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Transparent SiN_x thin-film anode for thin-film batteries by reactive sputtering at room temperature

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HIGHLIGHTS

- Exploration of transparent SiN_x thin films by reactive sputtering at RT.
- The capacity of $SiN_{0.85}$ thin films is 1018 mAh/g.
- The capacity retention of $SiN_{0.85}$ thin films is 95.4% after 100 cycles.
- Transmittance of $SiN_{0.85}$ thin film exhibits 88%.

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ABSTRACT

Silicon is extensively researched as an substitute for carbon as the anode material in Li-ion batteries. However, the cycle life of Si is very short because of its high volume expansion. Herein, we propose SiN_x deposited by radio frequency reactive sputtering at room temperature as an anode material. Sputtering presents the advantage of being easily applicable to fabricate all-solid-state thin film batteries. In this study, we use a Si target and explore the deposition conditions, and the compositions of the SiN_x thin film are confirmed by X-ray photoelectron spectroscopy analysis. The $SiN_{0.85}$ thin film shows an initial discharge capacity of 1018 mAh g^{-1} and capacity retention of 95.4% after 100 cycles, thus exhibiting stable performance. In addition, the transmittance of the $SiN_{0.85}$ thin film on the glass substrate is 88% in the visible region (400–800 nm). Meanwhile, on the transparent conducting electrode, the transmittance before and after lithiation is 80% and 55% in the visible region, respectively. These results demonstrate that the $SiN_{0.85}$ thin film, which can be used as the anode of transparent thin-film batteries, can be fabricated using reactive RF magnetron sputtering at room temperature.

1. Introduction

Over the last decade, there has been significant research on transparent devices, including transparent batteries [1–3]. For example, researchers have fabricated transparent batteries using grid-shaped electrodes [2–4]. The transparency of the battery can be increased by decreasing the grid-line width to be lower than the resolution of the human eye. However, because some components of a battery are not transparent, researchers have been attempting to develop a larger variety of transparent materials for batteries. Most studies that focused on attaining a cathode with high transmittance have used olivine-based materials [5,6]. These materials have a wide band gap, which makes them excellent candidates for cathode materials in a transparent battery.

For anode materials, $Li_4Ti_7O_{12}$ (LTO) has been investigated because it has a wide band gap [7,8]. However, the transmittance of LTO-based batteries is known to change because the color of LTO changes during the discharge process. For example, Roeder et al. reported a battery with a high transmittance before charge–discharge, but its transmittance decreased owing to Li intercalation during discharge [7].

Abbreviations: RF, radio frequency; LTO, $Li_4Ti_7O_{12}$; XPS, X-ray photoelectron spectroscopy; UV–Vis, ultraviolet–visible; SEI, solid-electrolyte interphase; XRR, X-ray reflectivity

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