

Porous ceramic solid electrolyte for Na⁺ ion batteries.

Auteur : Roni, Md Rafiul Alam

Promoteur(s) : Job, Nathalie

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DEVELOPMENT OF POROUS SOLID CERAMIC ELECTROLYTE SCAFFOLD FOR SODIUM ION BATTERIES

Summary of the report

Md Rafiul Alam RONI

**Thesis presented for obtaining the master's degree in
Chemical and Materials engineering**

**Supervisor:
Prof. Nathalie Job**

Owing to growing energy demand, safety issues originating from liquid electrolytes, and awareness of the critical elements used in lithium-ion batteries, research in sodium all-solid-state batteries is gaining significant attention. This research aimed to investigate the possibility of developing a ceramic electrolyte scaffold with unidirectionally oriented pore for sodium-ion batteries. In addition, the possibility of obtaining an electrolyte structure with a controlled pore diameter was investigated. The templating method was used to synthesize the porous electrolyte scaffold, where two different types of wood (balsa and cedar) were used as the template. The electrolyte material used in this experiment was NASICON (sodium superionic conductor)-type $\text{Na}_{3.4}\text{Zr}_2\text{Si}_2.4\text{P}_{0.6}\text{O}_{12}$ (NZSP).

The experimental procedure included preparing the carbon template from the wood, infiltration of ceramic slurry into the carbon template, and sintering of the infiltrated carbon template. At first, the wood was cut in the radial direction with a thickness of 1 mm to open the porous microstructure. This wood disc was then pyrolyzed in argon (Ar) to prepare the carbon template. After the template was prepared, a NZSP ceramic slurry was prepared with a 25 wt% solid content. This slurry was then infiltrated into the carbon template. After infiltration, the infiltrated templates were sintered in the air, where the carbon template oxidized, leaving only the NZSP ceramic. Two different infiltration methods were performed. On the one hand, the ceramic slurry was dropped on the carbon template under atmospheric pressure conditions. On the other hand, the infiltration was performed in a vacuum (20000 Pa). The vacuum infiltration proved to be fruitful in infiltrating the ceramic particles within the carbon template. Moving onward, the slurry composition was optimized with successive experimental trials. In this work, mainly the binder (PVB) content was adjusted during the optimization of the slurry, keeping the overall wt% constant at 25 wt%. Finally, the composition with a 5 wt% binder and a 25 wt% overall solid content proved to be useful in successfully synthesizing the intended porous electrolyte structure. After sintering, the pore diameter was 5–15 μm , and the void fraction was 30%–40%. This illustrates the possibility of obtaining microstructures with different pore diameters according to the intended goal. This novel architecture promises the possibility of facilitating the complete loading of active materials into the electrolyte, enhancing electrolyte/electrode interfacial contact, and significantly reducing the ion migration pathway. The microstructural image of the sintered NZSP ceramic is presented below in Figure 1.

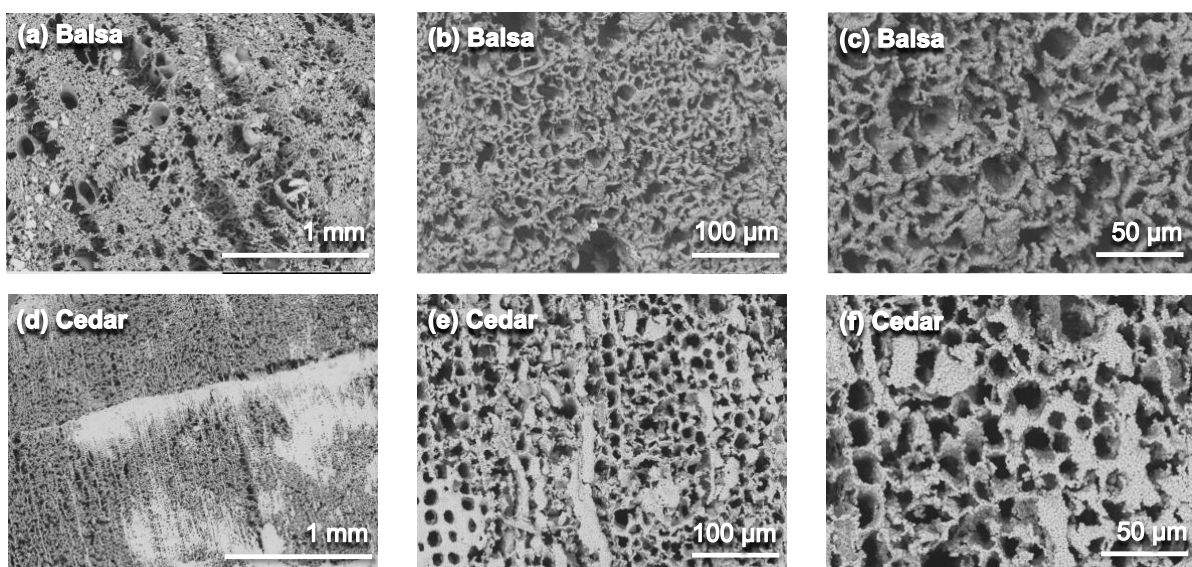


Figure 1: Sintered ceramics after two infiltrations using the slurry with 5 wt% binder and 25 Wt% solid content, (a – c) infiltrated balsa template, (d – f) cedar template.