Niobium Phosphate as Intermediate Temperature Proton Conductors

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Niobium phosphates were synthesized from niobium oxide and phosphoric acid. The existence of proton-containing groups in the phosphates even after heat treatment above 500 ℃ were verified and contribute to the anhydrous proton conductivity of 10^{-2} S cm^{-1} level and higher conductivity under humidification at 250 ℃. Doping another metal ion with a low value such as In^{3+} could improve further the conductivity. The obtained conductors showed acceptable stabilities during test of up to 50 hours under both dry and humidified atmospheres. The good electromotive force results and a stable open circuit voltage of 1.045 V confirmed the protonic nature of the ionic conductivity. The prepared niobium phosphate shows potential as electrolyte material for intermediate temperature fuel cell applications.

Proton confirmation: Fig. 1 indicated that the OH groups could be verified for the Nb phosphates treated at different temperatures. NbP350, NbP500, NbP650 and NbP800 were Nb phosphates from heat treatment of 350 ºC, 500 ºC, 650 ºC and 800 ºC in sequence.

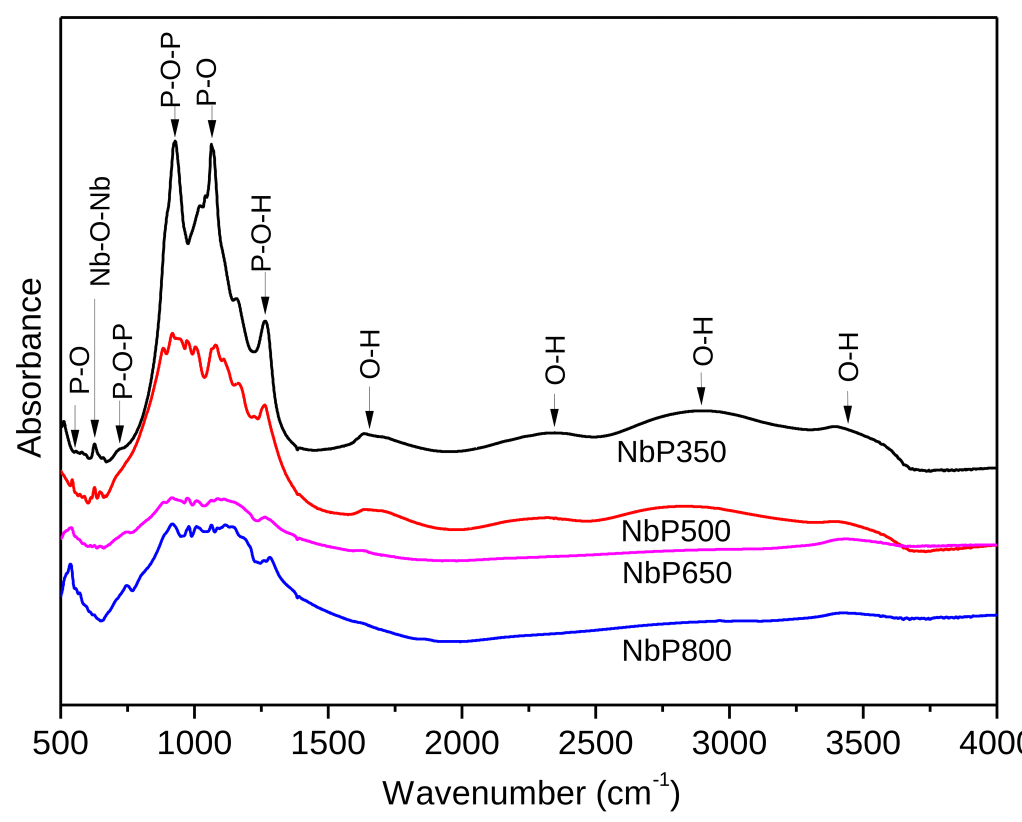

Figure 1: FT-IR spectra of niobium phosphates heat treated at different temperatures as indicated in the figure.

Conductivity: The obtained Nb phosphates exhibited conductivity of 10^{-2} S cm^{-1} level under dry air and higher conductivity under humidification condition at 250 ℃, as shown in Fig. 2. The highest conductivity at total water atmosphere was 0.06 S cm^{-1}.

