Impedance spectroscopy for the detection of monosaccharides using functionalized carbon screen-printed electrodes on paper

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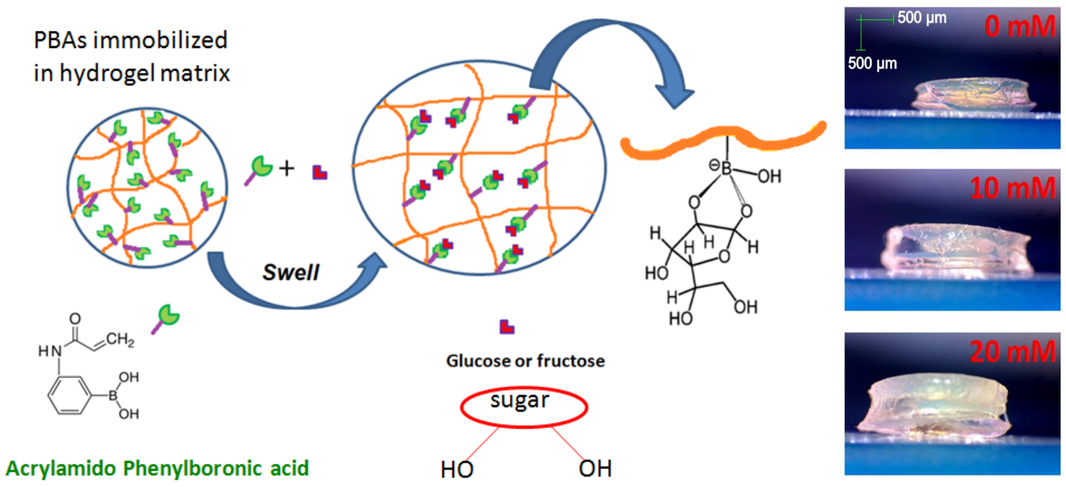
Insight

Introduction

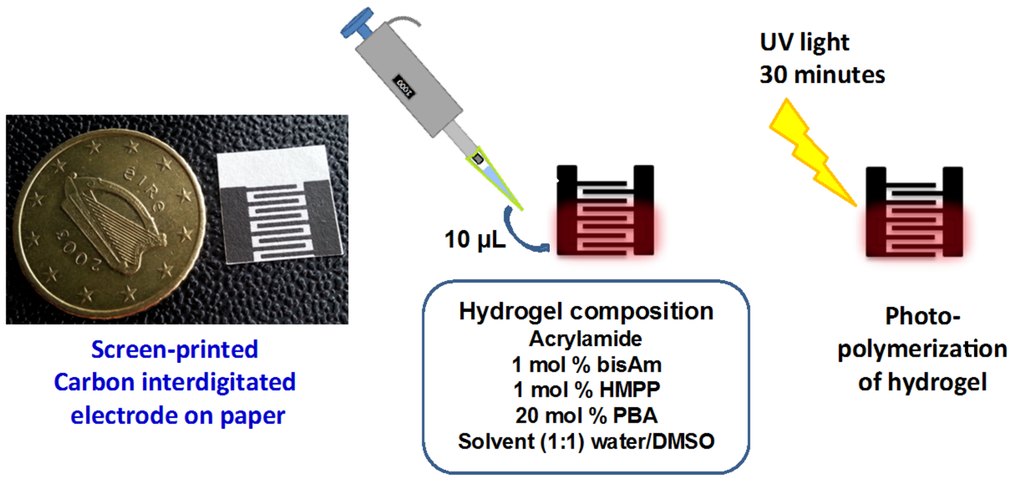
Herein we present a novel sensor for the detection of monosaccharides (*e.g.* glucose, fructose) in solution using electrical impedance spectroscopy. The sensor is based on carbon interdigitated electrodes printed on paper using screen printing. The surface of the electrodes was modified with a hydrogel containing acrylamide copolymerised with 5 and 20 mol% 3-(Acrylamido)phenylboronic acid (PBA), respectively. It was observed that the hydrogel layer containing 20 mol% PBA swells considerably in the presence of glucose and fructose. This in turn changes the electrical conductivity of the hydrogel layer making it a suitable impedance sensor for the quantitative detection of saccharides.

