Development of a Microfluidic Based Electrochemical Cell for Analyzing Bacterial Biofilms

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Introduction: Biofilms are surface adhered bacterial cells secured inside of a matrix of extracellular polymeric substance(EPS) that exist in numerous industrial and medical environments to the detriment of those environments[1]. The mechanical properties of the EPS matrix are the primary factors in determining biofilm stability and viability. Therefore it is desired to be able to integrate an atomic force microscope(AFM)[2] analysis system with an electrochemical impedance spectroscopy(EIS) measurement system[3] to better understand the relationship between EPS characteristics and growth stage.

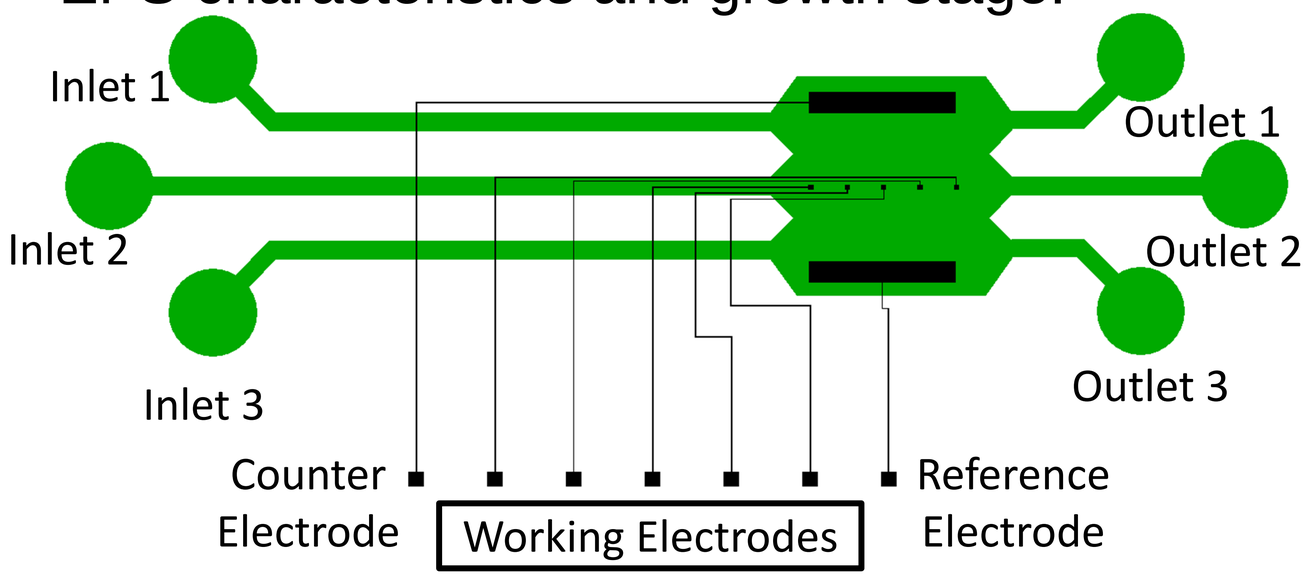

Figure 1. Biofilm Analysis System

Computational Methods: The key challenge of incorporating the electrochemical sensor into the AFM package was how to prevent colonization of the reference and counter electrodes. In order to determine the optimum flow geometry and conditions, a parametric study was performed using the Laminar Flow and Transport of Diluted Species physics packages.