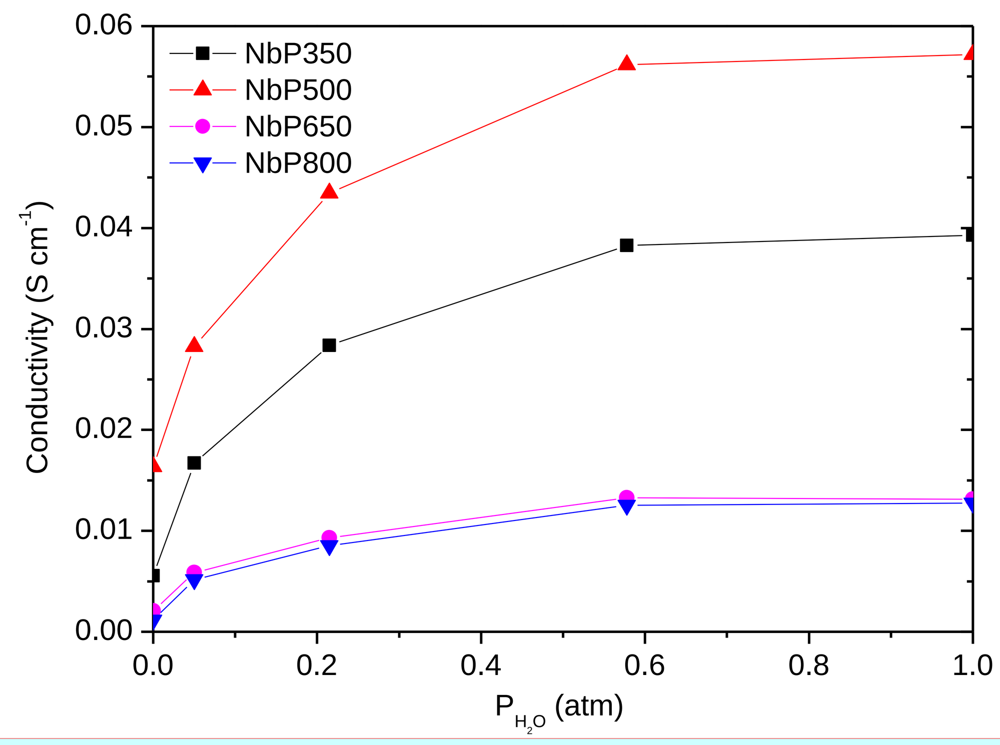

Figure 2: Proton conductivity of Nb phosphates at 250 ℃ as a function of water partial pressure in the ambient pressure air.

Conductivity stability: As shown in Fig. 3, the conductor from higher heat treatment temperature showed a higher conductivity stability. The conductivity stabilities were also compared with SnP_2O_7 based conductors from literature and presented accepted stabilities.

