New $Ni_{0.5}Ti_2(PO_4)_3$@C NASICON-type Electrode Material with High Rate Capability Performance for Lithium-Ion Batteries: Synthesis and Electrochemical Properties

Mohammed Srout,[a, b] Nam Hee Kwon,[b] Wen Luo,[d, e] Andreas Züttel,[d, e] Katharina M. Fromm,[b] and Ismael Saadoune*[a, c]

Supporting information

New $Ni_{0.5}Ti_2(PO_4)_3$@C Nasicon-type electrode material with high rate capability performance for Lithium-ion batteries: Synthesis and Electrochemical properties

Mohammed SROUT[a,b], Nam Hee KWON[b], Wen LUO[d,e], Andreas ZÜTTEL[d,e], Katharina M. FROMM[b], Ismael SAADOUNE[a,c]

[a]*LCME, Faculty of Science and Technology- Cadi Ayyad University, Av. A. El Khattabi, P.B..549 Marrakesh, Morocco*

[b]*University of Fribourg, Department of Chemistry, Chemin du Musee 9, CH-1700 Fribourg, Switzerland*

[c]*Materials Science and Nano-engineering, Mohammed VI Polytechnic University, Lot 660-Hay Moulay Rachid, Ben Guerir, Morocco*

[d]*Laboratory of Materials for Renewable Energy (LMER), Institute of Chemical Sciences and Engineering (ISIC), Basic Science Faculty (SB), École Polytechnique Fédérale de Lausanne (EPFL) Valais/Wallis, Energypolis, Rue de l'Industrie 17, CH-1951 Sion, Switzerland*

[e]*Empa Materials Science & Technology, CH-8600 Dübendorf, Switzerland*

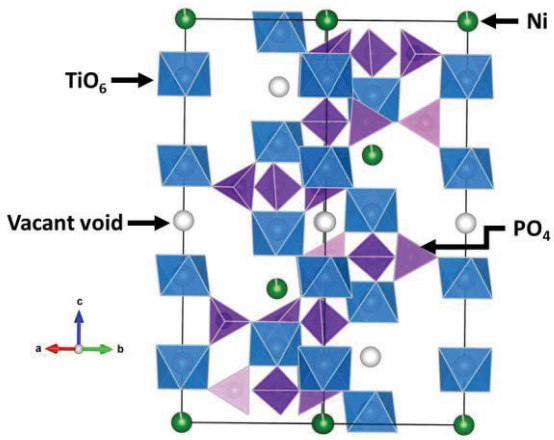

Fig. S1: Schematic crystal structure of the NTP material.

