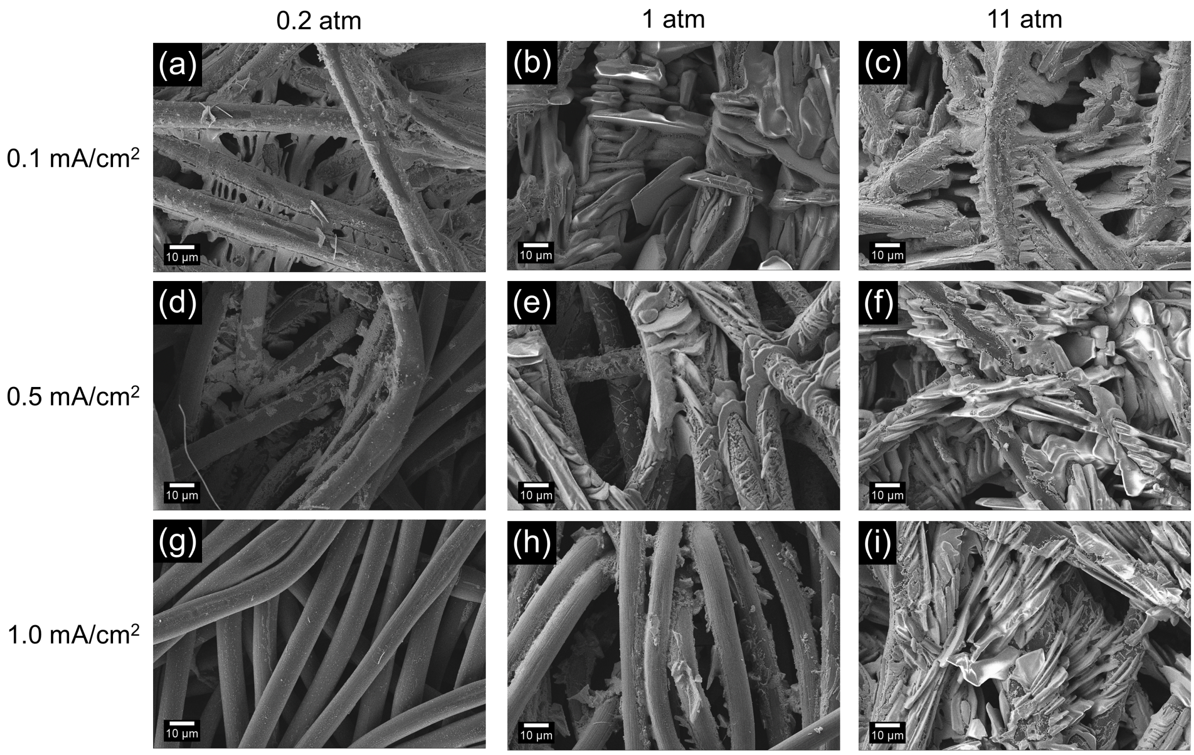

Figure S1. SEM images of the O_2 supply-side of cathodes after discharge at different J and $p(O_2)$. (a-c) J = 0.1 mA/cm^2. (d-f) J = 0.5 mA/cm^2. (g-i) J = 1.0 mA/cm^2. (a,d,g) $p(O_2)$ = 0.2 atm. (b,e,h) $p(O_2)$ = 1 atm. (c,f,i) $p(O_2)$ = 11 atm.