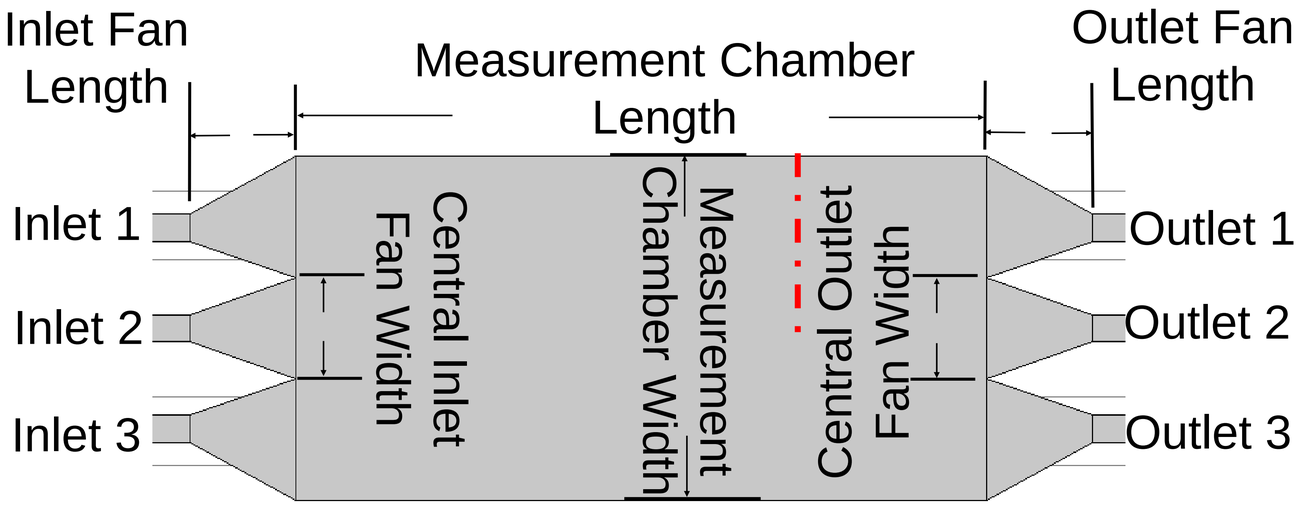

Figure 2. Model Geometry with analysis location shown in red.

Model Parameters	7.5mm Wide Measurement Chamber
Measurement Chamber Length	6.5mm
Flow Cell Depth	100µm
Inlet Width	600µm
Outlet Width	600µm
Diffusion Rate	$1e^{-9}m^2/sec$
Inlet Flow Rate	3.48µl/min
Inflow at Inlet 1/2/3	0/1/0 mol/m^3
Outlet Conditions	0Pa (Suppress Backflow)
Inlet Fan Length	100µm, 550µm, 1000µm
Central Inlet Fan Width	400µm, 2200µm, 4000µm
Outlet Fan Length	100µm,550µm,1000µm
Central Outlet Fan Width	400µm, 2200µm, 4000µm

Table 1. Model Parameters

Results: Shown below is the effect different geometric parameters had on the bacteria concentration at the location highlighted in Figure 2.

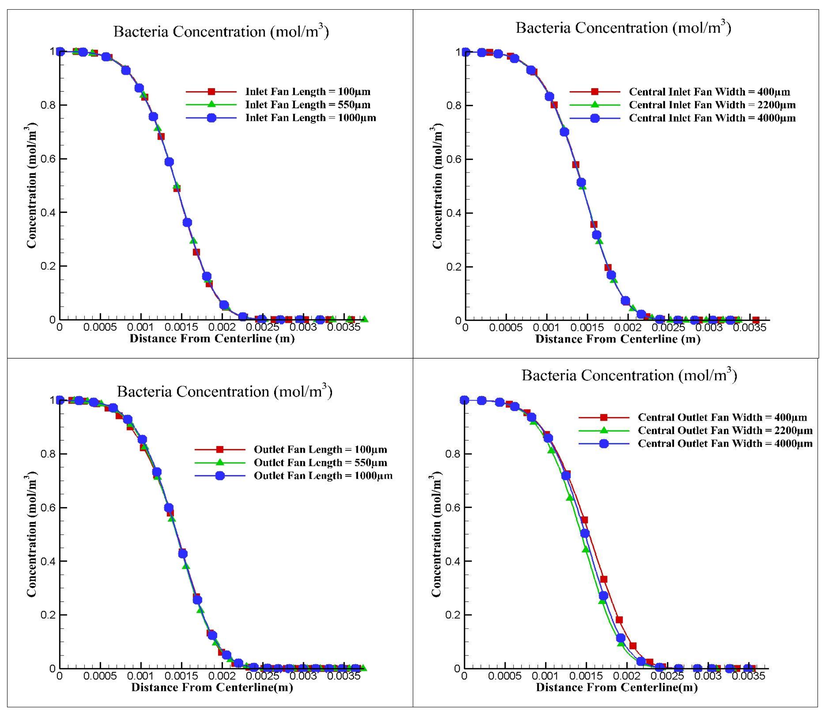

Figure 3. Variation of bacteria concentration at the location shown in Figure 2 due to geometric variations

Conclusions: The work here proved that the integration of the EIS device into the AFM system is feasible. In turn, providing a better understanding of the relationship between the mechanical properties and the growth stage of the biofilm.

References:

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