

# Abstract

Over the past two decades there has been an increasing trend towards miniaturised analytical systems. These so called 'Lab-on-a-Chip' (LOC) devices offer considerable advantages over traditional lab scale instrumentation in terms of greatly reduced manufacture and analysis costs (associated with decreased reagent and analyte consumption), improved analysis timeframes and increased instrument portability. Notably, one of the main driving forces for LOC production has been the development of simple, low cost fabrication techniques. Nevertheless, despite its great potential, there remains a considerable number of limiting factors in producing commercially viable portable LOC systems. These arise from the complex fabrication processes required to integrate commonly utilised detection systems with the microchip. Capacitively coupled contactless conductivity detection (C<sup>4</sup>D) offers a readily miniaturised, potentially portable detection approach that is well suited to LOC systems. Whilst its integration with LOC systems has been well studied, most reported methods require cost (and time) intensive equipment and multi-step electrode patterning/fabrication processes to manufacture the devices. Furthermore the ex-situ manufacture of the detection system results in difficulty in consistently aligning the C<sup>4</sup>D detection electrodes. These limitations have the potential to compromise analytical performance of the detection system and significantly increase the time and cost of device production.

This thesis reports the first successful use of injected gallium metal electrodes for C<sup>4</sup>D in polymer microchips. The developed design and fabrication process is fast, simple (no complex instrumentation), highly reproducible, and eliminates difficulties with electrode alignment. Using this approach C<sup>4</sup>D can be readily achieved in any microchip by simply adding extra 'electrode' channels to the microchip design. This design flexibility allowed for straightforward optimisation of electrode parameters to be performed; namely electrode geometry, distance from separation microchannel and length. Optimum values for each parameter were determined by evaluation of the peak heights and S/N ratios obtained for the model analytes lithium, sodium and potassium ions. This gave rise to optimised detection electrodes in anti-parallel geometry with a 75 µm electrode to separation microchannel distance and a 1000 µm electrode length.

The analytical performance of the injected gallium electrodes for C<sup>4</sup>D was evaluated by the quantitative determination of the model analyte mixture containing small cations. Utilising the optimised electrode system produced detection limits ranging from 6.2 to 8.7 µM for lithium, sodium and potassium ions with linear calibration data between 100 to 700 µM. Furthermore, the repeatability of the method demonstrated its suitability for quantitative analysis with both the inter-day and intra-day percentage relative standard deviation (%RSD) reported to be lower than 4% for both migration time and peak height.

To demonstrate the ability of the novel electrode system to perform sensitive and quantitative analysis

it was applied to the detection of histamine in fish flesh samples. Histamine is a primary amine formed by the decarboxylation of the amino acid L-histidine and belongs to a group of compounds known as biogenic amines (BAs). Despite being present naturally in certain foods; BAs are normally formed as a result of uncontrolled microbial action which can lead to high levels upon food decomposition. Elevated histamine levels ( $> 200 \text{ mg/kg}$ ) have been reported as the cause for scombroid fish poisoning and therefore, simple and portable quantitative methods for the determination of histamine levels in such products are of importance to monitor the spoilage and quality during processing and storage. The first use of microchip electrophoresis with  $\text{C}^4\text{D}$  for the direct detection of histamine in fish flesh samples is reported here. After optimisation of the background electrolyte (BGE) conditions a competitive detection limit of  $0.43 \text{ mg.L}^{-1}$  was achieved. The developed method was successfully applied to the determination of spiked histamine in yellowfin tuna flesh samples with excellent recoveries. Further versatility was demonstrated through the analysis of a variety of fish products purchased from local supermarkets.

In summary, due to the expensive and complex fabrication approaches used to integrate  $\text{C}^4\text{D}$  electrodes with LOC devices, the development of an alternative simple and inexpensive method is required. The research presented here introduces a novel approach utilising molten gallium metal injected into electrode guide channels patterned during microchip fabrication. The development of this technique provides a significant advance and allows for consistently aligned electrodes to be produced without the need for costly instrumentation.