Porous lithium-ion sieves designed for enhanced packing density

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Introduction

•**Lithium ion sieves (LIS)** are promising adsorbents for recovering lithium from **dilute, complex aqueous sources** such as geothermal brines and industrial effluents.

•These sources contain lithium below 2000 ppm, mixed with high levels of competing cations (Na^+, K^+, Ca^{2+}, Mg^{2+}), making selective recovery challenging.

•**LIS powders** offer high surface area and ion-exchange (IX) capacity but **cannot be used directly in continuous-flow columns** due to poor mechanical stability and risk of clogging.

•To enable column applications, **LIS must be shaped** into robust structures (beads, pellets, extrudates, corrugated packings, monoliths) that balance strength, flow, and mass transfer.

•High porosity aids diffusion and kinetics but lowers **packing density**, requiring larger columns. The goal of this work is to **develop and evaluate shaped LIS structures that balance porosity and packing density**, enabling mechanically robust, high-capacity, and scalable column applications.

Methodology

Figure 1. *NIPS of HTO fibers*

•Structuring of H_2TiO_3 LIS was performed using a Nonsolvent-Induced Phase Separation (NIPS) methodology,

- •LTO powder was blended with a PVC/NMP solution until a paste-like consistency was obtained.
- •The paste was extruded through a nozzle and cut in a water bath to form ~1 cm fibers.
- •Fibers were washed with water and the LTO converted to HTO by acid treatment.

•The beads and fibers have finger-like and fiber/sponge-like pore structures respectively.

• The fibers have enhanced packing density compared with that of the beads. (0.36 g/cm³ vs. 0.22 g/cm³ in earlier versions).

•The structured titanium based LIS were tested for Li^+ uptake in a batch setup where aliquots were collected at different times and analyzed by ICP-OES.

