**Conducting polymers for sensing in agriculture**

*Sam RuddA, Drew EvansA*

AFuture Industries Institute, University of South Australia, Adelaide, Australia.

**Introduction**

Nitrate (NO3−) is a key nutrient of interest in agriculture, essential for increasing crop productivity and yield. Chemical fertilisers are synthetic substances that provide the necessary nutrients for healthy plant growth and development in modern agriculture. The Food and Agriculture Organization of the United Nations (FAO) estimates by 2020 a total yearly supply of 273 million tonnes of chemical fertilisers will be used globally, with Australia being one of the top 10 importing countries of nitrate fertilisers. Currently, farmers rely on their experience to judge the timing of fertiliser application, which means the process is often sub-optimal. However, an immediate concern with chemical fertilisers is the effect on human health. For instance, overuse of nitrate-based fertilisers can cause problems for plants, while excess NO3− can leach into groundwater - potentially impacting human health and the environment. Hence, the development of new technologies to detect and monitor NO3− levels is of increasing importance, as it will allow fertilisers to be applied using a precision approach. In this study we report for the first time the NO3− selectivity of the inherently conducting polymer poly(3,4-ethylenedioxythiophene) (PEDOT). This selectivity occurs when PEDOT thin films are exposed to an aqueous environment containing not only NO3−, but a mixture of other ions present in concentrations (ppm) typical of real agricultural soil.

**Methods**

PEDOT films were synthesized using Vapour Phase Polymerisation (VPP) process. Since PEDOT is almost fully doped via this process, a three electrode system in electrochemical cell was employed to electrochemically reduce the PEDOT films in the presence of a standard Ag/AgCl electrode (3.8 M KCl) as the reference electrode, in order to remove most of the anions from the PEDOT films. PEDOT films were then exposed to extracted water samples from the agricultural field. Treated PEDOT films were investigated before and after treatment using various techniques to study their chemical composition, electrical and optical properties.

**Results**

A crucial set of the experiments focused on evaluating the anion selectivity of PEDOT that was synthesised using VPP technique. Once the PEDOT had been electrochemically reduced, it was exposed to aqueous solutions containing different anions, to determine if the anions would be taken up by PEDOT. This identified that NO3−was rapidly absorbed from solution. It was then demonstrated that NO3−was selectively taken up by PEDOT when present in a mixed electrolyte solution (Rudd *et al.* 2017). Through fabrication of a variety of VPP-PEDOT films, it has been observed that the structure and properties of the polymer film have great influence on the sensitivity of NO3− uptake (Rudd *et al.* 2019). These important fundamental discoveries led to filing a joint patent with Sentek Pty Ltd to develop the next generation of agricultural sensors using conducting polymers. (International Publication Number WO 2018/068079 A8).

**Conclusion**

In summary, the conductive polymer PEDOT is observed to show specific selectivity for NO3− uptake from aqueous solutions. The NO3− dopes PEDOT via a passive process (not requiring external driving voltages or electric fields) in preference to other anions even if present in equal or higher concentrations in solution Such sensing is of interest in relation to aqueous environments where NO3− is present, such as agricultural soil.

**References**

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*\**Corresponding author email: Sam.Rudd@unisa.edu.au