Fabrication of a Copper Based Electrochemical Nitrate Sensor for Hydroponic Media

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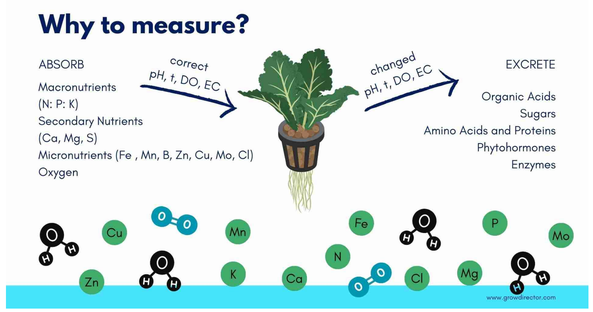
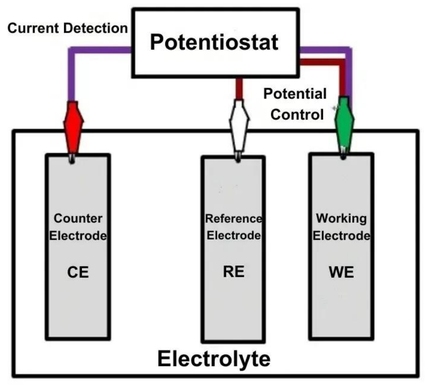
Introduction

- It has been estimated that 50% of the arable land around the world will be unusable for farming by 2050,
- Hydroponics good for growing plants
- The detection of nutrients in hydroponics solutions currently involves measuring the current of the solution to get a measure of how many nutrients are still in the bath



Methods

Detection of Nitrate



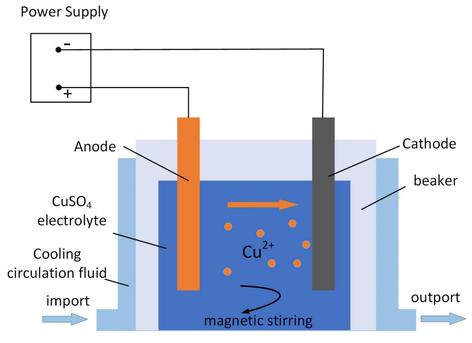
- Three electrode electrochemical cell for detecting nitrate in solution.
- The working electrode is electroplated copper tape, the reference electrode is a saturated calomel electrode, and the counter electrode is palatium wire.
- Scans a range of potentials and measures the current from the solution for peaks in current from the solution.
- Nitrate reduces at -0.6V to ammonium

$$NO_3^- + 10H^+ + 8e^- \rightarrow 3H_2O + NH_4^+ \qquad i_p = 0.4463(\frac{F^3}{RT})n^{3/2}AD^{1/2}C^*V^{1/2}$$

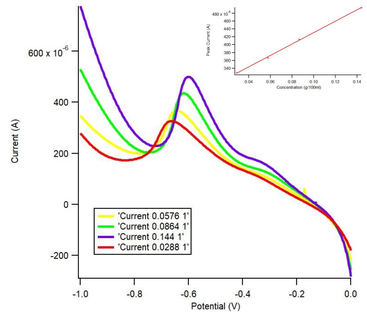
Ip: peak current A: surface area T: temperature C: concentration
F: faradays constant D: diffusion constant N: electrons transferred V: scan rate

Fabrication of sensor

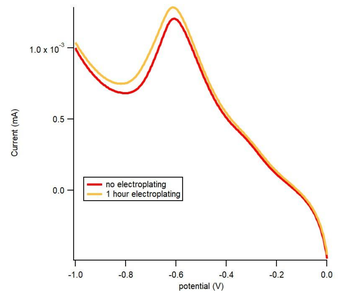
- EG&G 263A Potentiostat/Galvanostat used to electroplate and measure current.
- Increase in surface area for more signal.
- A 0.2M $CuSO_4$ plating bath for electroplating.