Results

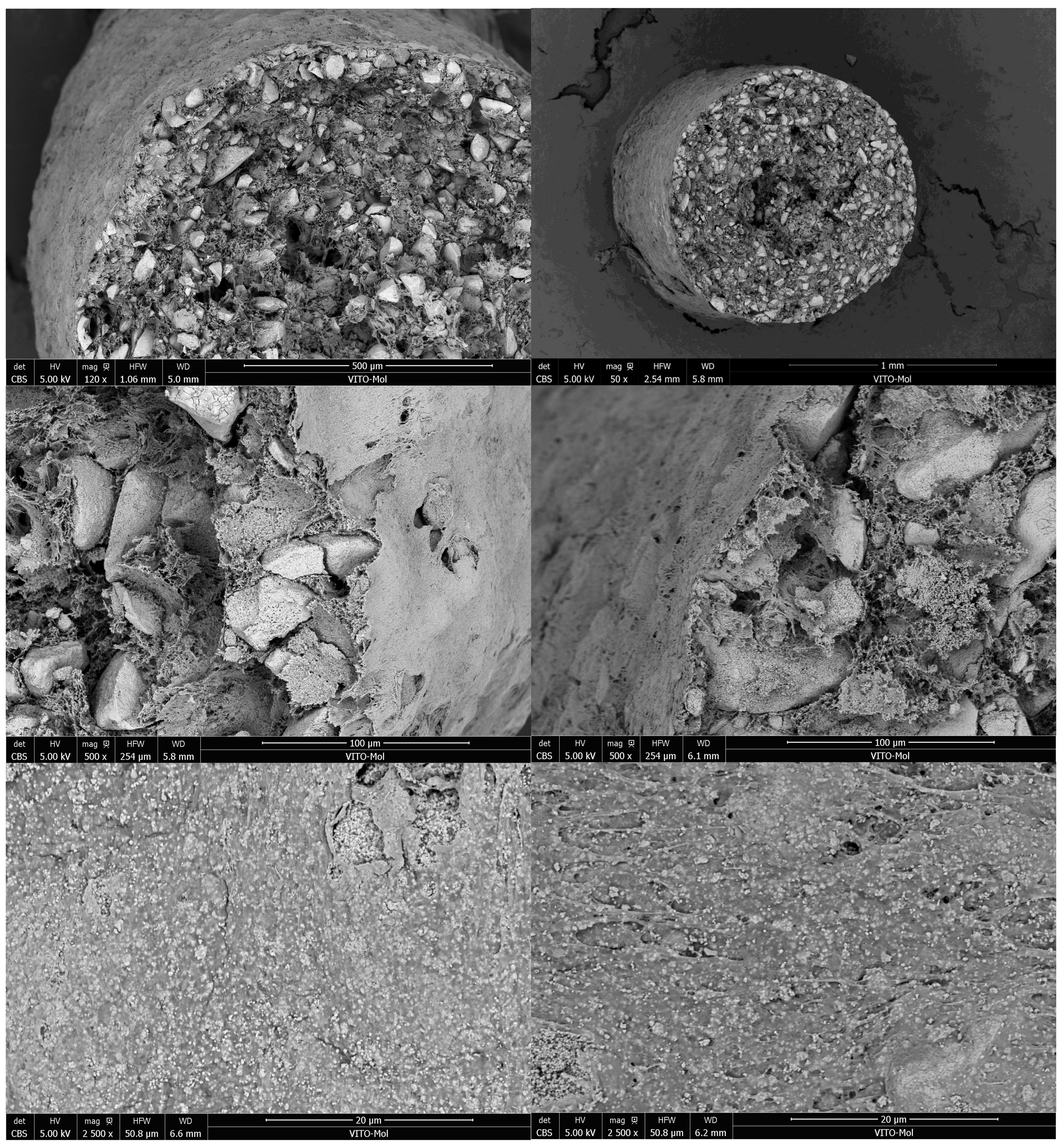

Figure 2. *SEM images of fibers extruded by NIPS using a 1600 µm nozzle (top) and a 600 µm nozzle (bottom). The cross-sectional views (left) reveal a central void and poorly defined, sponge-like porous structures (middle). Surface images (right) further show the absence of macroporosity.*

