Impedance-based Detection of Blood Clotting Time

Riya Varma†, Asish Koruprolu†, and Drew A. Hall

† Equally Credited Authors

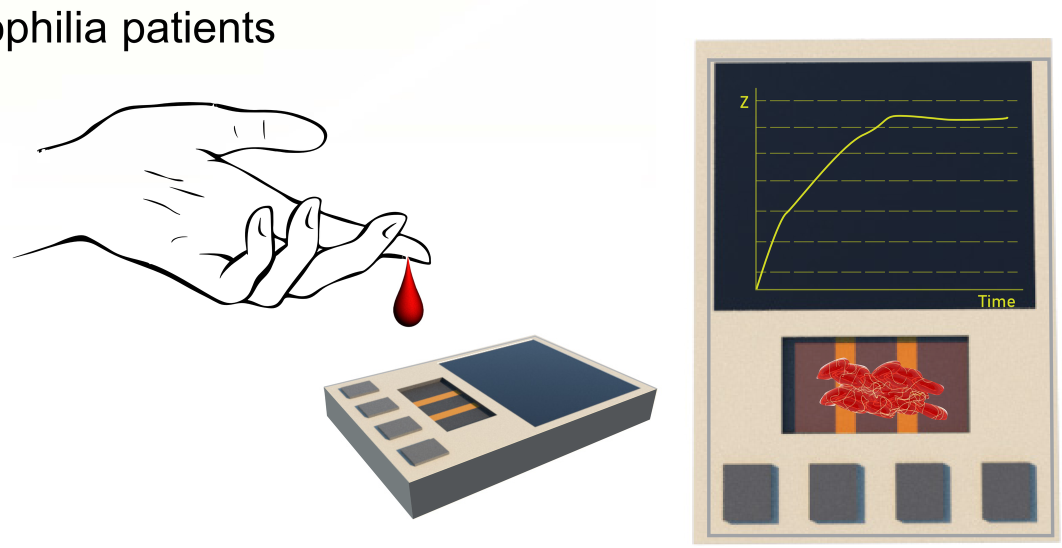
Electrical and Computer Engineering, University of California San Diego

IEEE BioCAS 2023 Toronto
Biomedical Circuits and Systems Conference
October 19-21, 2023 | Toronto, Canada

