Liquids Sensing for Industrial Applications

(Microwave Sensing Techniques)

Emerging Device Technology (EDT) Research Group

UNIVERSITY OF BIRMINGHAM

College of Engineering & Physical sciences
Dept. of Electronic & Electrical Engineering

Ali Mohammed (amm338@bham.ac.uk)
Supervisors: Dr Yi Wang & Prof M. J. Lancaster

PTDF PETROLEUM TECHNOLOGY DEVELOPMENT FUND

Background

Introduction

- Accurate measurement of material properties is required for a number applications in Petroleum, food, medicine and pharmaceuticals industries.
- The fact that every material (liquids, gas or solids) have distinct property called the **dielectric constant or permittivity**. It gives us the opportunity to measure and analyse various form of liquids by simply exposing them to some sort of electrical signal **(known as Microwave signal).**
- Microwave signals are signal over the frequency range of 300MHz to 300GHz (common example is the microwave oven operating at 2.4GHz).
- The main property monitored by microwave signals is the dielectric constant, thus precise determination of the permittivity is key to the design of microwave sensors and the measurement systems

Why microwave…? Because of

- Their flexibility due to wide frequency range
- Their ability to penetrate all materials except metals
- Their non-invasive nature (do not affect the material under measurement)
- They see a vey good contrast between water and most other material….

My research aims to…

- Design sensors that are capable of accurate measurement of material property
  - ✓ To use the sensors to investigate crude oil properties at desire frequencies

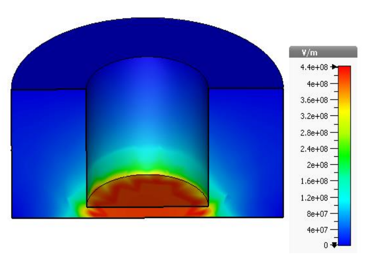
For this, we have proposed a microwave based sensor

- A modified design over the conventional method
- Aim at improving sensitivity
- By 3D printing technology

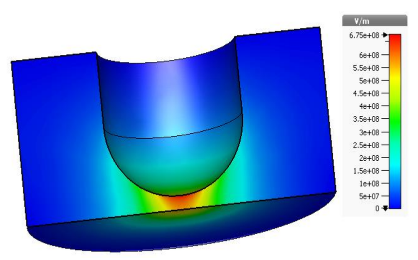
Our work

We design...

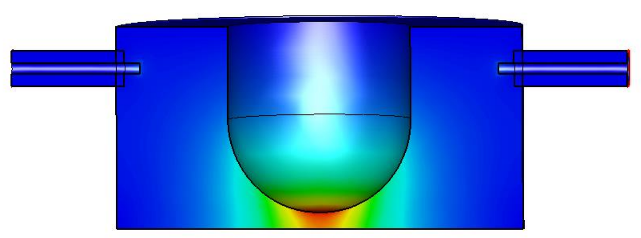
- Using Computer Simulation Technology CST software



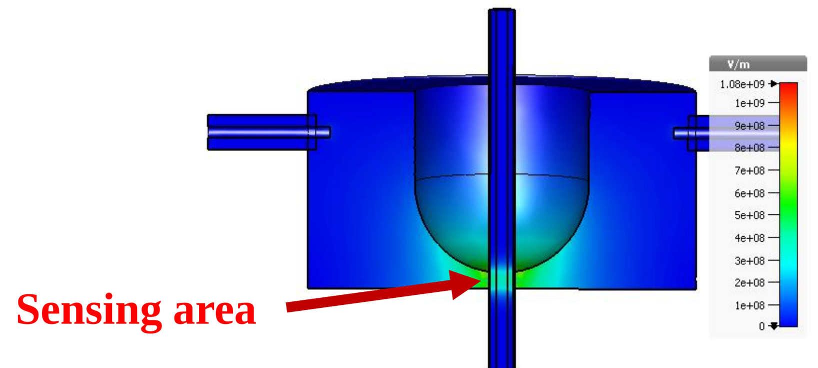
Convectional cavity sensor



Modified cavity sensor



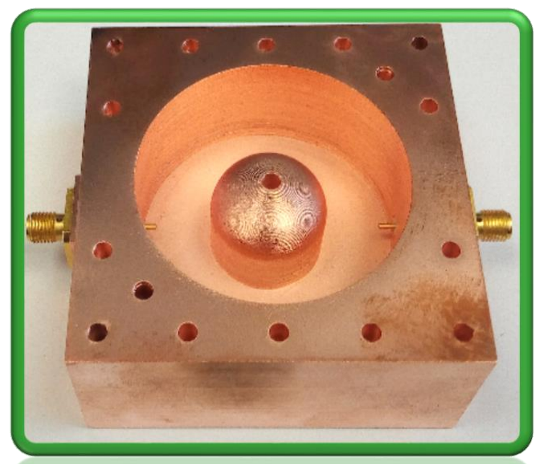
Modified cavity sensor without sample holder



