Mo/TiN novel composite powder for an alkali metal thermal to electric converter (AMTEC) electrode

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Up till now, thin and porous Mo electrodes have shown the best performance as AMTEC electrodes [1-4]. This result is due to the formation of Na-Mo-O compounds, which might be responsible for the enhancement of Na transport through the Mo electrode. However, from the work of Williams et al. [4], it is confirmed that this compound evaporated at temperatures above 800 °C, resulting in the degradation of the electrode performance. To develop better electrode materials for use at high temperatures, Nakata et al. [5] investigated the reactivity of a ceramic electrode with liquid sodium, and TiN, TiC, NbN and NbC were considered as candidates for the AMTEC electrode material [5,6]. Although TiN and TiC can be used for the AMTEC electrode, Mo is the best material by far in terms of the electrochemical performance and the activity with a Na vapor [6].

Thus, the aim of this research is to achieve an AMTEC electrode with high electrochemical performance and microstructural stability at high temperatures using a Mo/TiN composite powder. The Mo/TiN composite powder offers the following advantages: (1) microstructural stability – sintering of the metallic (Mo) phase is controlled by the conjugated ceramic (TiN) phase, (2) high interfacial affinity with the BASE – wet processes (screen printing, dip-coating, etc.) can be used for electrode coating, (3) self-assembly of a porous microstructure without using a pore-former, (4) mixed homogeneity and (5) TiN and Mo supplementing effects.

Mo/TiN composite powder has been synthesized by a Pechini-type polymerizable complex method that uses ethylenediaminetetraacetic acid (EDTA) as a chelating reagent and ethylene glycol (EG) as a polymerization precursor. A commercial titanium nitride (TiN, Aldrich) was used as a support, i.e. a core material, and molybdenum shells were synthesized from ammonium molybdate ($(NH_4)_6Mo_7O_{24}\cdot 4H_2O$), Aldrich) aqueous polymeric solution.

The composite powder is primarily composed of submicron (≒ 400~800 nm) particles that are crystallized on a core (> 3~5 μm) particle surface and was successfully synthesized by a sol-gel method with EDTA as the chelating reagent. The interfacial affinity between the alumina substrate and Mo/TiN composite electrode is significantly improved compared with that of the Mo electrode (Fig. 1). The electrode made from the Mo/TiN composite powder exhibited high electrical conductivities of 1000 Scm^{-1} at 300 °C and 260 Scm^{-1} at 700 °C, even with a reduced Mo content (50 vol%) (Fig. 2). The Mo/TiN composite electrode exhibited excellent tolerance against grain growth at elevated temperatures. The average growth rate of the Mo grains in the Mo/TiN composite electrodes was controlled and less than 0.5 %/time (0.62 → 0.65 μm), while the growth rate in the Mo electrodes was 306.7 %/time (0.24 → 3.92 μm) during the thermal cycling tests. From these results, it can be concluded that the Mo/TiN composite powder has very effective electrical properties and high-temperature stability.

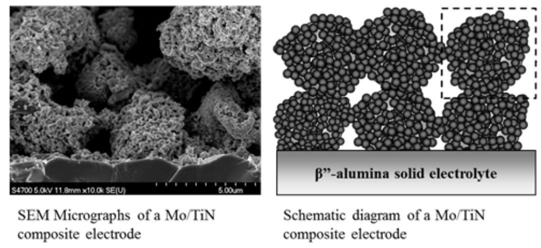

Fig. 1. SEM micrographs and Schematic diagram of Mo/TiN composite electrode for AMTEC.

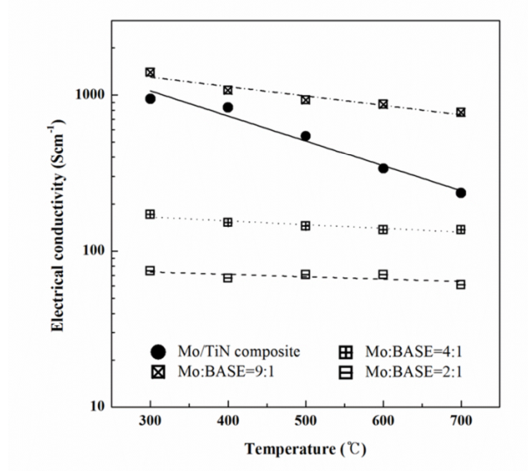

Fig. 2. Electrical conductivity of the electrodes as a function of temperature.

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