Pt Recovery for End-of-Life Halide Perovskite Photoelectrochemical Devices

Laasya Thiagarajan[1], Huilong Liu[1], and Shubhra Bansal[1,2,*]

[1]School of Mechanical Engineering, [2]School of Materials Engineering, Purdue University, West Lafayette IN 47906

[*]Contact Email: bansal91@purdue.edu

Perovskites refer to broad classes of materials that share the same crystal structure as the calcium titanium oxide mineral with the chemical formula of $CaTiO_3$. A Pt-based halide perovskite is a vacancy-ordered double perovskite. It typically has the formula A_2PtX_6, where A is a monovalent cation (Cs) and X is a halide (Cl, Br, I), and alternate B cation sites are intentionally left vacant, making the unit cell as A_2PtX_6. In this 0D or vacancy-ordered structure, Pt exists in 4+ state and the perovskite phase is environmentally stable and is free of the toxic PbI_2. Since Pt exhibits chemical stability, high electrical conductivity, and catalytic properties, it can enhance the properties of perovskite phase. Pt-based halide perovskites are generally studied for their potential in solar cells, thermoelectric devices, and water splitting photocatalysis.

Pt is typically very expensive and scarce due to its complex properties, making it a critical metal. Extracting platinum from Pt-based halide perovskite thin-film semiconductors has significant importance for the circular economy and for other applications that require Pt-based technologies, which allows for sustainability, cost efficiency, and material optimization.

This study focuses on using a chloride and nitrate based aqua regia along with ammonium chloride to extract elemental platinum from Pt-based halide perovskite thin-film semiconductors. These thin films are placed in the aqua regia, and then ammonium chloride is added to form a precipitate. Through heating of the precipitate, elemental platinum powder can be produced. The step-by-step reactions are listed below:

$$3Pt + 4HNO_3 + 18HCl \rightarrow 3H_2PtCl_6 + 4NO\uparrow + 8H_2O$$

$$PtCl_2 + 2HNO_3 + 4HCl \rightarrow H_2PtCl_6 + 2NO_2\uparrow + 2H_2O$$

$$PtCl_4 + 2HCl \rightarrow H_2PtCl_6$$

$$H_2PtCl_6 + 2NH_4Cl \rightarrow (NH_4)_2PtCl_6\downarrow + 2HCl$$

$$3(NH_4)_2PtCl_6 = 3Pt + 16HCl + 2NH_4Cl + 2N_2\uparrow$$

To evaluate the purity of the platinum extracted, Inductively Coupled Plasma Mass Spectrometry (ICP-MS) will be used which is where plasma is used to ionize and evaluate mass to charge ratios. Another common method that will be used is X-ray Fluorescence (XRF) which measures emitted X-rays to determine chemical composition. These methods will be used to analyze the purity of recovered Pt, which can then be used as a catalyst in fuel cells or as catalyst in the automotive industry to convert harmful exhaust gases to less harmful emissions.