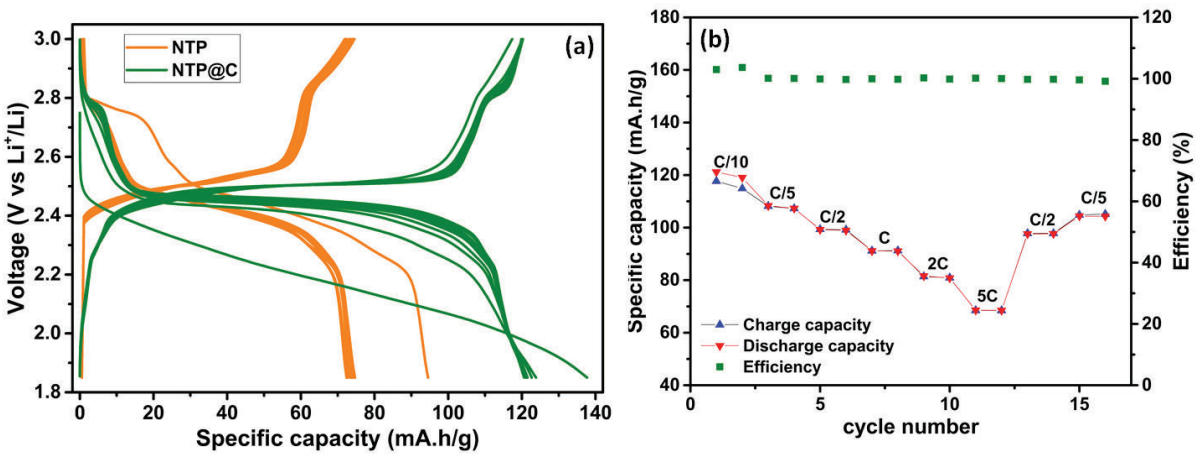

Fig. S2: (a) Galvanostatic performances of the NTP and NTP@C materials at the current rate of 0.5C in the voltage range 1.85-3.0V; (b) Rate performance of the NTP material within the voltage range 1.85 – 3.0 V.

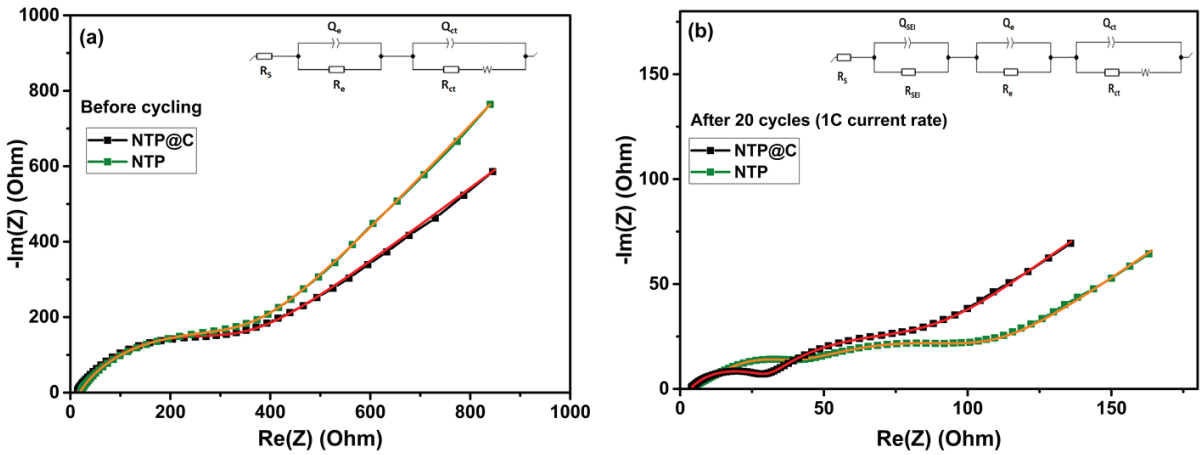

Fig. S3: Nyquist plots of the NTP and NTP@C materials: a) before cycling, b) after 20 cycles in the voltage window 1.85 – 3.0 V (1C current rate).

Table S1: R values of the fitted Nyquist curves of both pristine NTP and carbon coated NTP@C materials before cycling.

SOC	R_s (Ohm)	R_e (Ohm)	R_{ct} (Ohm)
NTP@C	13.23	250.6	11.38
NTP	18.39	290.3	15.56

Table S2: R value of the fitted Nyquist curves of both pristine NTP and carbon coated NTP@C materials after 20 cycles within the voltage range 1.85- 3.0 V (1C current rate).

SOC	R_s (Ohm)	R_{SEI} (Ohm)	R_e (Ohm)	R_{ct} (Ohm)
NTP@C	3.49	38.06	0.09	27.54
NTP	3.38	55.11	8.76	35.19

