



Electrochemical formation of Mg–Lu alloy and alloy layer in molten LiCl–KCl



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ABSTRACT

In the present work, the electrochemical behaviors of Lu (III) ions in molten LiCl–KCl and LiCl–KCl–MgCl₂ were investigated by cyclic voltammetry, square wave voltammetry, and chronopotentiometry, respectively. Galvanostatic electrolysis was conducted on a molybdenum electrode to prepare the Mg–Lu alloys, while potentiostatic electrolysis was conducted on a magnesium electrode to prepare the Mg–Lu alloy layers. The microstructure and microzone analysis of the obtained deposits were characterized by XRD and SEM–EDS. An intermetallic compound of MgLu was formed by galvanostatic electrolysis, whereas two kinds of intermetallic compound (Mg₂₄Lu₅ and MgLu) and Lu metal in the alloy layer.

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1. Introduction

Today, the pyrochemical processes based on molten salts electrochemistry are becoming a more important and promising approach for lanthanides/actinides separation in spent nuclear fuel, because of the radiation resistant, thermal resistant and high solubility of molten salts [1,2]. The mass of lanthanides is ten times higher than actinides [3]. After the selective extraction of actinides, the extraction of lanthanides for decontamination of the salt will be performed [1].

In the past few years, several studies on the electrochemical behaviors, separation and formation of alloys and alloy layers of lanthanides and actinides have been performed [4–20]. It's found that aluminum could serve as the most effective metallic solvent for lanthanides and actinides extraction. Besides aluminum, magnesium and lanthanides/actinides can also interact strongly and yield intermetallic compounds.

Some researchers have done some beneficial attempt to the co-reduction of magnesium and other metal ions [21,22]. Bermejo et al. [23] investigated the electrodeposition of Lutetium on tungsten and aluminum electrodes. They found that the

electroreduction of Lu (III) would proceed in a single step. Furthermore, the diffusion coefficient of Lu (III) was determined by chronopotentiometry according to the Sand equation. The preparation of Mg–Li–Er alloys was performed by co-deposition in the molten LiCl–KCl–MgCl₂ [24].

Production of pure magnesium and lanthanide metals by electrolysis is a high energy-consuming process. Furthermore, the traditional approach for the preparation of Mg–RE alloy is principally based on pyrometallurgy, which is another high energy-consuming process. As such, molten salts electrolysis is a promising technology for the co-reduction of Mg and rare earth ions to prepare Mg–RE alloys in one step with energy-saving and cost-saving. In general, with a high current density, lithium could also be reduced with the Mg–Lu alloy under galvanostatic electrolysis. Addition of lithium will improve strength, toughness and stiffness of ternary alloy, which is desirable [25]. Lutetium is a heavy lanthanide which can absorb the neutrons and prevent the transmutable actinides to capture neutron, and reduce the efficiency of transmutation [26].

Thus, it is of great importance to investigate the electrochemical behavior of Lu (III) in LiCl–KCl melts. However, the electrochemical behavior, the formation mechanism of Mg–Lu alloy as well as alloy layer, and some other properties have not yet been clarified. It is significant to expand the basic knowledge of Lu electrochemistry and to separate Lu from spent fuels.

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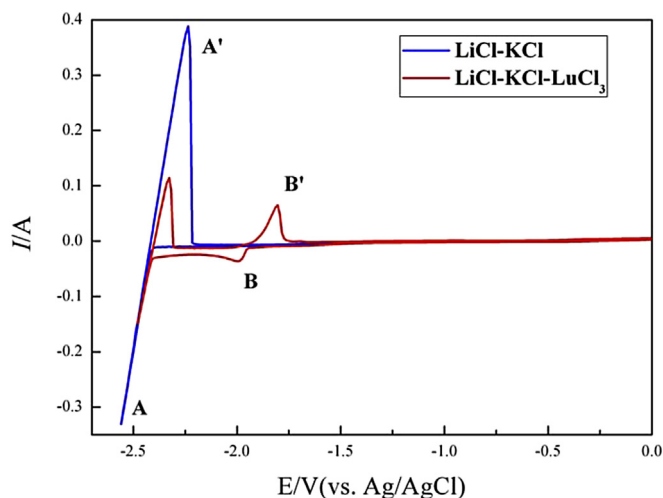


Fig. 1. CVs of the LiCl–KCl melts before (blue curve) and after (red curve) the addition of 2 wt. % LuCl₃ on a Mo electrode ($S = 0.322 \text{ cm}^2$) at 873 K. Scan rate: 100 mV s^{-1} . (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

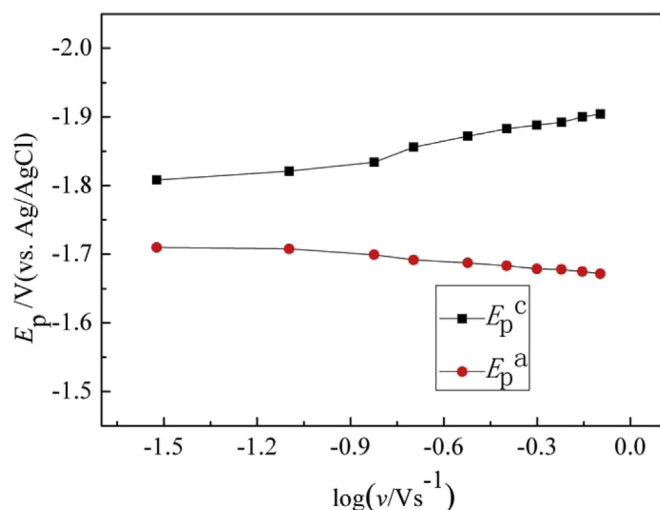


Fig. 4. Relationship of the cathodic potentials (E_p^c) and anodic peak potentials (E_p^a) with the logarithm of the sweep rate ($\log v$) at 873 K.