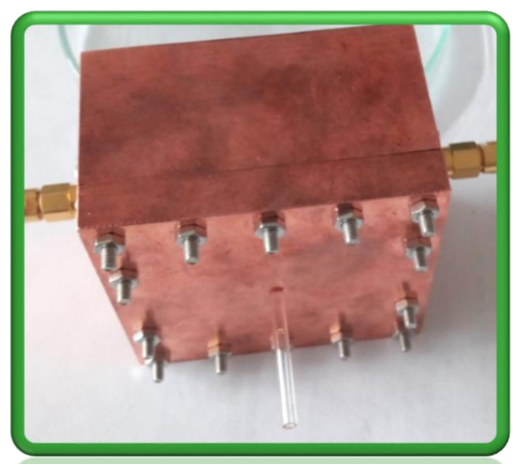
Modified cavity sensor with sample holder

It was then, made..

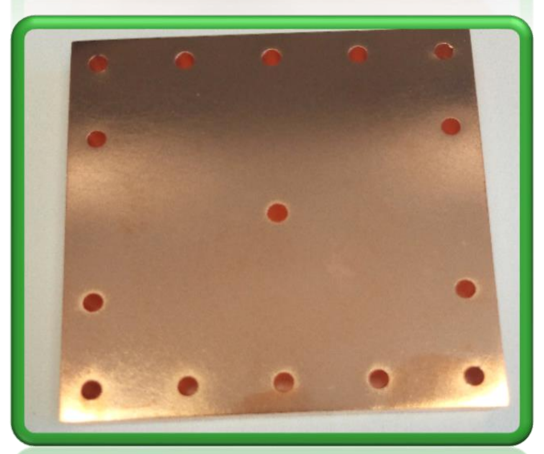
- By **3D printing** using polymer and coated it with copper material



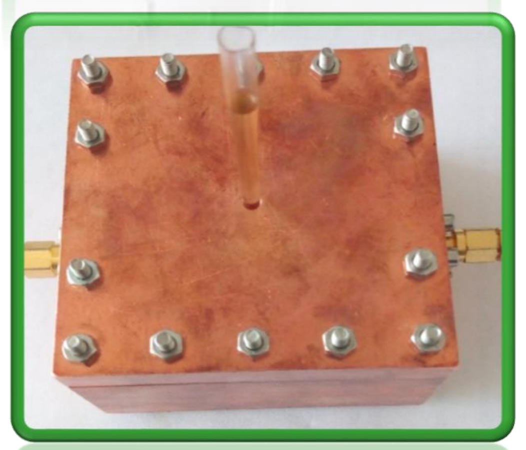
Cavity sensor



Sensor with both end open sample holder



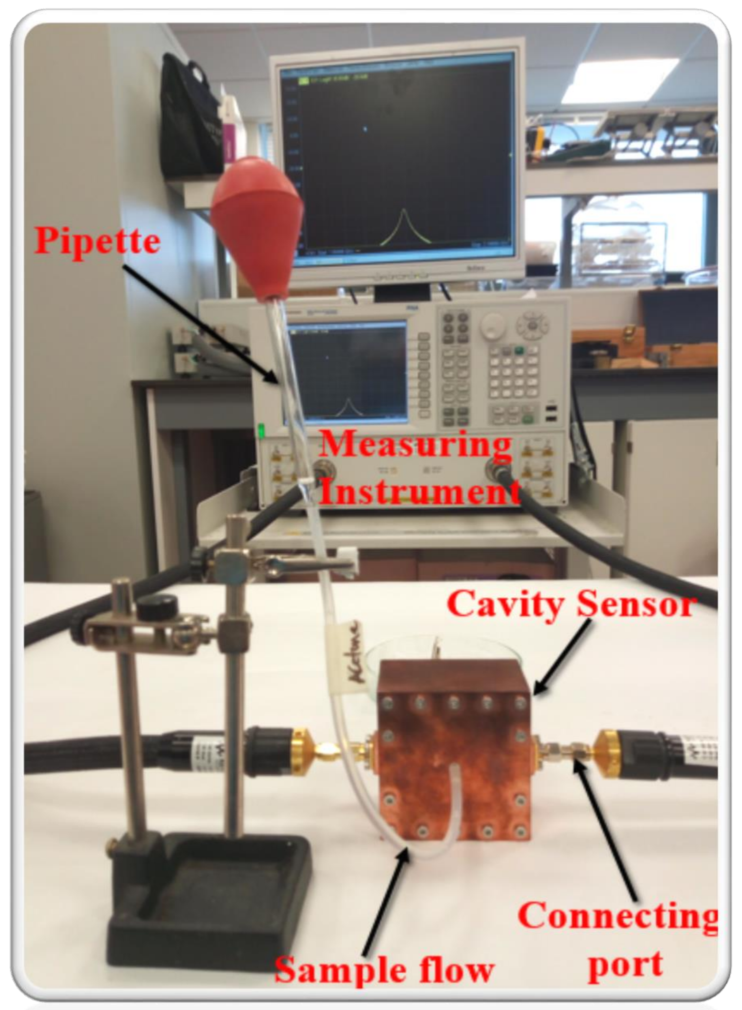
Sensor lid (cover)



