Graphene/SiC platform towards Lead detection in aqueous solutions

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When exceeding maximal allowable concentrations, Lead (Pb) has the most detrimental effect on children, being accumulated in bones, blood and in the digestive tract [1]. For this reason, there is a strong impetus towards designing environmentally-friendly sensors for Pb detection, especially at low concentrations. Due to its excellent sensing ability, graphene is a promising candidate for fabrication of green environmental sensors.

In this work, we investigate the electrochemical activity of epitaxial graphene (Gr/SiC) towards Lead detection by two different techniques – anodic stripping voltammetry (ASV) and current-voltage (*I-V*) characterization. Graphene electrode exhibits sharp current peak (Figure 1) for Pb ions with detection limit of 2.07 $\mu g \cdot L^{-1}$. This is significantly lower than the WHO permissible limit of 10 $\mu g \cdot L^{-1}$ for Pb in drinking water. In the second case the current across the graphene resistor decreases significantly even with small increasing concentration of the target metal ions (Figure 2).

The sensing mechanism of epitaxial graphene is governed by the physisorption of neutral Pb atoms (charge transfer ~ $+0.2e^-$) in the case of graphene electrode and chemisorption of divalent Pb ions (charge transfer ~$-0.6e^-$) in the case of graphene resistor.

Two adsorption configurations of both Pb atom and Pb^{2+} ion on graphene are illustrated in Figure 1 and Figure 2, respectively. The calculated adsorption energy of Pb^{2+} ion is 7.05 eV, which is significantly larger than that of neutral Pb atom (0.2 eV). Neutral Pb atom was stabilized in the bridge site of graphene, while the divalent ion tends to occupy the hollow sites. According to DFT calculations and experimental results Pb adsorption ability on graphene resistor is significantly larger than that on graphene electrode. Further optimization towards real sensors, also for other heavy metals, is in progress.

Figures

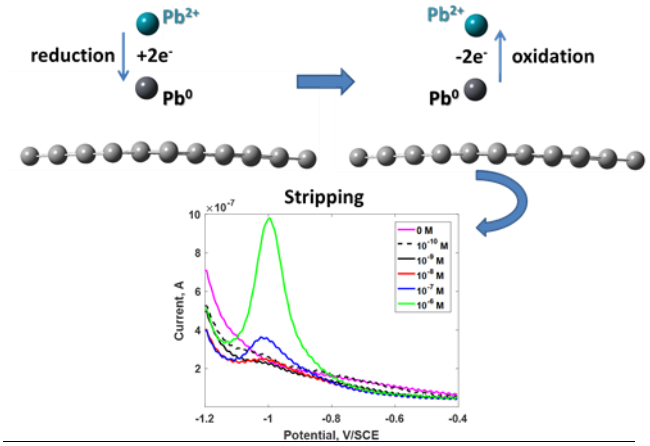

Figure 1: Top panel: schematic illustration of sensing mechanism, including optimized stable structure for Pb^0 adsorption on graphene. Bottom panel: stripping voltammograms of graphene working electrode in acetate-buffer solution containing Pb ions in the concentration range of10^{-10}-10^{-6} Mol/L.

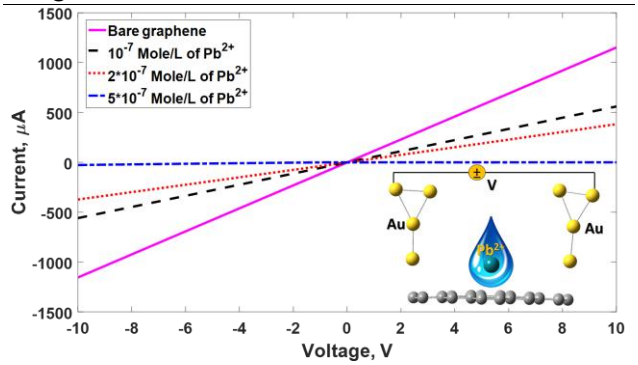

Figure 2: Response of Graphene resistor to the Pb^{2+} exposure. Insert shows optimized structure of the proposed sensing device.

References

[1] W. Yantasee, Environ Health Perspect. 2007 Dec; 115(12): 1683–1690