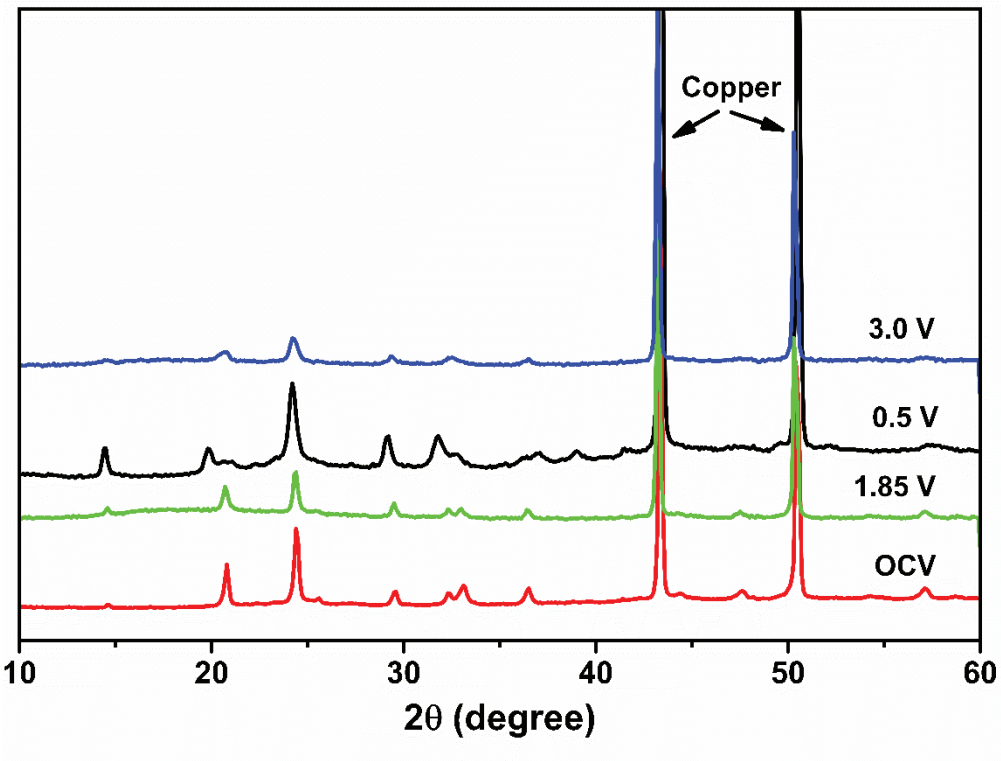

Fig. S4: Ex-situ XRD at different states of charge and discharge.

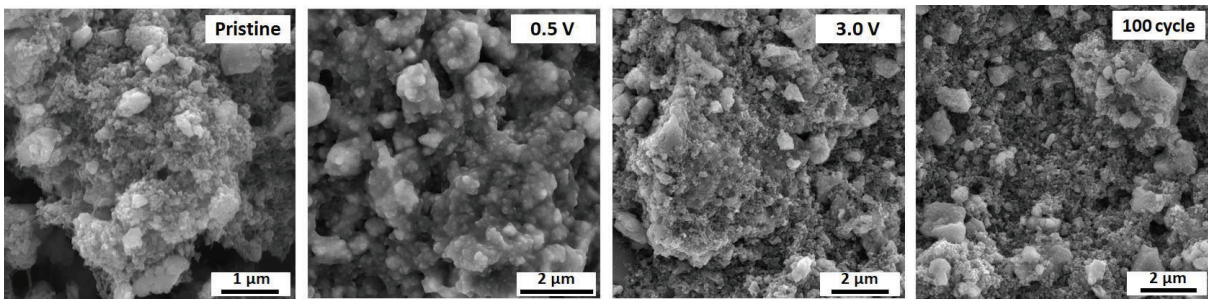

Fig. S5: Comparative SEM images of the NTP@C electrodes: before cycling (pristine), after discharge to 0.5V, After one cycle 3.0 V (discharge to 0.5 and charge back to 3.0 V), and after 100 cycles in the voltage range 1.85-3.0 V (current rate of 20C).