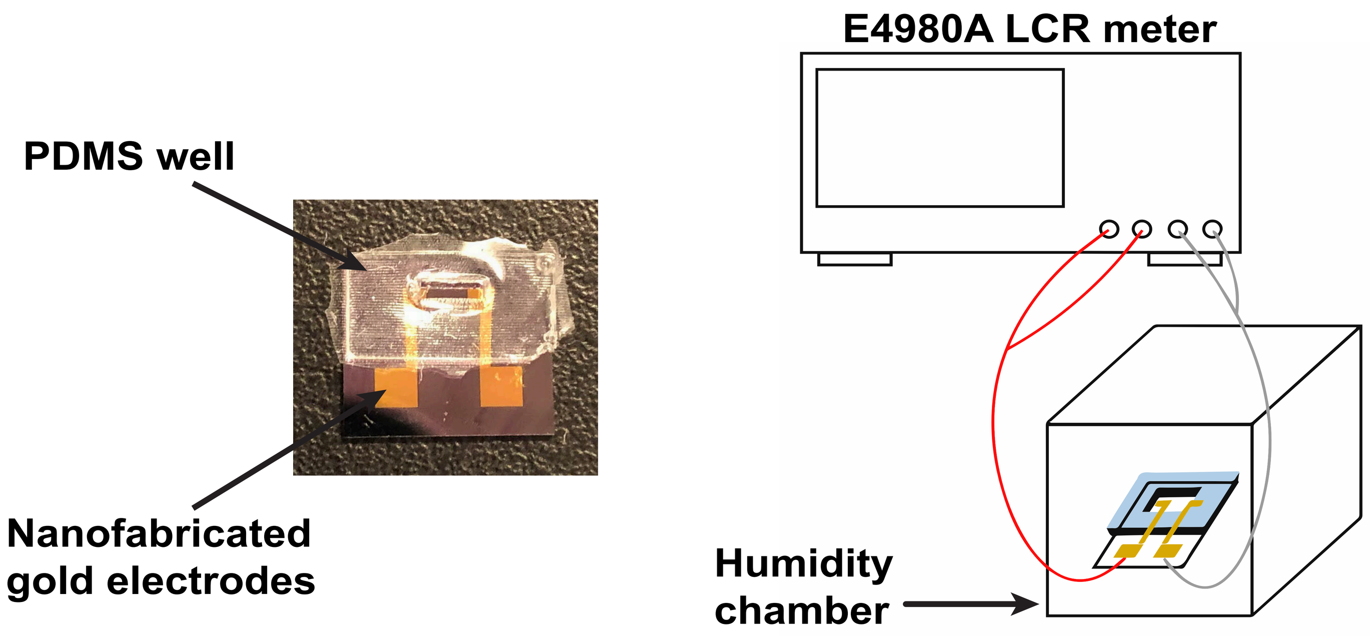
Poster No. B6P-B 5288

Point-of-Care (PoC) Sensor

This research investigates an impedance-based clotting time measurement technique that requires minimal blood volume (80 µL) and holds the potential to be developed into a low-cost PoC screening system for hemophilia and thrombophilia patients

