Supplementary material for: Selective gold recovery with electrochemically-assisted aqueous reduction

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Reima Herrala[a,b], Kirsi Yliniemi[a], Jaana Vapaavuori[a], Mari Lundström[b*]

[a]Department of Chemistry and Materials Science, Aalto University, Espoo 02105, Finland

[b]Department of Chemical and Metallurgical Engineering, Aalto University, Espoo 02105, Finland

* mari.lundstrom@aalto.fi

The electrochemically-assisted aqueous reduction (EAR) method was used to recover gold from solutions with varying Cu^{2+} and Fe^{3+} concentration. The used EAR parameters were i_1 = -1 mA cm^{-2}, t_1 = 0.2 s, and t_2 = 30 s. The observed potential changes during ten cycles are shown in Figure S1. With increasing Cu^{2+} concentration, the potential during and between pulses increased. The same effect can be observed with the Fe^{3+} solution, however with noticeably higher potentials. These EAR parameters were not effective for recovery in the Fe^{3+} solution, as can be seen in Figure S2 where the mass change is negative for the higher Fe^{3+} concentration solutions due to significant corrosion of the electrode between pulses.

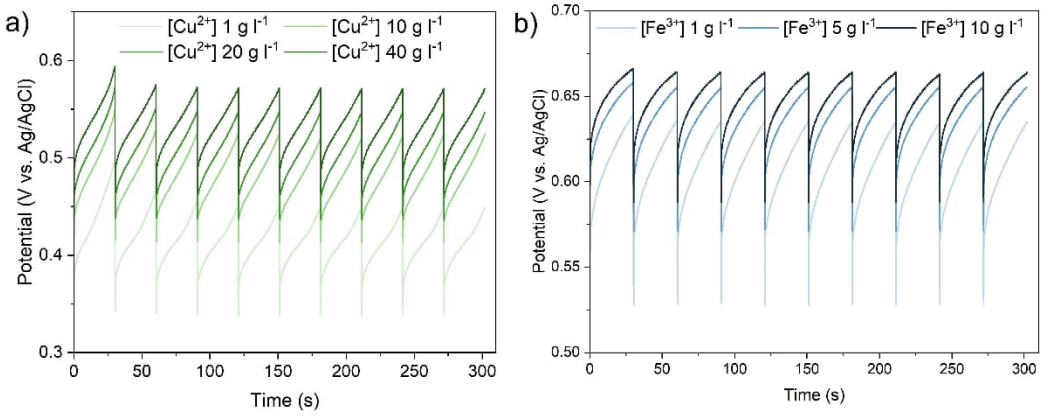

***Fig. S1**. Measured potential during ten cycles of EAR with i_1 = -1 mA cm^{-2}, t_1 = 0.2 s, t_2 = 30 s for solutions with varying a) cupric and b) ferric ion concentration. Other solution properties: 5 mg l^{-1} Au, 110 g l^{-1} NaCl, pH ~1.5.*

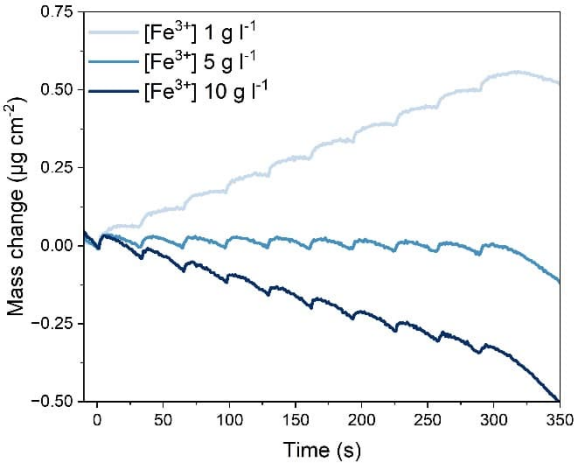

Fig. S2 *Measured mass change during ten cycles of EAR as a function of Fe^{3+} concentration. EAR parameters: i_1 = -1 mA cm^{-2}, t_1 = 0.2 s, t_2 = 30 s. $[Au^{3+}]$ = 5 mg l^{-1}.*

The reactivity of Zn^{2+}, Ni^{2+} and Al^{3+} impurities in the solution containing 2 M Cl^{-1} was studied with cyclic voltammetry in the EQCM cell (Figure S3). No deposition or other redox peaks corresponding to the added metals were found in the studied potential range between H_2 evolution and dissolution of the gold electrode.

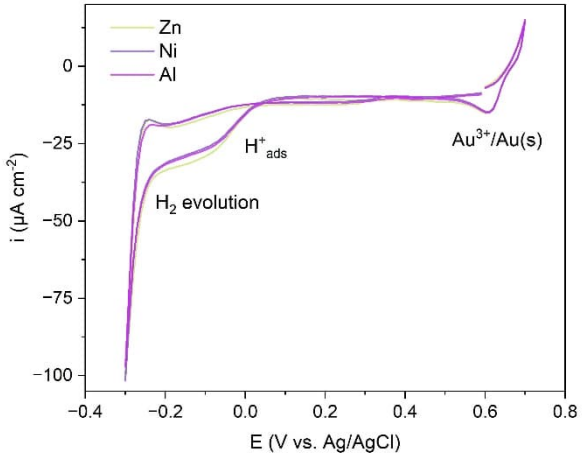

Fig. S3 *Cyclic voltammetry in 2 M NaCl solution with 1 g l^{-1} of Zn^{2+}, Ni^{2+} or Al^{3+} showing no deposition in the studied potential range.*

The mass change during cyclic voltammetry in blank electrolyte (110 g l^{-1} NaCl) was measured as comparison to noble metal deposition measurements (Figure S4). It was found that that above 0.6 V vs. Ag/AgCl gold corrosion and redeposition reactions occur. Below this potential there is a slow and constant change in mass which is likely due to adsorption/desorption of ions such as Cl^-.