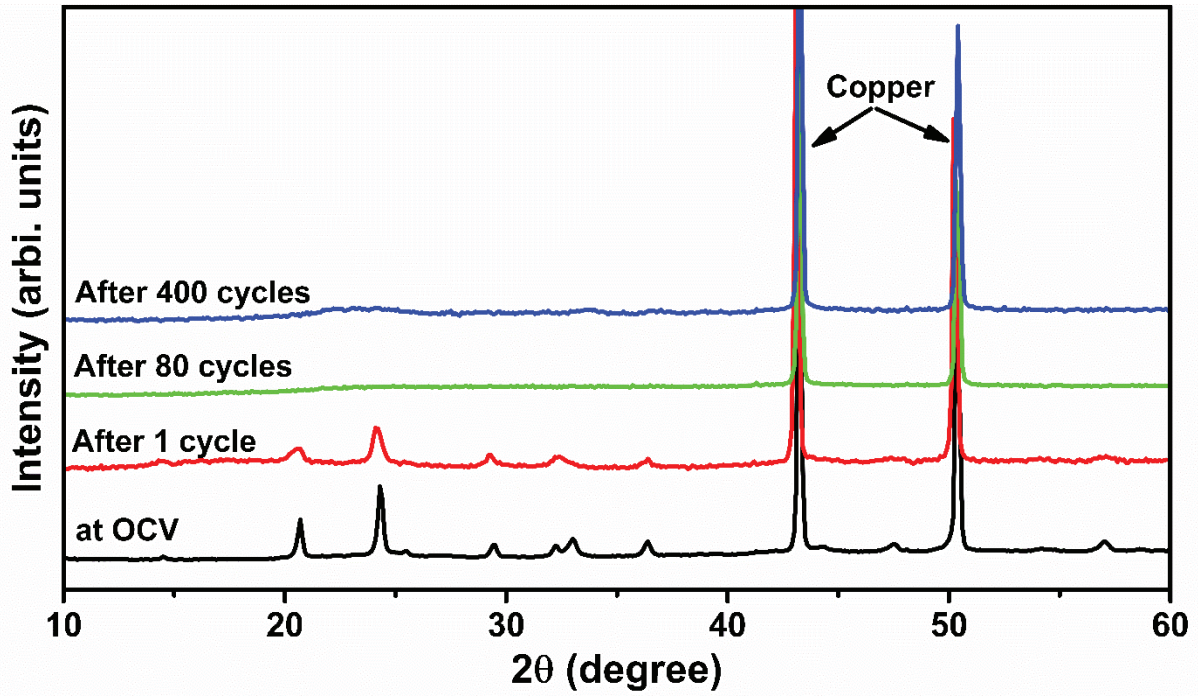

Fig. S6: XRD of the NTP@C electrode at the OCV, after 1 cycle at a current rate of 0.1C, after 80 cycles at the current rate of 0.5C, and 400 cycles at the current rate of 5C, in the voltage range 0.5-3.0V.

