Autonomous Droplet Microfluidic Sensor for Highly Variable Ocean Alkalinity

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Ocean alkalinity is the capacity of seawater to resist changes in pH

Application

Fast-changing environments

Titration frequency in continuous microfluidics is limited by mixing

Diffusion mixing in laminar flow

This droplet sensor aims to improve on shortcomings of current continuous microfluidic alkalinity sensors

REDUCED WASTE

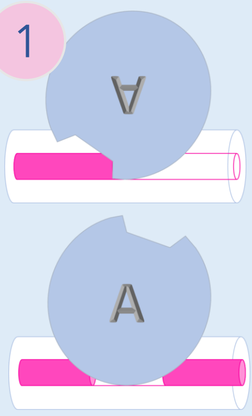
FASTER MIXING

HIGH SAMPLE FREQUENCY

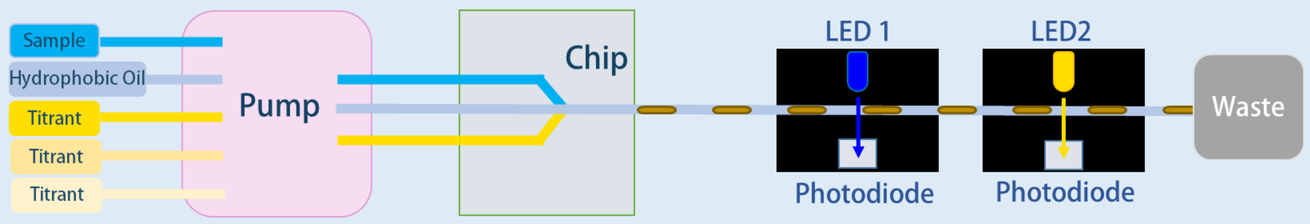
INCREASED RANGE

Sensor Set Up

1



Within the peristaltic pump, the roller has **anti-phase features** that alternately move the oil and aqueous phases



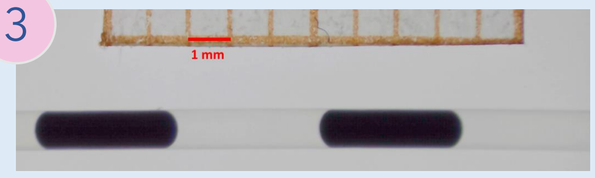
Droplet sensor set up **[1]**

Pump Function

2

Sample and titrant arrive simultaneously, and rapidly mix to create a reaction droplet

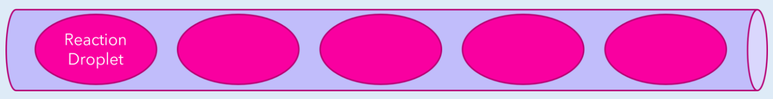
3



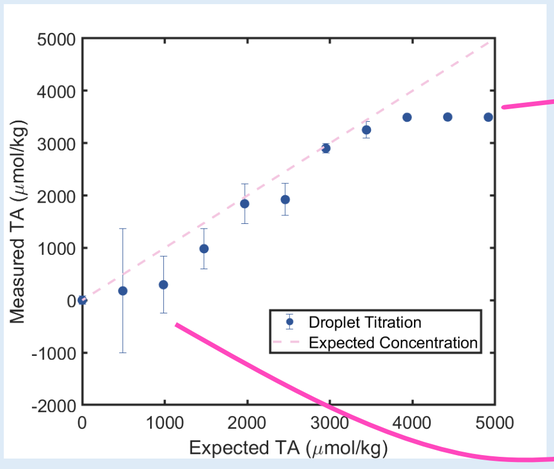
The droplet passes through flow cells, measuring at the peak absorbing wavelengths of the dye

Single-Point Measurement

Discrete, single-point **total alkalinity** (TA) titrations are performed in microfluidic droplets.



Seawater is combined with **titrant** (acid and a pH-sensitive, colour-changing dye) and measured spectrophotometrically



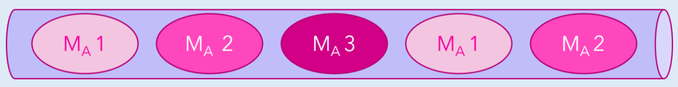
Under-acidified
Plateau of TA (deprotonated dominates)

However, single-point measurements only cover a **limited range** of TA.

Over-acidified
Large error (protonated dominates)

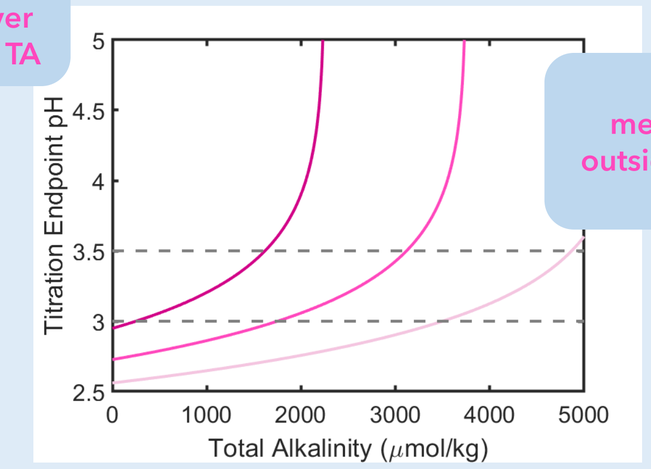
Multi-Point Measurement

The droplet system measures over the **entire TA range** by increasing acid strength in consecutive droplets



M_A = Acid Strength

Acid concentrations chosen to cover wide range of TA



Remove measurements outside of pH 3 – 4 range

'Goldilocks' TA remains

Future Work:

Continuous sea surface measurements

Measuring removal of alkalinity by coccolithophore blooms

Norwegian Sea
↓
North Atlantic
↓
Mediterranean Sea

References
[1] Nightingale, A.M., Hassan, S.U., Warren, B.M., Makris, K., Evans, G.W., Papadopoulou, E., Coleman, S. and Niu, X., 2019. A droplet microfluidic-based sensor for simultaneous in situ monitoring of nitrate and nitrite in natural waters. *Environmental science & technology*, *53*(16), pp.9677-9685.
Estuary Image | Image Source: RSPB| URL: rspb.org.uk/fun-and-learning/for-kids/facts-about-nature/facts-about-habitats/estuaries-and-mudflats/
Coral Reef Image | Image Source: Earth Blog | URL: earthspacecircle.blogspot.com/2016/07/coral-reef.html
Image of Coccolithophore bloom off Brittany | Image Source: France *Jacques Descloitres, MODIS Rapid Response Team, NASA/GSFC, June 15, 2004.*

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This work has been presented elsewhere