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Impedance-based sensor for potassium ions

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Abstract

A conductometric sensor for potassium ions in solution is presented. Interdigitated, planar gold electrodes were coated with a potassium-selective polymer membrane composed of a poly(vinyl chloride) matrix with about 65 wt% of plasticiser and 2 - 5 wt% of a potassium-selective ionophore. The impedance of the membrane was measured, using the electrodes as a transducer, and related to the concentration of potassium in a sample solution in contact with the membrane. Sensitivity was optimised by varying the sensor components, and selectivity for potassium over sodium was also shown. The resulting devices are compact, miniature, robust sensors which, by means of impedance measurements, eliminate the need for a reference electrode. The sensor was tested for potassium concentration changes of 2 mM across the clinically relevant range of 2.7 - 18.7 mM.

Keywords: potassium, impedance spectroscopy, conductometric sensor, ion-selective membrane, blood analysis, portable sensor

1. Introduction

Detection of potassium-ion concentration in solution is essential for multiple applications, the main ones being soil analysis for crop growth [1, 2], and clinical analysis of blood and other biological fluids [3, 4]. Almost all such sensor devices are based on an ionophore, usually valinomycin, embedded in a plasticised polymer membrane matrix, often poly(vinyl chloride) (PVC). These ion-selective membranes have been widely researched and developed since their introduction in the 1970s [5–7]. Multiple transduction methods have been investigated, principally ion-selective electrodes (ISEs), optodes, and ion-selective field-effect transistors (ISFETs). Mikhelson et al provide an overview [8].

Most commonly employed are ISEs; these are present in traditional off-line methods of soil-sample potassium testing [1], as well as more modern *in situ* measurement devices [2]. Similarly, ISEs are employed in almost all commercial, clinical blood analysers used in hospitals [9]. Traditional ISEs in larger machines have an internal filling solution, which creates a limit on miniaturisation and durability [10]. However, the demand for miniature sensors for *in situ* and point-of-care monitoring has increased significantly, and recently, all-solid-state ISEs have been developed which are miniaturisable [4, 10–12]. The requirement for a reference electrode and for frequent calibration, however, remains a drawback of ISEs [10].

Recently, optical methods for potassium detection have become more prevalent, both for crop growth [13] and in blood analyses [14, 15]. However, spectrophotometers remain relatively large, making miniaturisation

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