

# Electrochemical Detection of Metal Ions in Water Using a Six-Electrode Microfluidic Device

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**Abstract:** The ability to detect trace amounts of heavy metals in water is of growing importance. The World Health Organization recognizes many heavy metals as health hazards because of the tendency to accumulate in living organisms over time [1]. Current standard methods such as inductively coupled plasma(ICP) and atomic absorption spectroscopy(AAS) are highly expensive and not convenient for field applications. A PDMS microfluidic device that incorporates 6 gold working electrodes on a glass substrate was fabricated and tested using an electrochemical method known as Differential Pulse Voltammetry. Lead ( $Pb^{2+}$ ) and Cadmium ( $Cd^{2+}$ ) were the primary ions used for detection, but future work will include other ions. Using a bismuth coating on the electrode, the device successfully detected  $Pb^{2+}$  and  $Cd^{2+}$  ions at parts per billion( $\mu g/L$ ) concentrations.

## Materials and Methods

### Device Fabrication:

Six gold working electrodes were made using **Thermal Evaporation(TE)** to deposit a 15 nm layer of chromium followed by a 200 nm layer of gold on a clean glass substrate(1 mm thick microscope slide). The mask for Cr/Au deposition was fabricated in a machine shop. Photolithography was used to create a photoresist mold for fabrication of a **polydimethylsiloxane(PDMS)** layer with individual channels for each electrode. Another PDMS layer was added to create a well for the bulk solution. (See Figure 1)