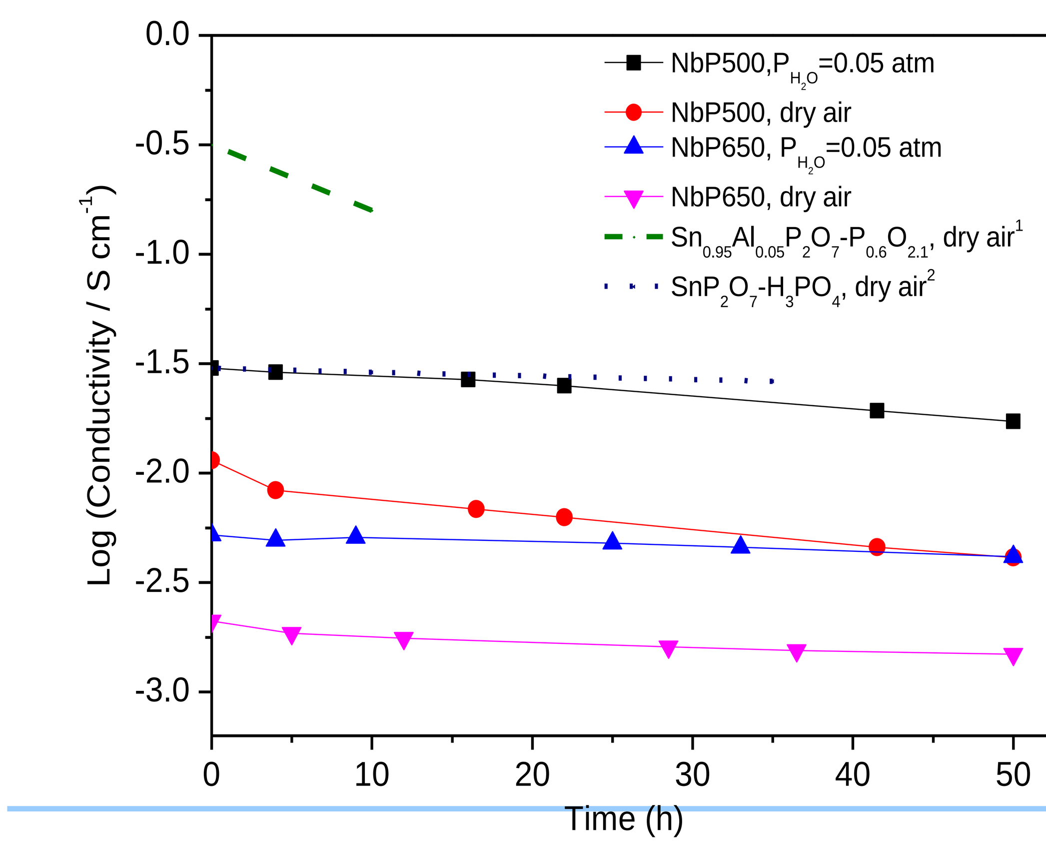

Figure 3: Conductivity stability of NBP500 and NBP650 under dry air and humidified air with the water partial pressure of 0.05 atm at 250 ℃.

In doping: Nb phosphates were also doped with In^{3+} ion. The distinct improvement of conductivity was found as shown in Fig.1 and could attributed to the enhanced formation of OH groups and possible increased proton mobility from the changed crystal structure.