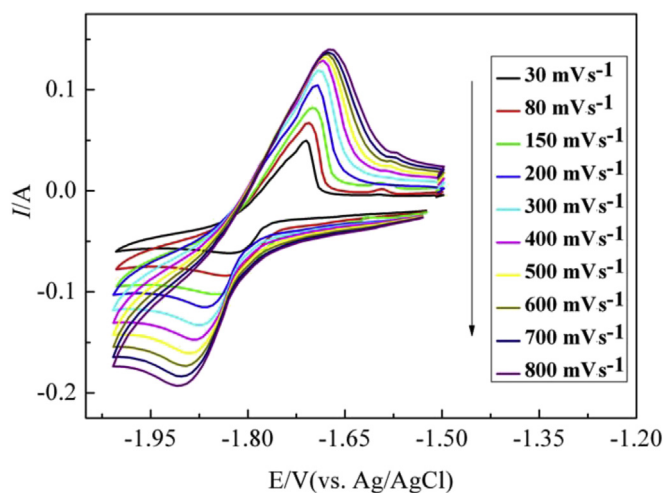


Fig. 2. CVs of the LiCl–KCl-(2 wt. %) LuCl₃ melts on a Mo electrode ($S = 0.322 \text{ cm}^2$) at 873 K at different scan rates.

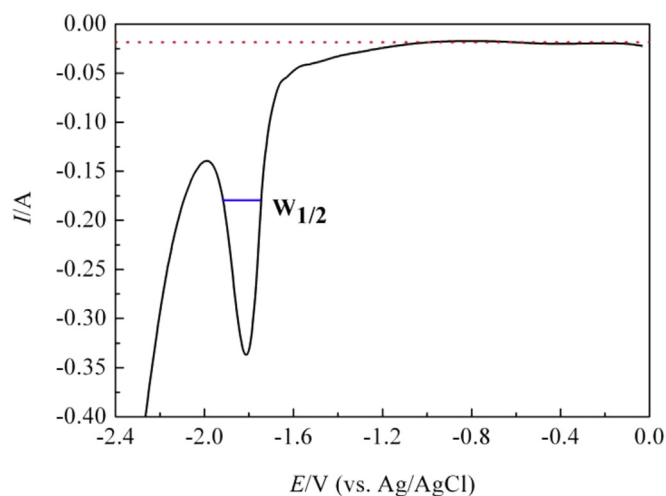


Fig. 5. Square wave voltammogram of the LiCl–KCl-(2 wt. %) LuCl₃ melts on a Mo electrode ($S = 0.322 \text{ cm}^2$) at 873 K. Pulse height: 25 mV; Potential step: 1 mV; Frequency: 10 Hz.

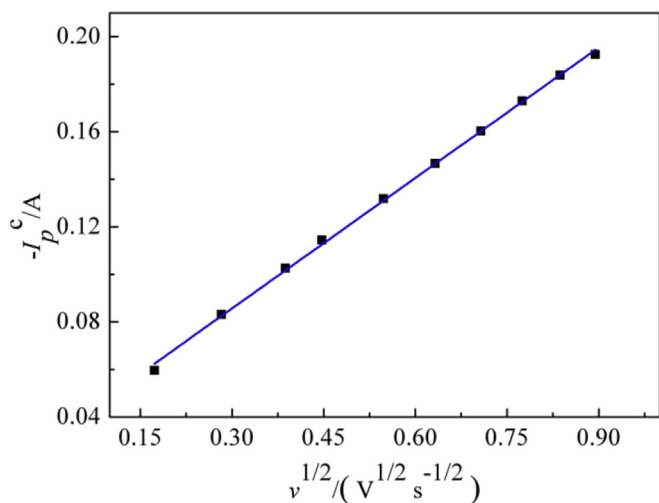


Fig. 3. Linear relationship of Lu(III) cathodic reduction peaks current (I_p^c) vs the square root of the potential scanning rate ($v^{1/2}$) on a Mo electrode ($s = 0.322 \text{ cm}^2$) in the LiCl–KCl-(2 wt. %) LuCl₃ melts at 873 K.

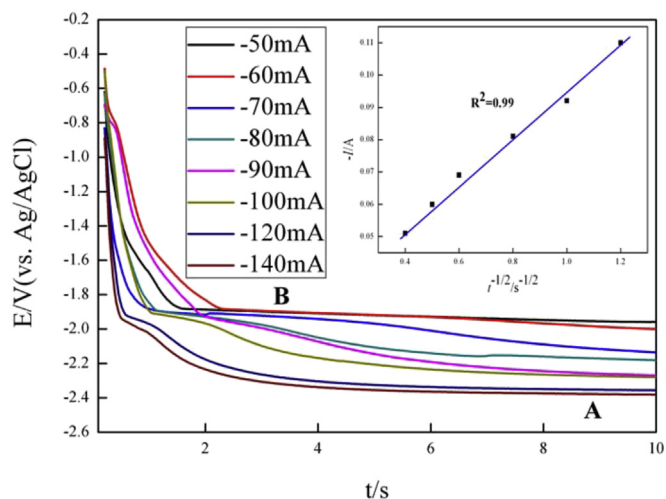


Fig. 6. Chronopotentiogram curves of the molten LiCl–KCl-(2 wt. %) LuCl₃ melts on a Mo electrode ($S = 0.322 \text{ cm}^2$) at 873 K at different current intensities. Inset: Relationship of the square root of transition time ($\tau^{1/2}$) and current intensity ($-I$).

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