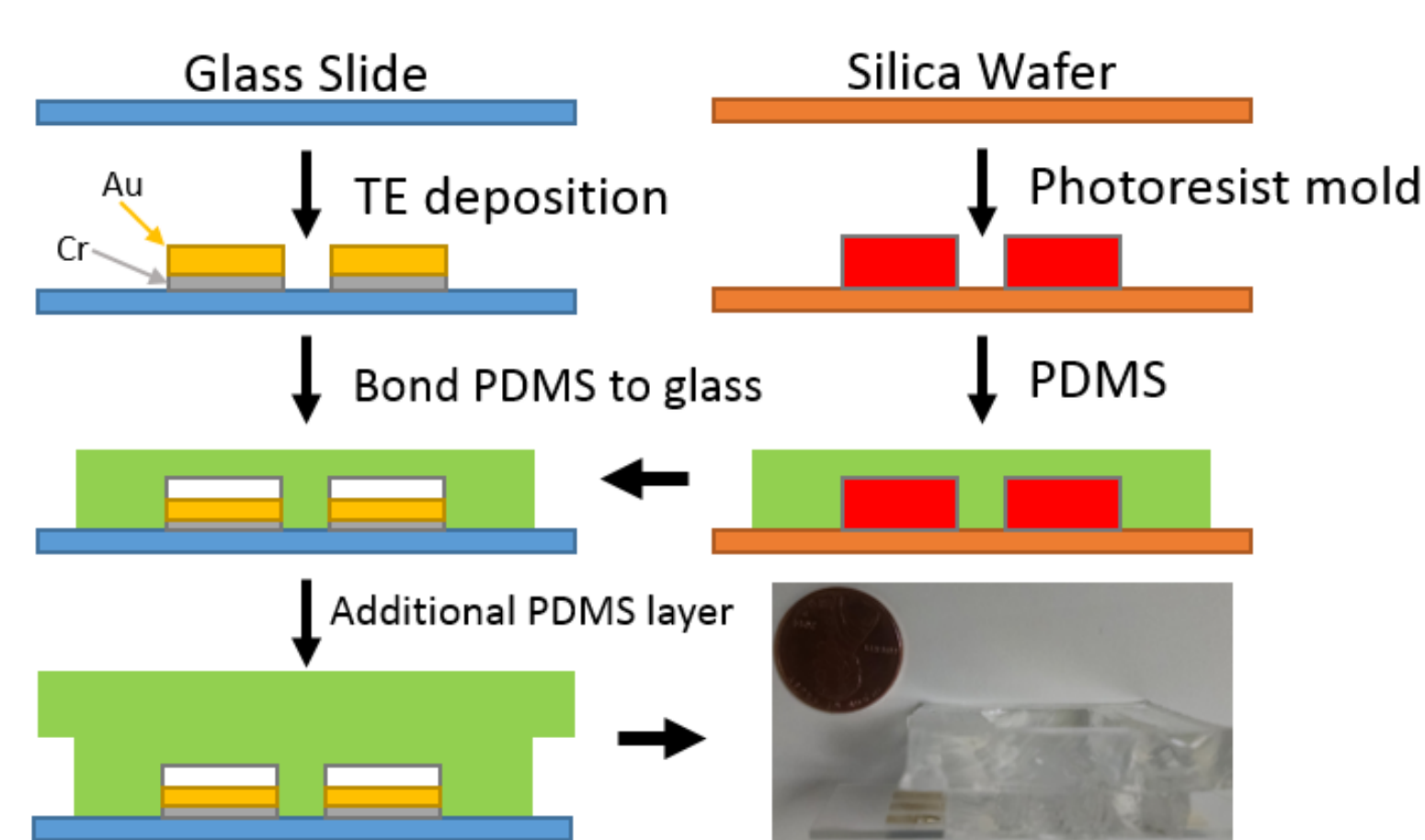


Figure 1. Simple diagram of the fabrication process is shown on the left, and on the right are some actual images of the fabricated device.

**Differential-Pulse Voltammetry(DPV)** is a technique that measures current while using a series of discrete potential steps rather than a linear potential ramp

- The commonly used method for detection of ions using DPV is known as **Anodic Stripping Voltammetry(ASV)**. This allows for a layer of positively charged ions to be deposited onto a negative surface, and then as the potential changes (See Figure 2) the ions are oxidized at a specific potential. A peak in current is seen as the ions are stripped from the surface of the working electrode.