Sensor with one end open sample holder

We tested it using standard sample

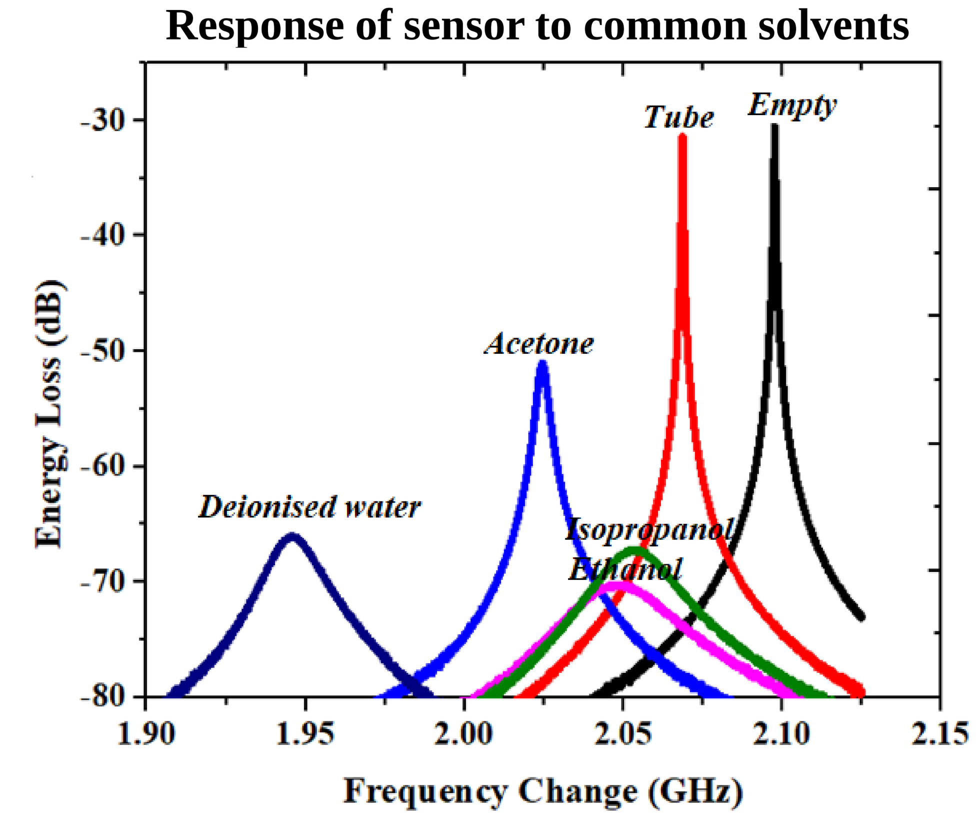
- Acetone, IPA, Deionised water & Ethanol
- Then, measure three samples of crude oil



Measurement set-up

Findings

Results



Two Changes are measured

- *Frequency shift*
- *Energy loss*

- These two parameters are use in extracting the **dielectric constant** (frequency shift) and **loss tangent** (change in energy loss) using mathematical formula (which we developed based on our sensor geometry) other than the convectional perturbation theory.

$$Dielectric\ const. = 12257.96\left(\frac{\Delta f}{f_c}\right)^2 + 762.1\frac{\Delta f}{f_c} + 1.05$$

Conclusion

- The device has the capability of accurate measurement of liquid dielectric constant or complex permittivity
- The modified sensor has better sensitivity than conventional type operating at the same frequency

Future work

- Investigate crude oil properties through dielectric measurement
- Further develop novel sensor that can be utilised in same way

Reference

- H. Hamzah, A. Abduljabar, J. Lees and A. Porch, "Compact Microwave Microfluidic Sensor Using a Re-Entrant Cavity'," *Sensors (Basel)*,, vol. 18, no. 3, pp. 1-12, 2018.
- A. Punase and B. Hascakir, "Stability Determination of Asphaltenes through Dielectric Constant Measurements of Polar Oil Fractions," *Energy Fuels*, vol. 31, no. 1, pp. 65-72

Acknowledgement

I wish to thank Petroleum Technology Development Fund (PTDF) Nigeria, for providing the scholarship towards this research work