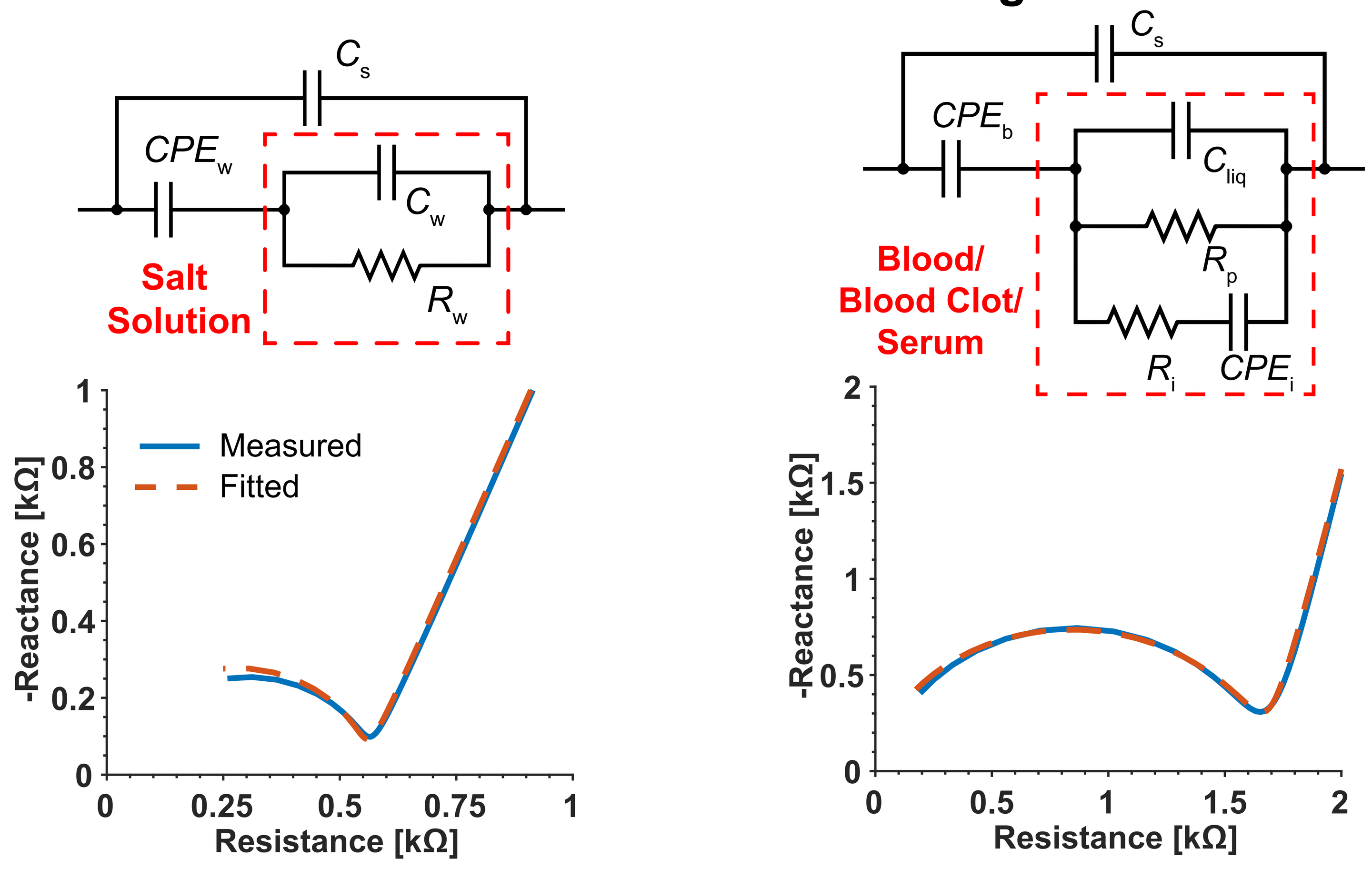


Measurement Setup

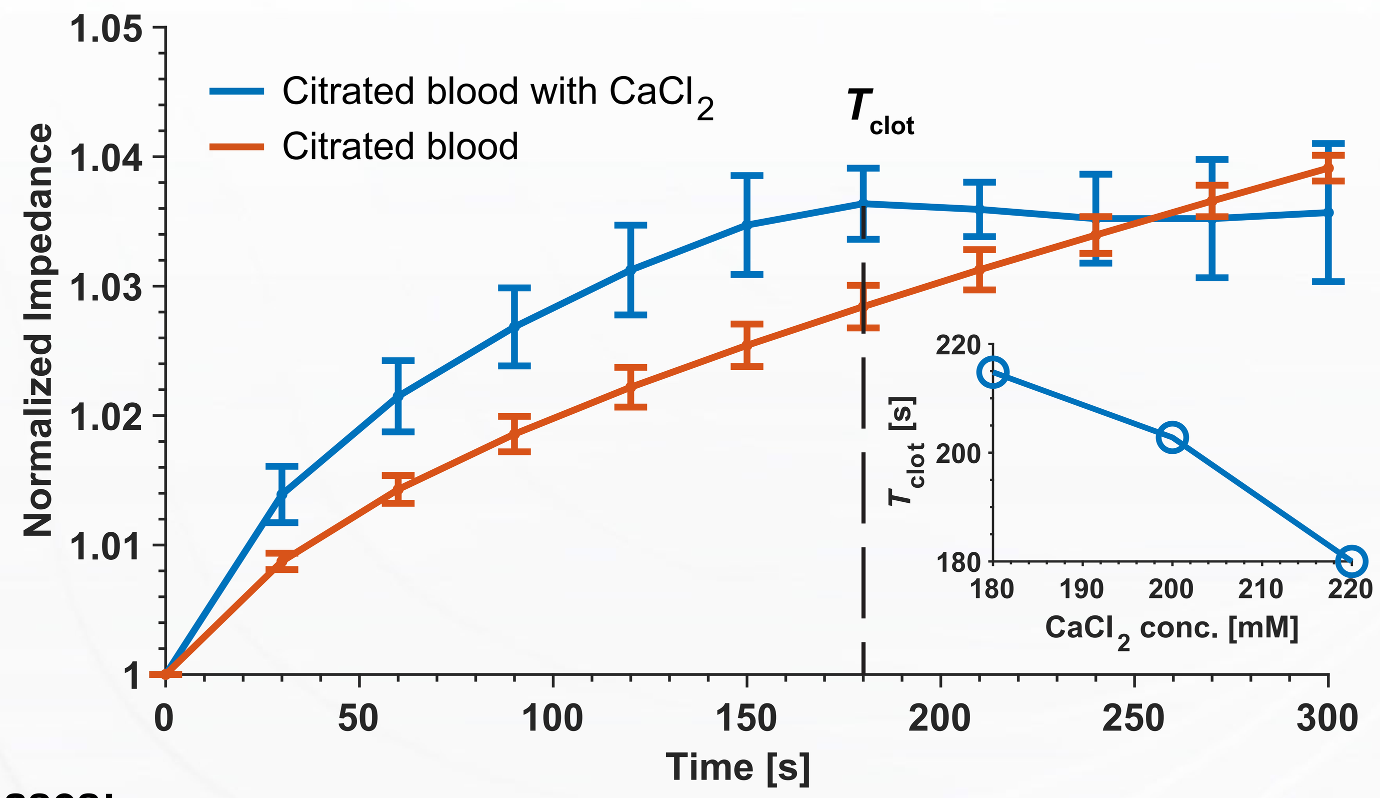


- Electrical impedance spectroscopy data acquired from 20 Hz – 2 MHz
- Electrode stray capacitance (C_s) and electrode polarization (CPE) were de-embedded when reporting the sample's impedance
- The cell constant was measured using a 0.1 M KCl solution with known conductivity to report absolute blood/blood clot impedance values
- 220 mM $CaCl_2$ was added to porcine blood with a sodium citrate anticoagulant (1:9 w/w ratio) to initiate the coagulation cascade