## Methods Continued

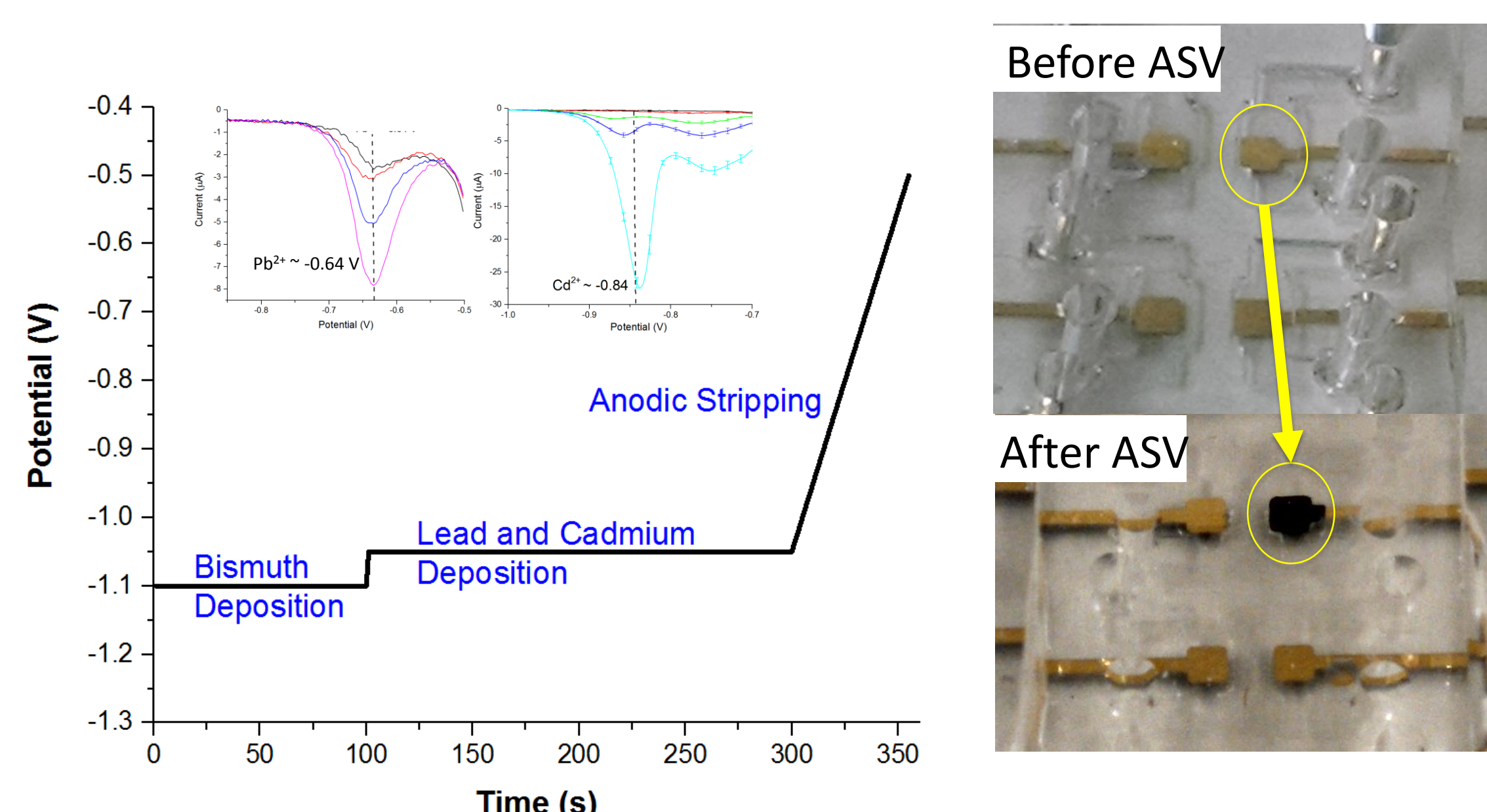


Figure 2. One cycle of ASV is shown on the left, including two deposition time periods followed by the stripping period where a current peak would be observed. The inset shows the oxidation potential for lead and cadmium on a commercial gold electrode. On the right is a before and after image.

## Results

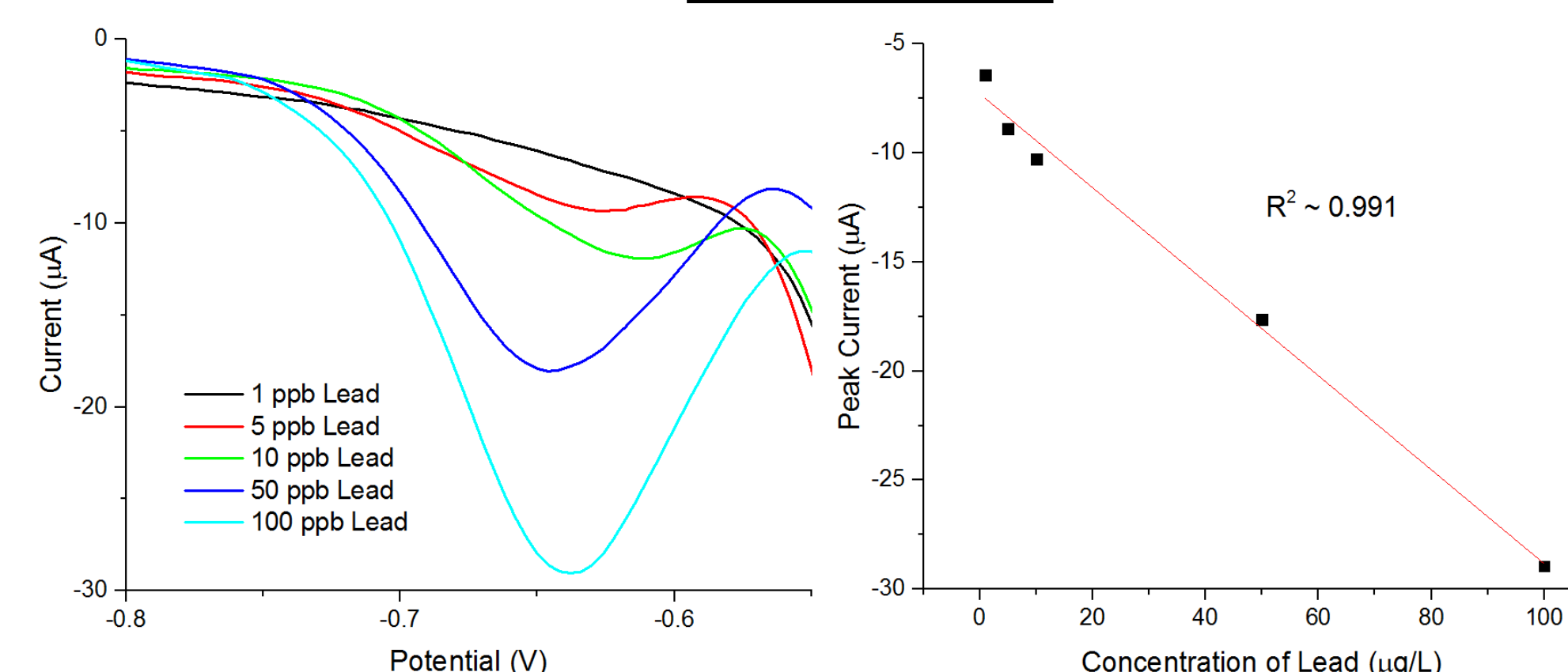


Figure 3. ASV results on the left for varying concentrations of lead. The potential range tested was from -1.1 V to -0.5 V, and the peak current response is seen at about -0.64 V. The corresponding calibration curve is on the left.