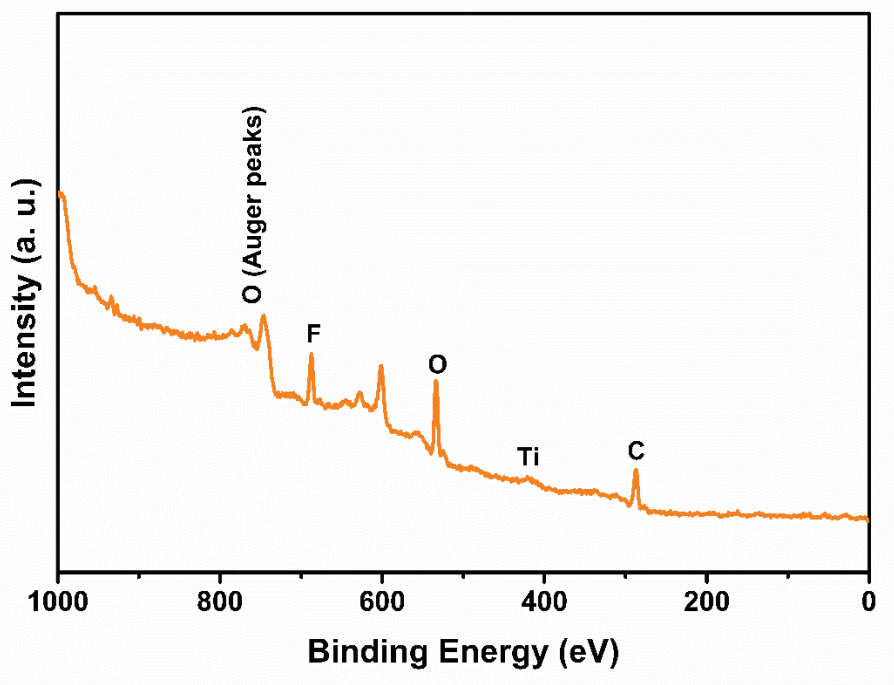

Fig. S7: XPS spectra of the NTP@C material after one cycle in the voltage range 0.5-3.0 V (current rate 0.1C).

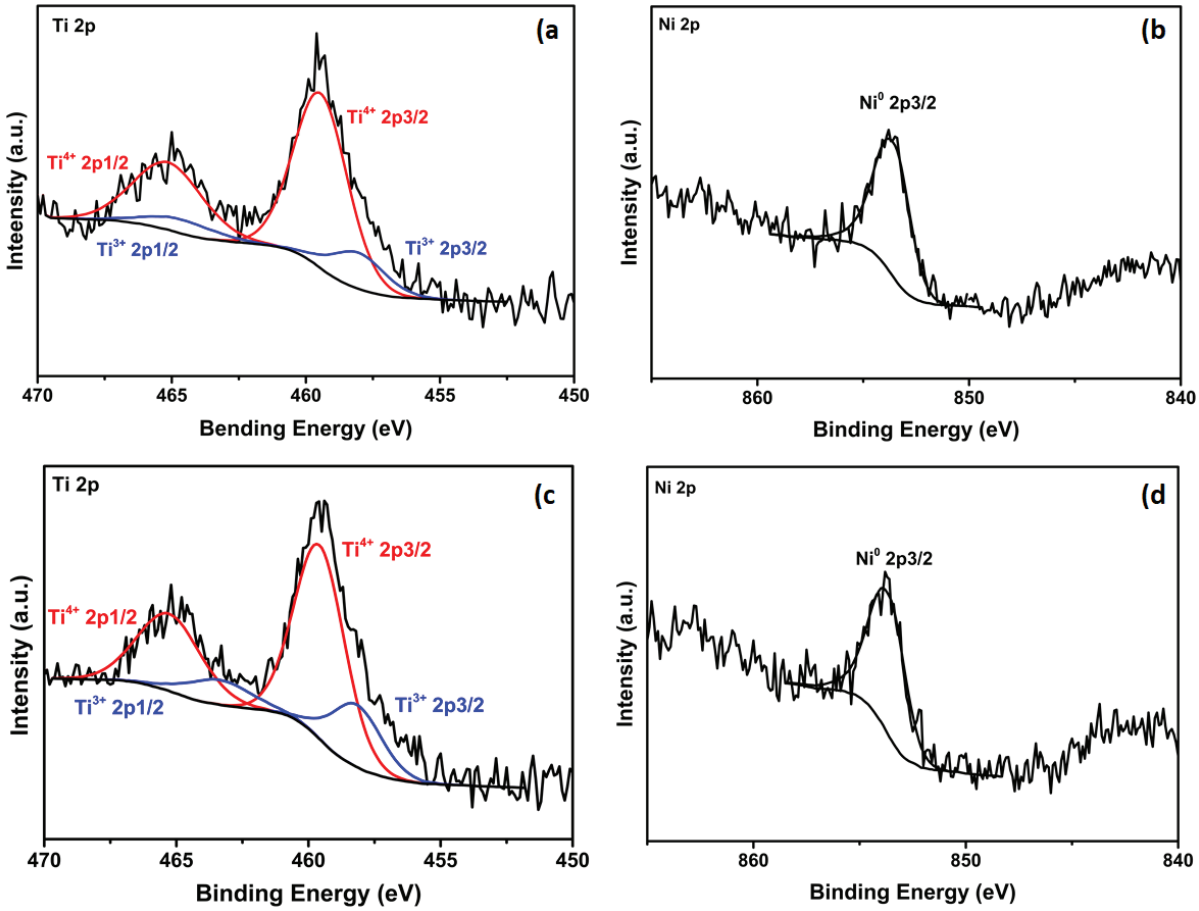

Fig. S8: XPS data of Ti2p and Ni2p at the OCV (a) & (b), and after 1 cycle (c) & (d) within the voltage window 0.5-3.0V.