Boronic Acid Functionalised Hydrogels

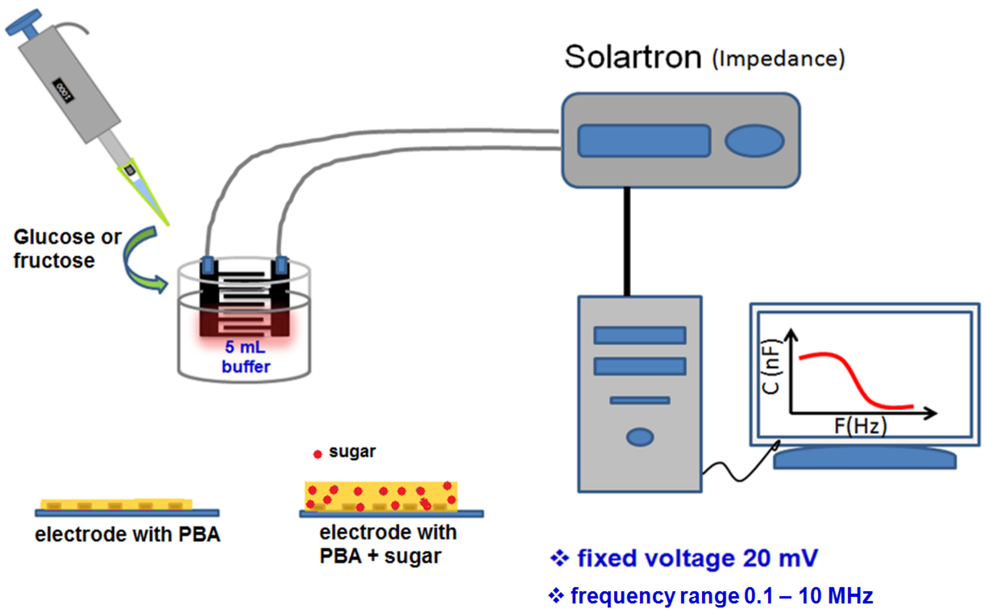
Boronic acids (BAs) are well known for their strong, reversible interactions with diol-containing compounds like sugars, such as glucose and fructose. Incorporating BAs in to a hydrogel matrix can influence the volume of the hydrogel upon saccharide binding. The photos (below, right) show the size of poly(acryl amide) hydrogels containing 20 mol % PBA in the presence of 0, 10 and 20 mM glucose solutions in PBS buffer.



Electrode Functionalisation Protocol



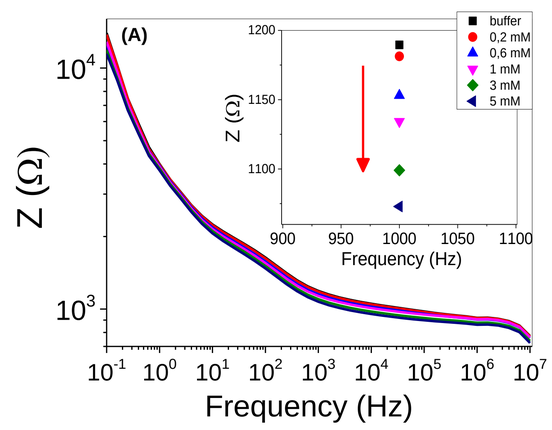
Experimental Setup

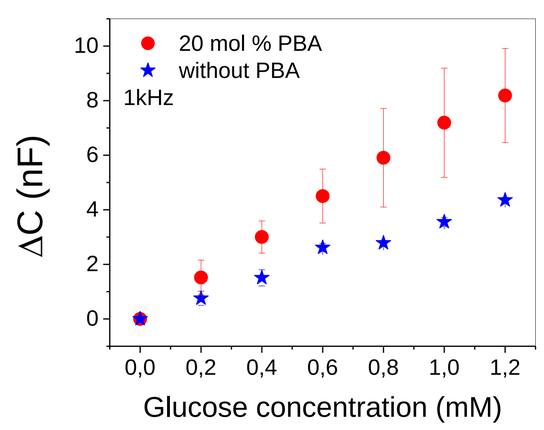


We investigated the capacitance and impedance variations with different concentrations of glucose and fructose (5-50 mM) present in phosphate buffer aqueous solutions. The measurements were made using Solartron 1260 Impedance analyser. 20 mV was applied and the impedance analyzed in the frequency range 0.1 – 10 MHz.

