Ambient pressure X-ray photoelectron spectroscopy studies of electrochemically mediated regeneration of amine solutions for CO_2 capture technologies

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Carbon capture with aqueous amine solutions is a mature technology that has been used for CO_2 removal from point source emissions, such as fossil fuel-fired power plants. Amines are known for their reversible reactions with CO_2, which make them particularly useful for the separation of CO_2 from many CO_2-containing gases, including flue gas. However, current aqueous amine-based capture technologies use a high temperature regeneration cycle that can lead to amine decomposition and a high energy penalty. Electrochemically mediated amine regeneration (EMAR) has been proposed [1] as an alternative method to regenerate aqueous amine-based CO_2 capture solutions in order to circumvent these problems. EMAR can help to overcome the high energy consumption and reduce amine decomposition caused by thermal regeneration. During EMAR, the captured CO_2 is released from the amine solution by oxidizing a metallic anode, typically copper. This produces metallic ions that form complexes with amines. Since complex formation is more favorable than CO_2 absorption, the CO_2 is released upon complex formation. Subsequent reduction of the complex at a cathode regenerates the aqueous amines and the solution's ability to capture CO_2. We have used the dip-and-pull method in combination with AP-HAXPES [2] to investigate copper-based EMAR systems. We investigated the copper(II)-ethylenediamine (EDA) complex by in-situ AP-HAXPES measurements, to identify and quantify the copper oxidation states and the amounts of EDA bound in complex. To reproduce the EMAR process, a copper electrode was immersed in a Cu(II)-EDA complex solution, and cyclic-voltammetry scans were performed to consecutively oxidize and reduce the Cu(II)-EDA complex on the electrode; AP-HAXPES measurements were conducted at selected potentials at both oxidation and reduction conditions, in order to understand both the state of the copper electrode and the composition of the aqueous solution near the electrode. The experiments were carried out at the SpAnTeX end-station, using tender X-rays from the KMC-1 beamline at BESSY II in Berlin.

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