Development of 3D and functionalised electrodes to metal decontamination of polluted water: application to the uranium recovery

Belnou Florent*[1], Michel Schlegel[1], Hicham Maskrot[1], and Thomas Proslier[2]

[1]laboratoire d'ingénierie des surfaces et lasers – CEA DES ISAS DRMP SRMA LISL – France
[2]Laboratoire d'intégration et de développement des cavités et des cryomodules (LIDC2) – CEA-DRF-IRFU-DACM – France

Résumé

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1 Abstract

The depletion of the worldwide reserves of conventional mining ores (1), (2) calls for developing alternative methods to collect strategic materials from non-conventional resources. The extraction of dissolved elements from natural waters is promising in view of the huge amounts possibly available. For example, there is more than 4.5 billion tons of uranium dissolved in oceans and seas (1)–(3). Several techniques can be used to extract dissolved elements. Among them, electrochemical extraction is an interesting approach because it combines chemical sobriety, reversibility, and limited impact on water quality after extraction (3). Currently, electrochemical metal collection is limited by the electrode surface and reactivity. In contrast, the development of additive manufacturing allows the fabrication of complex structures with a controlled porosity and a high surface area (4), thereby improving the flow and interaction of the electrolyte with the electrode surface. Moreover, the hybridization of additive manufacturing with Atomic Layer Deposition (ALD), which is a thin coating deposition technique, permits to functionalize the surface of the electrodes, enhancing the reactivity of the surface and increasing the electrode durability (5).

Laser-Power Bed Fusion (L-PBF) was used to fabricate porous, 3D and architected electrodes, with a large reactive surface and a lattice structure for improved solution stirring and mixing in a flow-by electrochemical system (Figure 1 a-b). The electrode was coated with Atomic Layer Deposition (ALD), which allows to deposit coatings even in the smallest pores of the electrode.

Electrochemical study of a hexacyanoferrate solution was performed to characterize and optimize the system. Hexacyanoferrate was chosen because its electrochemical behavior is well known. Then, electrochemical tests were carried out with a uranium solution, the solution of interest. First, electrochemical characterization is a cyclic voltammetry to characterize the behavior of the electrodes (Figure 2) between -0.5 and 0.5 V. Subsequently, chronoamperometric analysis was used to study uranium recovery, at a fixed potential and pH. The outcoming electrolyte is characterized by Inductively Coupled Plasma (ICP) to quantify the U(VI) reduced to U(IV) by electrodes. The results are compared to those of a flat and polished electrode made by L-PBF (Figure 1 c), used as a reference, to show the benefits of architected and/or functionalized electrodes.

*Intervenant

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