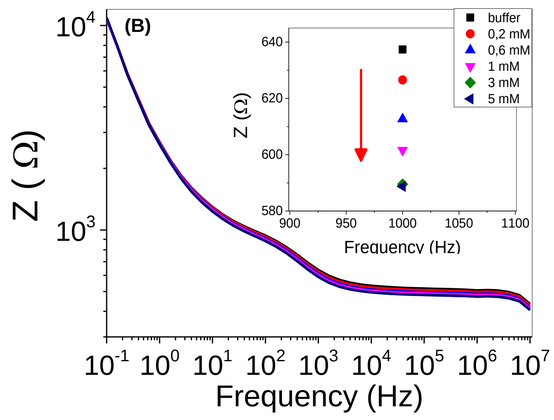
Results

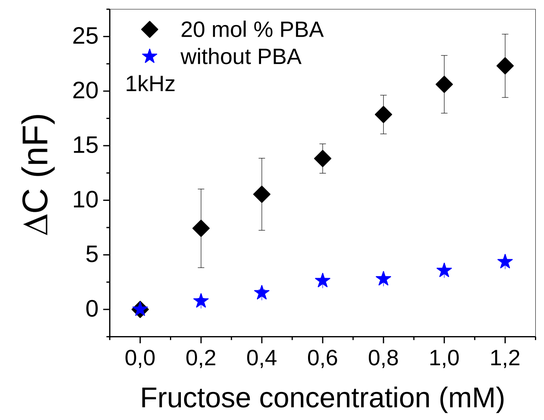
20 mol % PBA Hydrogel - Glucose Response



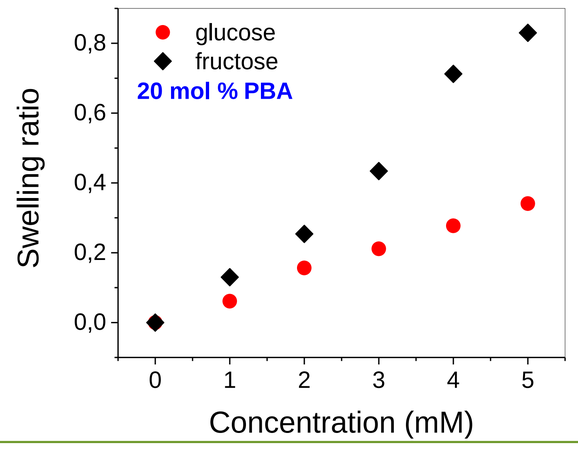


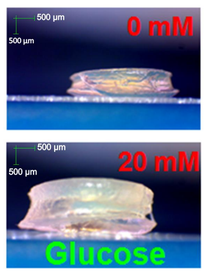
20 mol % PBA Hydrogel - Fructose Response



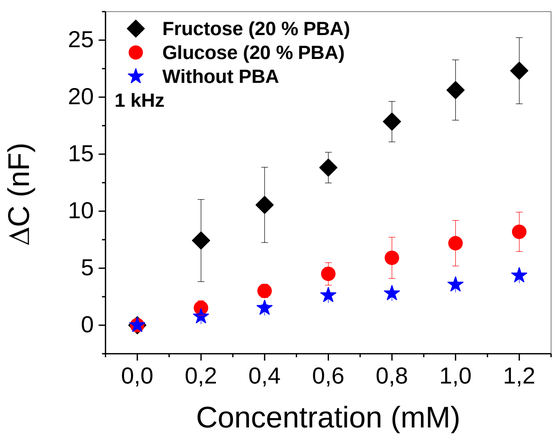


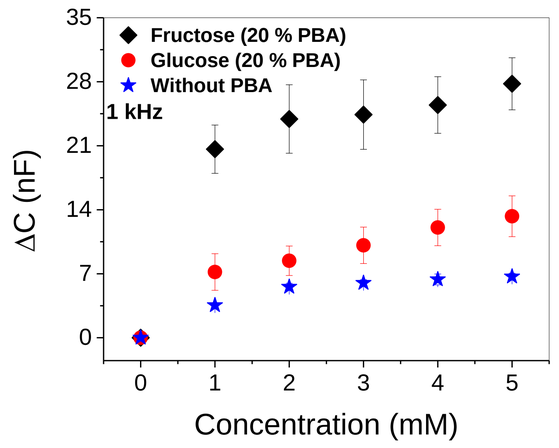
20 mol % PBA Hydrogel – Glucose & Fructose Response





Analysis of relative capacitance with varied sugar concentration





Conclusions

The results show a decrease in impedance with increasing glucose and fructose concentrations due to the monosaccharide-responsive swelling nature of the gels. Future work will focus on the incorporation of these simple, paper-based, modified carbon printed electrodes in wearable skin patch type platforms for non-invasive sugar monitoring in sweat.