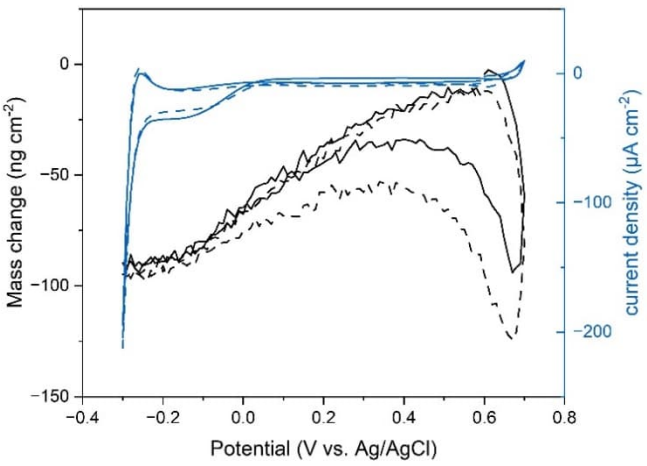

Fig. S4 *Measured mass change during cyclic voltammetry in solution of 2 M NaCl, pH~1.5. First (solid line) and second cycle (dashed line) are shown.*

As a control experiment, EAR was attempted from a multimetal solution containing all the studied metals except for gold (Figure S5). Comparing different pulse amplitudes, it was found that practically no deposition was observed for -1 or -5 mA cm^{-2} pulses, while the initial pulses at 300 or 0 mV vs. Ag/AgCl resulted in a small amount of deposition that then ended. Overall, a clear lack of recovery is observed compared to the solutions with 5 mg l^{-1} gold included.

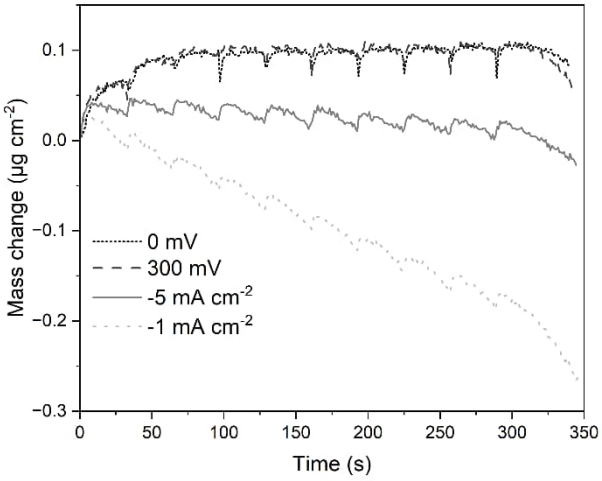

Fig. S5 *Attempted EAR with no gold in solution using various pulse amplitudes. Solution contained 20 g l^{-1} of Cu, 5 g l^{-1} Fe, 1 g l^{-1} Al, Ni, Zn, 5 mg l^{-1} Ag, Pt, Pd, 110 g l^{-1} NaCl, pH 1.5. EAR parameters: t_1 = 200 ms, t_2 = 30 s.*

The composition of particles deposited onto glassy carbon electrodes after one nucleation pulse (-500 mV vs. Ag/AgCl) and 500 cycles of EAR (0 mV, 200 ms) was characterized with EDS (Figure S6). Spot analysis of particles showed that the composition was entirely gold, with no peaks corresponding to the other metals in the solution (Pt, Pd, Ag, Cu, Fe, Ni, Zn, Al, Na).

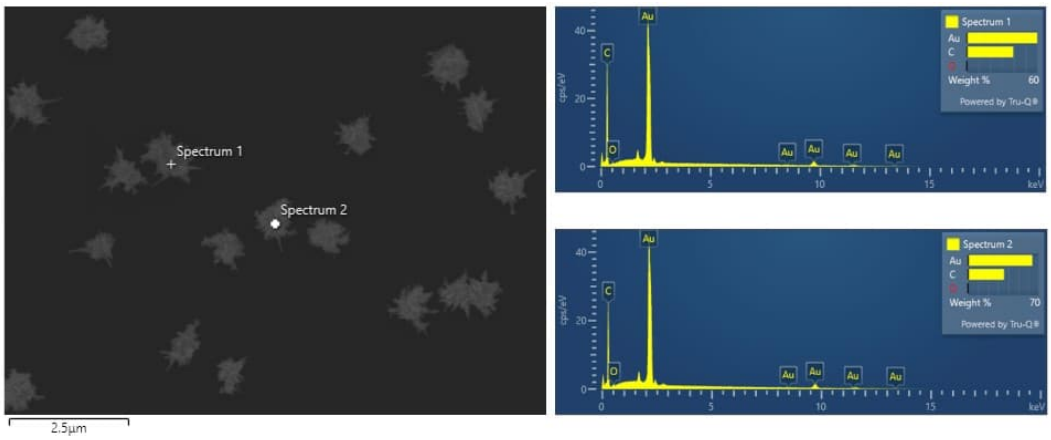

Fig. S6 *EDS analysis of nanoparticles on glassy carbon electrode after one nucleation pulse and 500 cycles of EAR.*