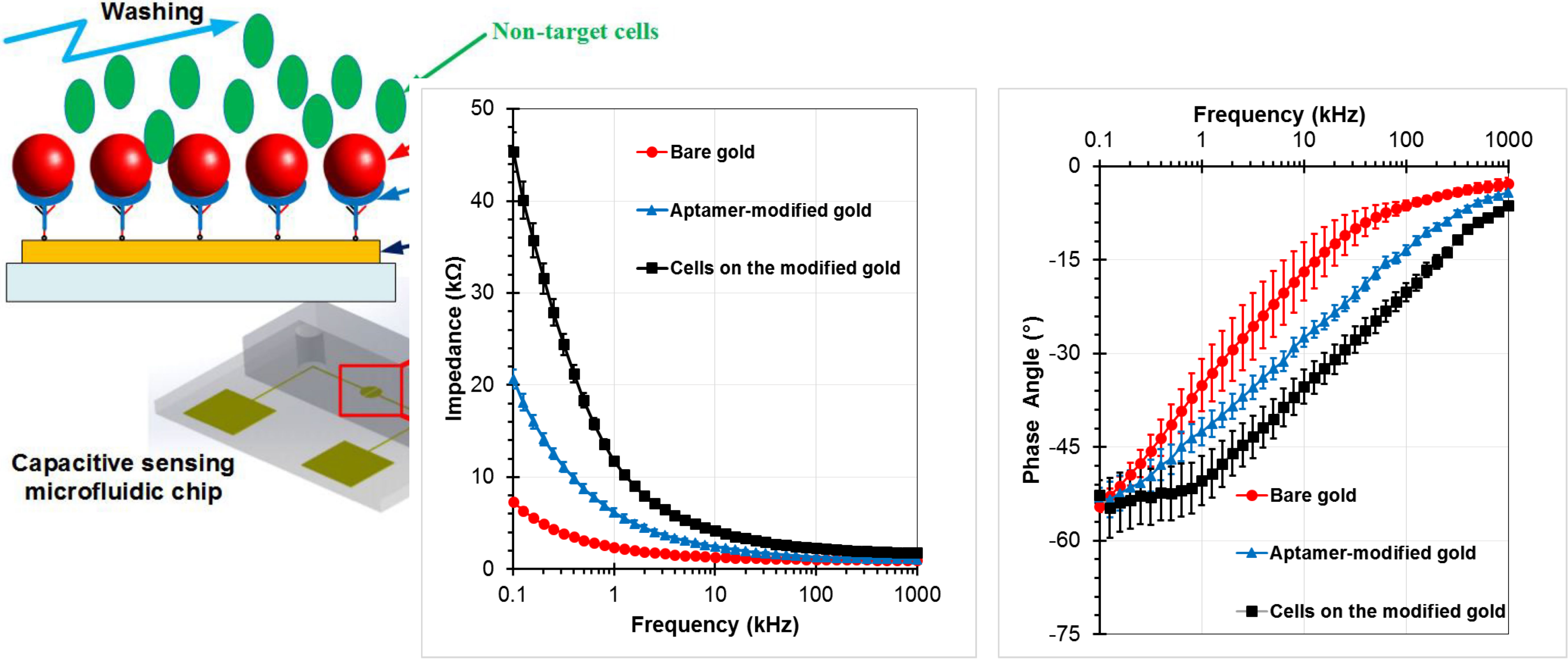
FIG. 4: Relative frequency varition as a function of the type of fracture (Type I, Type II or Type III) for each length ($l/2, l/3, l/5$) and probe (Origin and Magnetic probe).

Enabling Angioplasty-Ready "Smart" Stents to Detect In-Stent Restenosis and Occlusion



Advanced Science, Volume: 5, Issue: 5, First published: 16 February 2018, DOI: (10.1002/advs.201700560)

Capacitive Sensing Platform for Specific Detection of Lung Carcinoma Cells



(a) (b)

Biosensors 2018, 8(4), 98; https://doi.org/10.3390/bios8040098