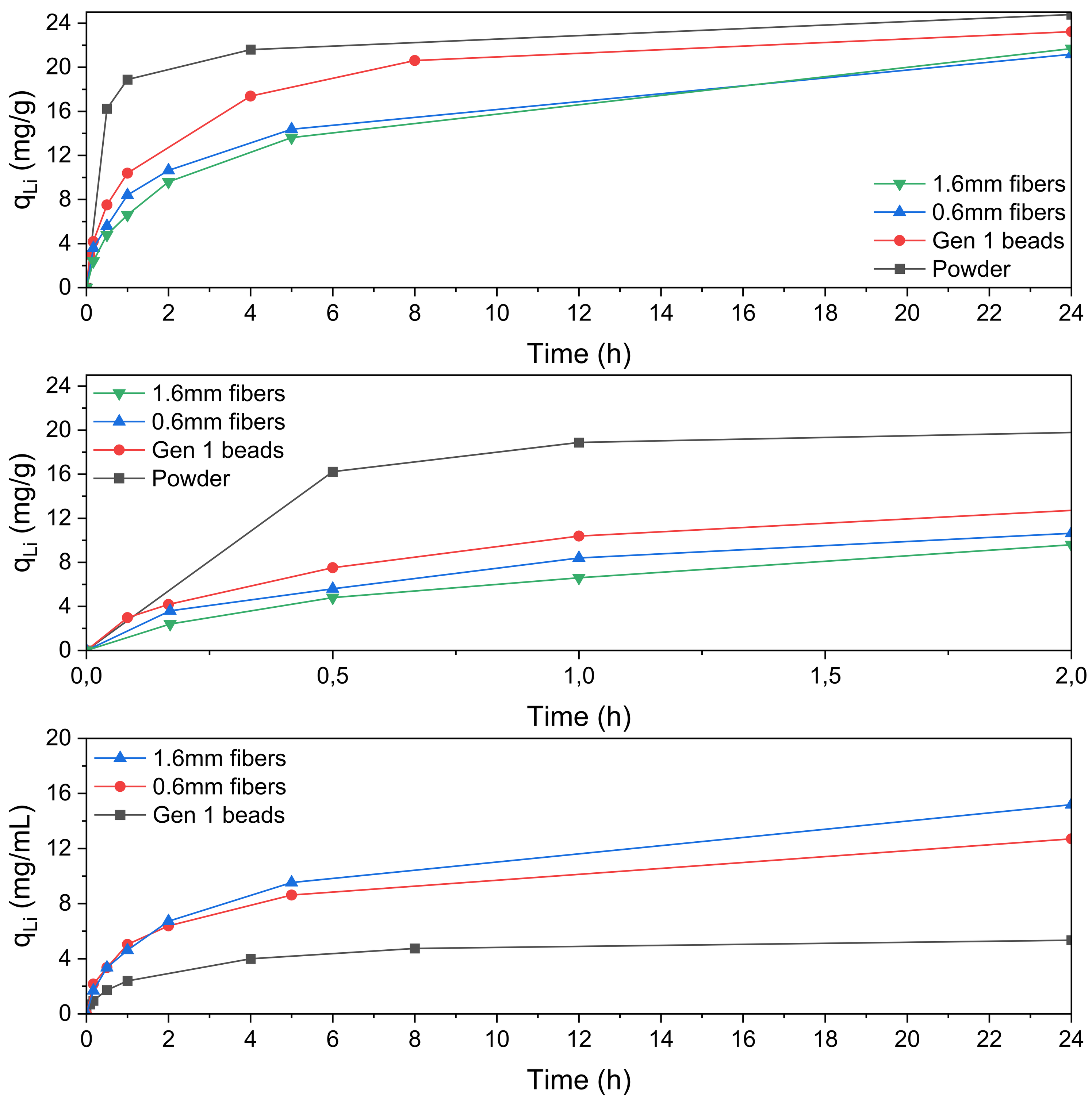

Figure 3. *Adsorption kinetics of powder, dense printed fibers, and SoA beads (Gen 1 beads). The powder reach maximum capacity within 1 h, while structured materials show slower uptake but similar behavior in short cycles (top and bottom graphs). When expressed per column volume (bottom graph), dense fibers surpass Gen 1 beads, highlighting their potential to boost working capacity and industrial productivity at low CAPEX.*

Conclusion and Outlook

•The denser materials developed in this work can **double the column capacity**, as demonstrated experimentally.
•Their performance still falls short of state-of-the-art beads, likely due to **diffusion limitations** preventing full capacity within comparable times.
•Further efforts will focus on **translating these materials into 3D-printed structures** suitable for column applications.
•**Column experiments are planned** to validate dynamic performance under flow-through conditions and to refine shaping strategies for bench- and pilot-scale production.
•This research establishes a pathway toward mechanically robust, high-performance lithium-ion sieves with optimized porosity, improved packing density, and scalable processing for advanced lithium extraction, purification, and concentration.

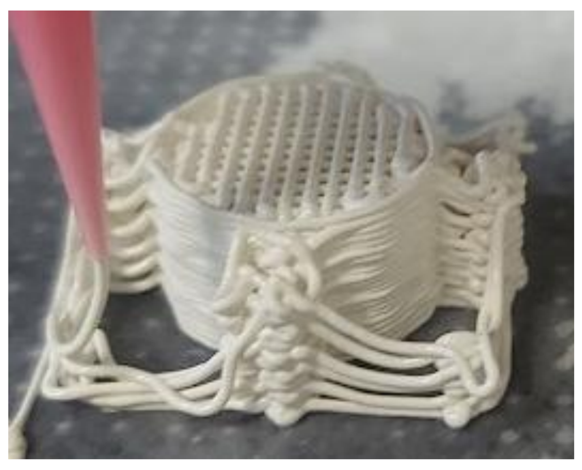

Figure 4. *Structure 3D-printed using the LTO paste.*

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