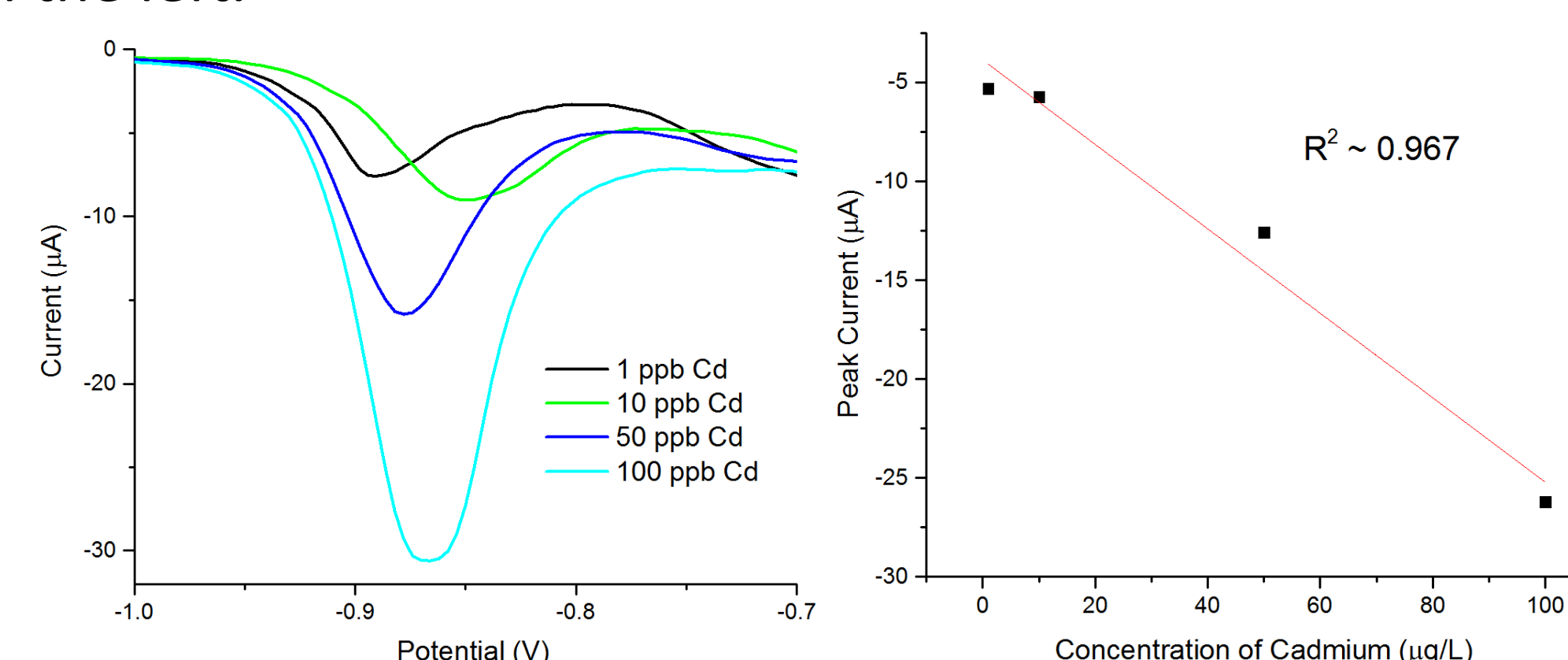


Figure 4. ASV results on the left for varying concentrations of cadmium. The potential range tested was from -1.1 V to -0.65 V, and the peak current response is seen at about -0.86 V. The corresponding calibration curve is on the left.

## Future Work

- Test the repeatability for detection of lead and cadmium, comparing 3 electrodes on the same device.
- Incorporate other metal ions such as zinc, chromium, nickel, and copper with varying modifications to the gold working electrode.
- Compare results with current standard methods such as ICP and AAS.
- Incorporate the reference and counter electrode into the device fabrication.

## Conclusion

The electrochemical device discussed can be fabricated quickly and efficiently, and has shown the potential to detect lead and cadmium ions down to parts per billion. The costs for such devices are far more affordable than the current ICP and AAS methods. Including 6 working electrodes also improves a previously introduced device with only 2 working electrodes[2]. This allows multiple tests to be performed on one device.

## References:

- Multilayer Paper-Based Device for Colorimetric and Electrochemical Quantification of Metals** Poomrat Rattananat, Wijitar Dungchai, David Cate, John Volckens, Orawon Chailapakul, and Charles S. Henry *Analytical Chemistry* **2014** 86 (7), 3555-3562
- Microfabricated three-electrode on-chip PDMS device with a vibration motor for stripping voltammetric detection of heavy metal ions** Wen Zhang, Han Zhang, Spencer E. Williams, Anhong Zhou *Talanta* **2014** (132), 321-326

## Acknowledgements:

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