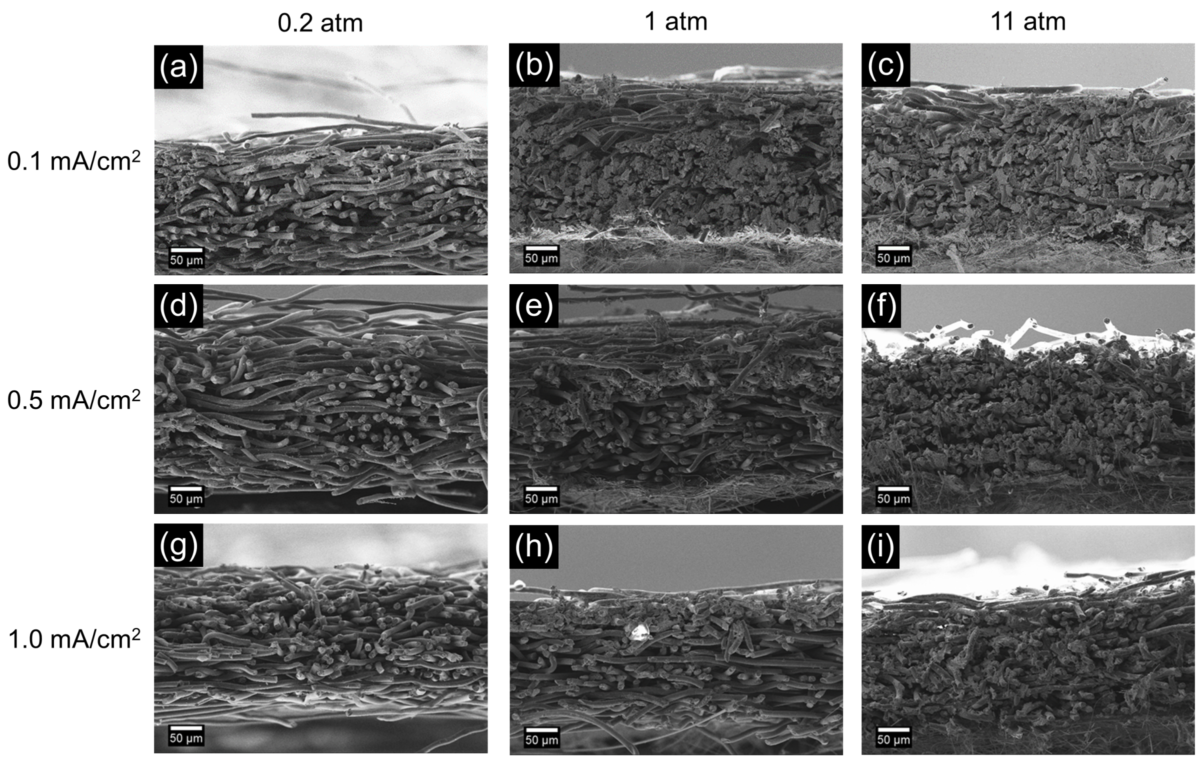

Figure S2. SEM images of the cross section of cathodes after discharge at different J and p(O_2). (a-c) J = 0.1 mA/cm^2. (d-f) J = 0.5 mA/cm^2. (g-i) J = 1.0 mA/cm^2. (a,d,g) $p(O_2)$ = 0.2 atm. (b,e,h) $p(O_2)$ = 1 atm. (c,f,i) $p(O_2)$ = 11 atm.

Addendum A1. Calculation of O_2/e^-

Only the linear section of the pressure evolution in Fig. 4a was considered for this calculation. The change in oxygen partial pressure (Δp) is the difference in pressure at the start (p_{start}) and end (p_{end}) of the linear regime.

$$\Delta p = p_{start} - p_{end} = 2.0232\text{ atm} - 1.6274\text{ atm} = 0.39575\text{ atm} \cdot \frac{101325\text{ Pa}}{atm} = 40099\text{ Pa}$$

The total transferred charge Δe is calculated using q: absolute capacity, Q: areal discharge capacity (5.5429 C cm^{-2}), A: nominal cathode surface area (1.539 cm^2), F: Faraday constant (96485 C mol^{-1})

$$\Delta e = \frac{Q\,A}{F}$$

The amount of consumed oxygen Δn is determined using the ideal gas law, where R: universal gas constant (8.3141 J mol^{-1} K^{-1}), T: temperature (298.15 K), V: Void volume of the cathode compartment (5.5 mL)

$$\Delta n = \frac{\Delta p\,V}{R\,T}$$

The ratio of consumed oxygen to total charge transferred O_2/e^- is obtained by

$$O_2/e^- = \frac{\Delta n}{\Delta e} = \frac{\Delta p\,V\,F}{R\,T\,Q\,A} = \frac{40099\,Pa \cdot 5.5 \cdot 10^{-6}\,m^3 \cdot 96485\,C\,mol^{-1}}{8.3141\,J\,mol^{-1}\,K^{-1} \cdot 298.15\,K \cdot 5.5429\,cm^{-2} \cdot 1.539\,cm^2} = 1.0$$

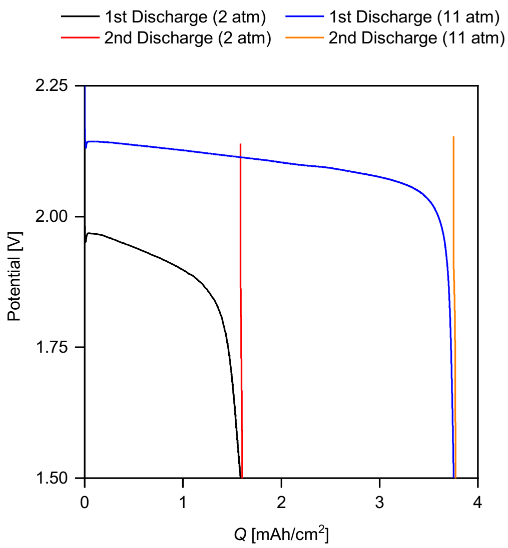

Figure S3. Discharge profiles of cells discharged twice at J = 1.0 mA/cm^2 with $p(O_2)$ of 2 atm (black and red lines) and 11 atm (blue and orange lines) with a 30 min rest at open-circuit potential between discharge steps.