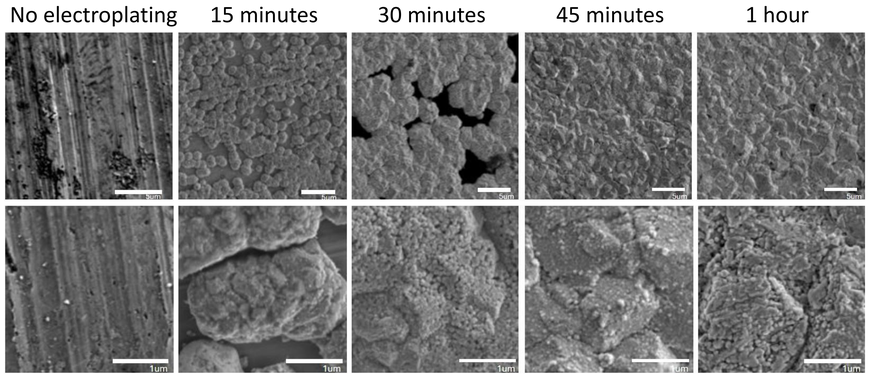
Results and Discussion



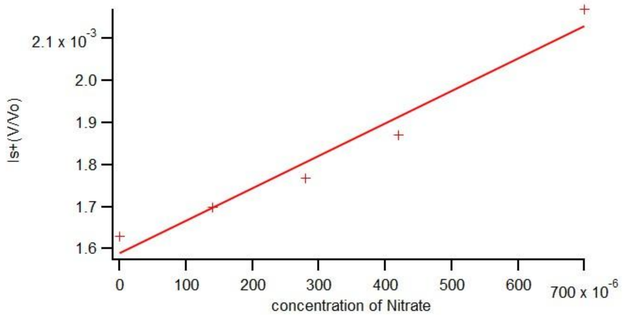
Signal increasing as the concentration of nitrate increases, in solutions of sodium nitrate.



After electroplating for an hour, the signal for nitrate was boosted by ~10µA, both signals were collected from the same concentration of sodium nitrate at 0.0567M in water



- the 15-minute electroplated has “islands” on the surface with not a full electroplated surface.
- the 30-minute electroplated copper tape with much of the copper “islands” coming together and creating a fuller electroplated surface with only small gaps appearing.
- the 45-minute electroplated copper tape with a much fuller electroplated surface with no gaps on the surface and a very rough surface.
- the 60-minute electroplated copper tape with the surface still being completely electroplated with there being slightly more surface area than the 45-minute electroplated surface



- The standard addition of nitrate into the Hoagland solution resulted in a relatively straight line with an R^2 of 0.9642.
- This allows for the testing of the boost in signal from nitrate without interferences from the complex matrix

Results continued

Sample	Sensitivity mA/mM	% error between actual and detected concentrations	concentration of nitrate detected mM	Actual concentration of nitrate mM	R^2
As prepared Hoagland flat	0.007717	85.203	2.07	13.99	0.9642
50% Diluted Hoagland flat	0.0172	75.125	1.74	6.995	0.8746
50% Diluted Hoagland 15 minutes	0.0220	80.557	1.36	6.995	0.9388
50% Diluted Hoagland 30 minutes	0.0367	80.557	1.36	6.995	0.9307
Diluted Hoagland 45 minutes	0.0323	73.409	1.86	6.995	0.8685
Diluted Hoagland 1 hour	0.0203	43.674	3.94	6.995	0.4603

Conclusions

- The increase in signal from the electroplated copper tape especially at 45 or 60 minutes demonstrated that electroplating could increase the signal of the sensor.
- Electroplated copper tape was able to detect the nitrate in the Hoagland using standard addition with an R^2 of 0.96 meaning the concentration fit a straight line and had a percent error of 85.203%

Future Work

- More testing with interferences such as Phosphate.
- Trying to make copper nanowires with a membrane.
- run additional trials for standard addition.
- Confirm Nitrate by alternate method

References

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