Ion-hydration-controlled large osmotic power with arrays of angstrom scale capillaries of vermiculite

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Abstract
In the osmotic power generation field, reaching the industrial benchmark has been challenging because of the need for capillaries close to the sizes of ions and molecules [1,2]. Here, we fabricate well-controlled "along-the-capillary" membranes of 2D Na-vermiculite with nanochannel sizes of ~ 5 Å. They exhibit 1,600 times enhanced conductivity compared with commonly studied "across-the-capillary" membranes [3,4]. Interestingly, they show a very high cation selectivity of 0.83 for NaCl solutions, which results in large power densities of 9.6 W/m² and 12.2 W/m² at concentration gradients of 50 and 1,000, respectively, at 296 K, for a large membrane length of 100 µm. The power density shows an exponential increase with temperature, reaching 65.1 W/m² for a concentration gradient of 50 at 333 K. This markedly differs from the classical behaviour and indicates the role of ion (de)hydration in enhancing power density, opening possibilities for exploiting other membranes made of 2D materials for energy harvesting applications.

References

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Figures

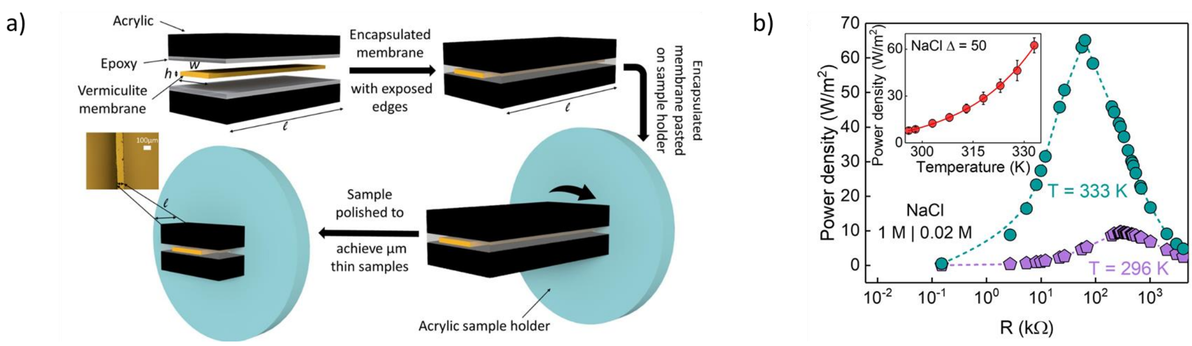

Figure 1: Performance and Fabrication of In-Plane Vermiculite Devices for Osmotic Power Generation. a) Schematic illustration of the in-plane vermiculite device fabrication process for osmotic power generation. b) Power density as a function of external load resistance at T = 296 K and T = 333 K (L ≈ 100 µm). Inset: Exponential increase in power density with temperature.