Circuit Models and Curve Fitting



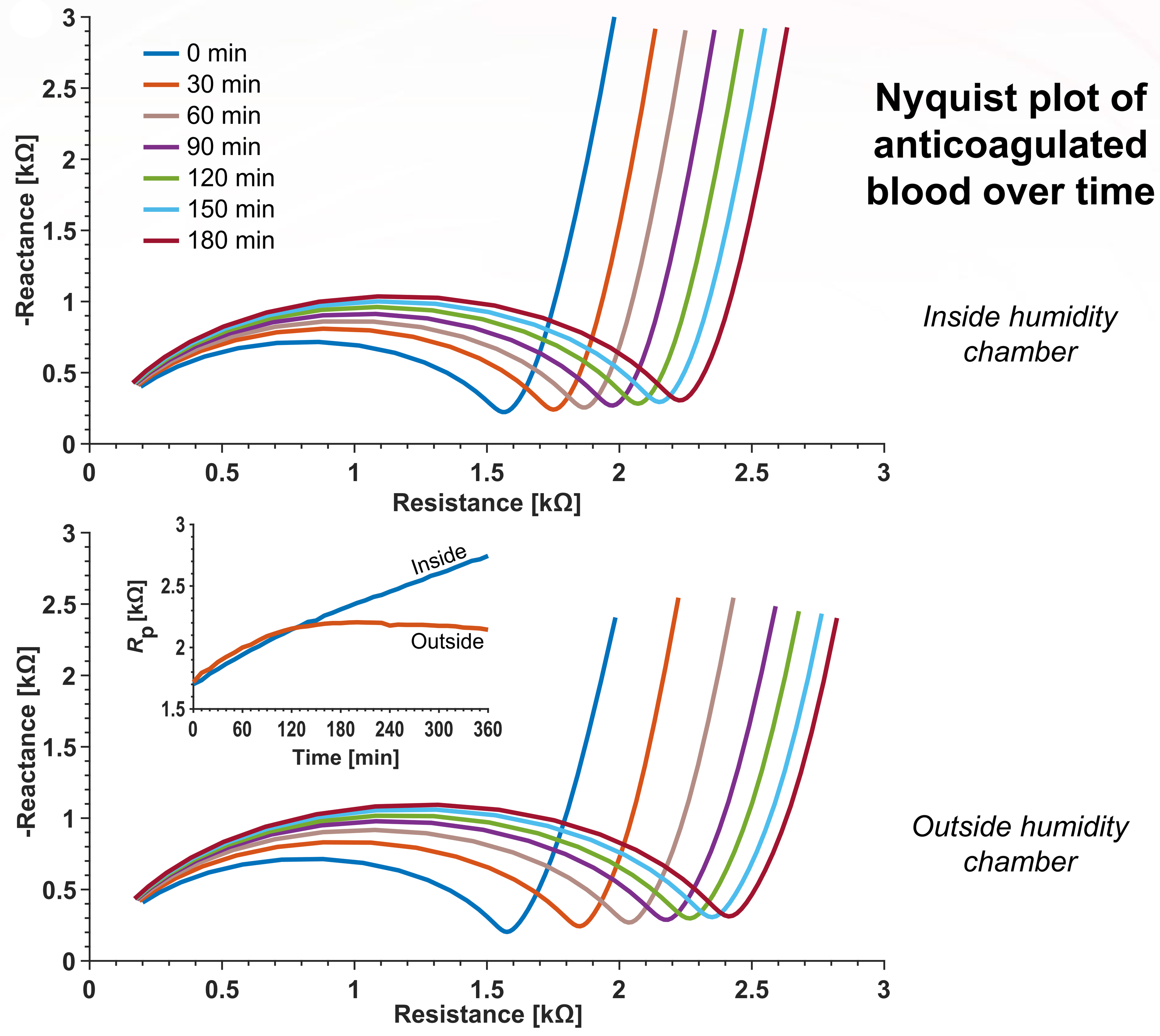
Clotting Time (T_{clot}) Analysis



Phases:

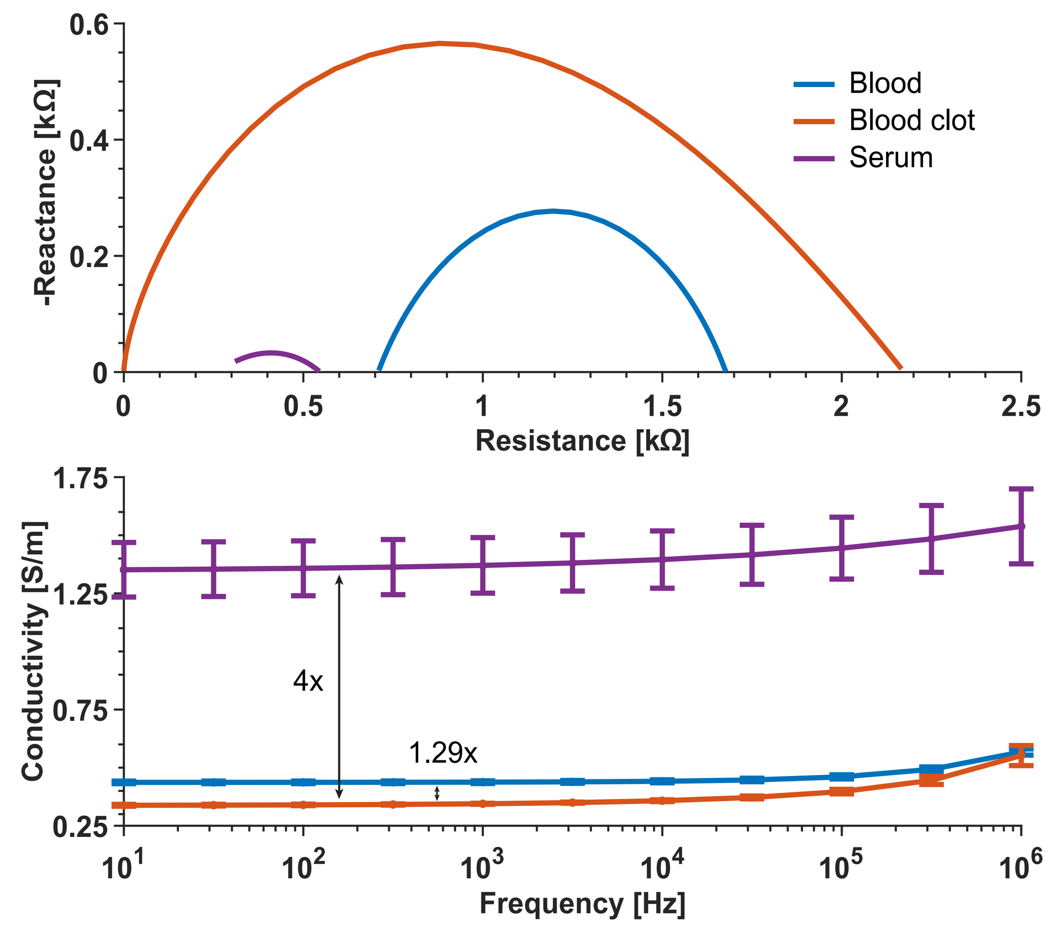
- **Peak value:** (denoted as T_{clot}) marks the beginning of clot retraction
- **Decrease after peak:** serum is retracted over the electrodes
- **Subsequent increase:** clot settles below serum and over electrodes

Erythrocyte Sedimentation Rate (ESR)



- ESR is a common hematology test of inflammatory activity
- Erythrocyte sedimentation over electrodes increases the impedance, which can be used as a proxy of ESR when humidity control is applied
- As erythrocytes settle at the bottom of the well, the impedance due to the plasma increases linearly with time, which can be used as measure of ESR after calibration

Conductivity Analysis



- Blood conductivity is 0.44 S/m, blood clot is 0.34 S/m, and serum is 1.50 S/m at 1 kHz
- Blood is 1.29× more conductive than blood clots, while serum is 4× more conductive
- Blood conductivity is nearly constant below 100 kHz
- The blood-to-blood clot conductivity ratio is concordant with previous studies, except for one outlier

Parameter	KF Lei *et al.*	G. D'Ambrogio *et al.*	A. Affanni *et al.*	N. Istuk *et al.*	This Work
Blood Species	Porcine	Human	Human	Human	Porcine
Anticoagulant	ACD	Citrate	PPACK	EDTA	Na Citrate
Test frequency (kHz)	1	10	300	1	1
Humidity Control	No	Yes	No	No	Yes
Blood σ (S/m)	-	-	-	0.4	0.44
Clot σ (S/m)	-	-	-	-	0.34
Serum σ (S/m)	-	-	-	-	1.5
Blood to Clot σ ratio	1,000	1.28	1.16	-	1.29

Conclusion

- This study measured the absolute conductivity of blood, blood clots, and serum, finding that a humidity chamber is necessary to mitigate the drying effect for accurate impedance measurements
- This research opens the door to point-of-care applications, reducing the reliance on extensive laboratory processing and decreasing turnaround time
- The technique can be further developed for analyzing material-blood interactions, aiding in assessing materials' thrombogenicity and potentially benefiting cardiovascular prosthesis development