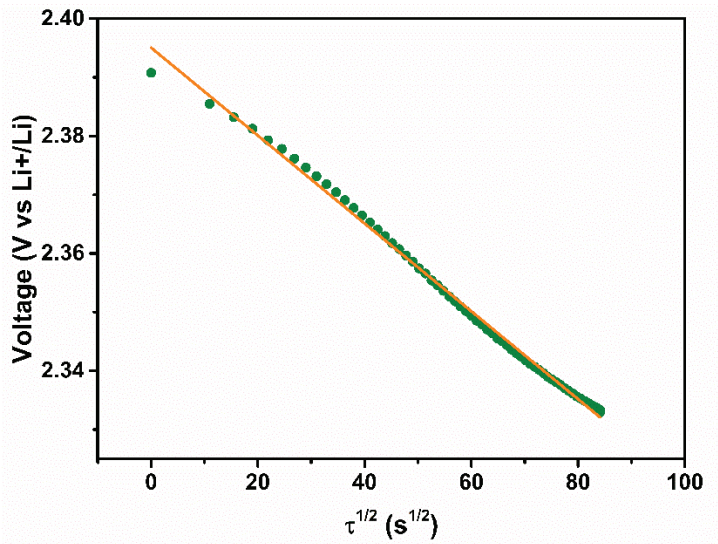

Fig. S9: Plot of voltage V vs $\tau^{1/2}$ showing the linear fit.

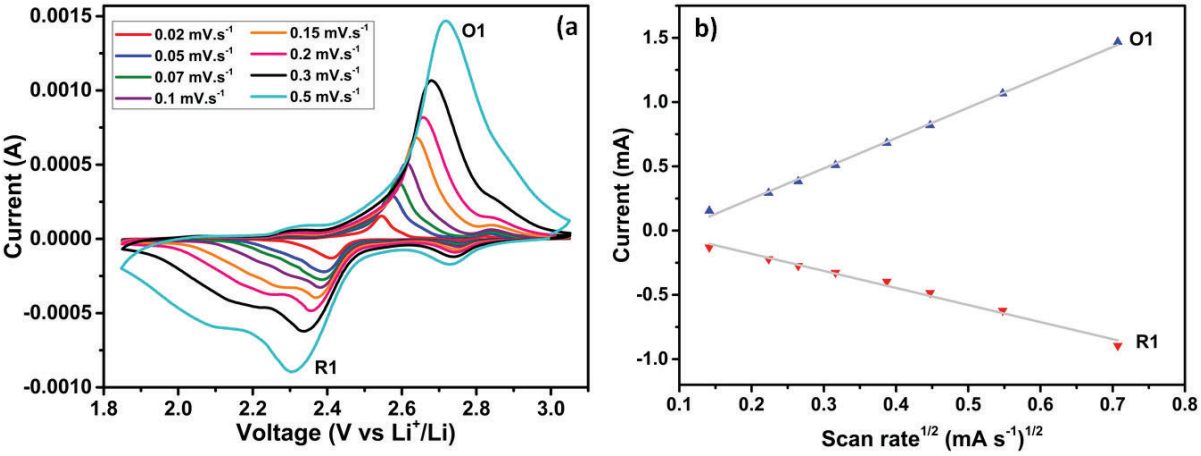

Fig. S10: a) CV at different scan rates in the voltage window 1.85-3V; b) peak current rates vs the square root of the scan rate.