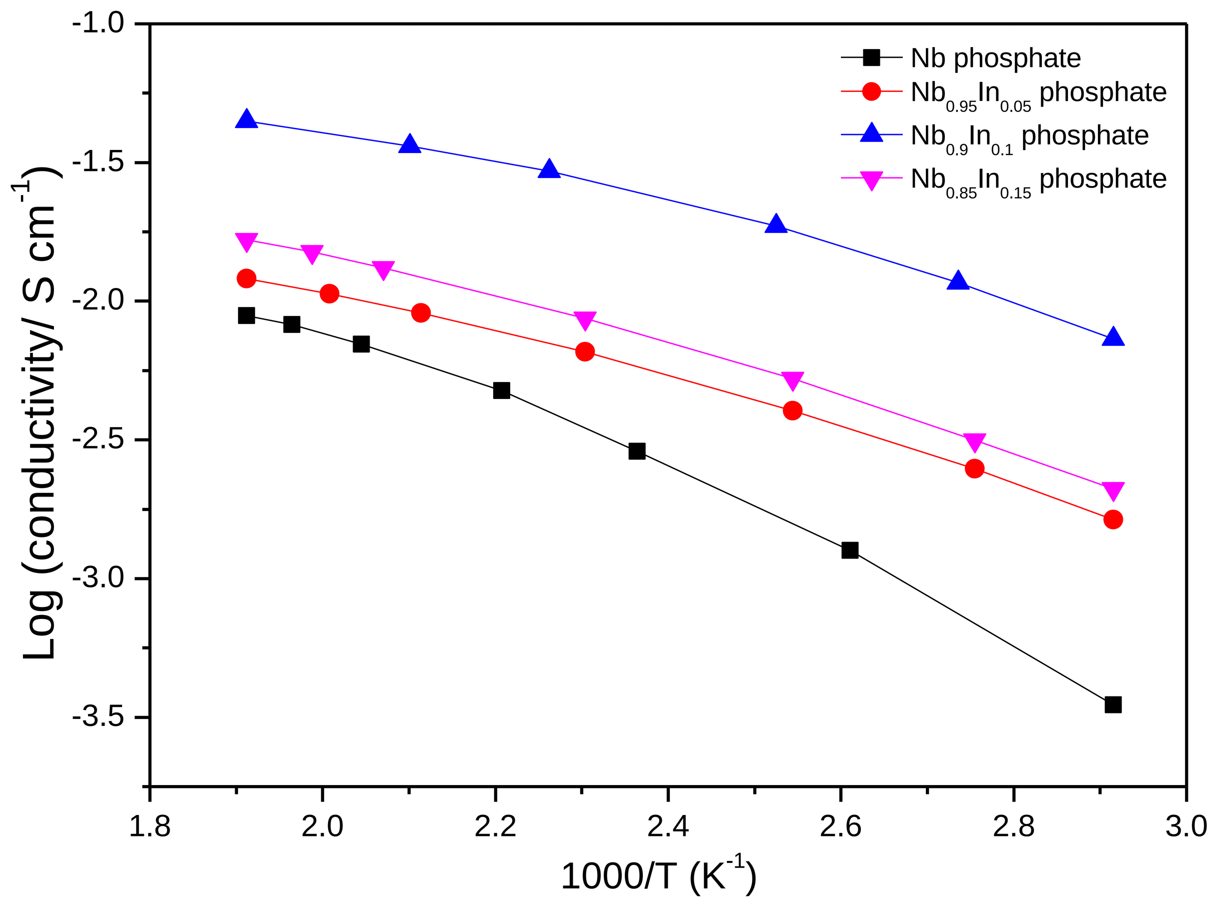

Figure 4: Temperature dependence of conductivity of the obtained In doped and un-doped phosphates under dry air condition.

Open circuit voltage (OCV): the OCV was checked at different temperature. As shown in Fig.5, the OCV was very stable in the 10 hours measurements. The decrease of OCV at elevated temperatures is assumed to be associated mainly with sealing difficulties, and Pt oxidation and a somewhat lower Gibbs energy.

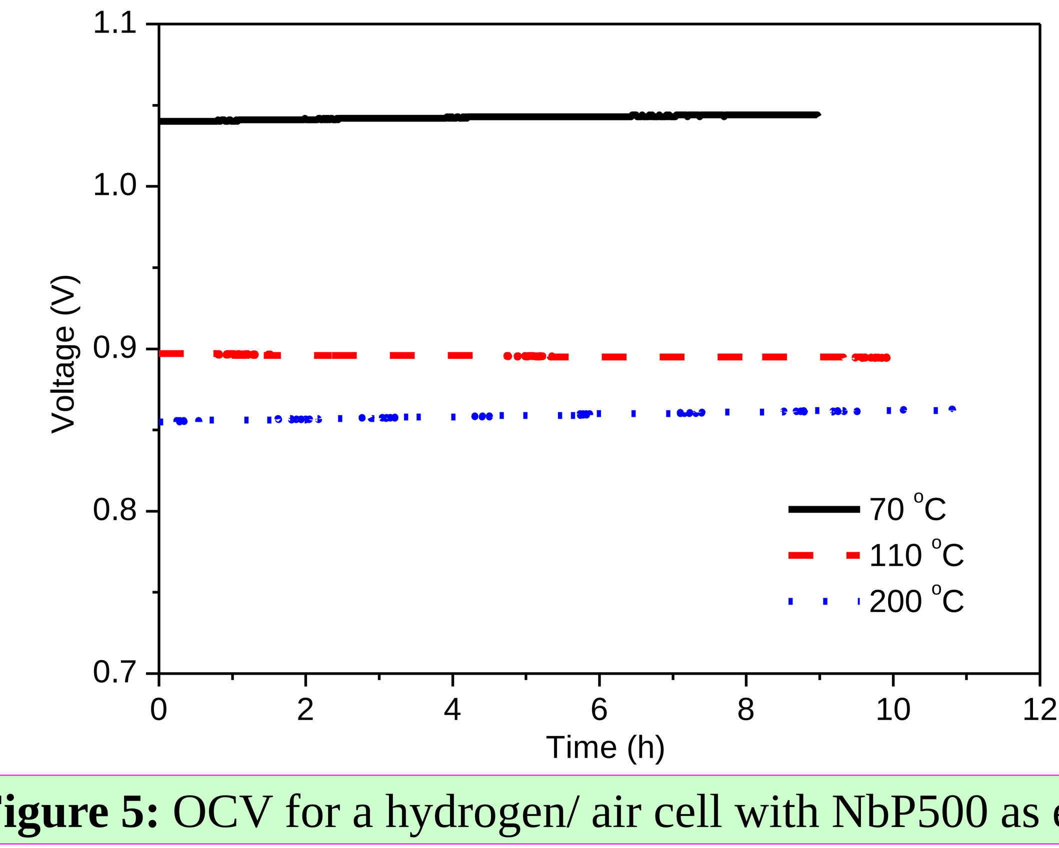

Figure 5: OCV for a hydrogen/ air cell with NbP500 as electrolyte

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References

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