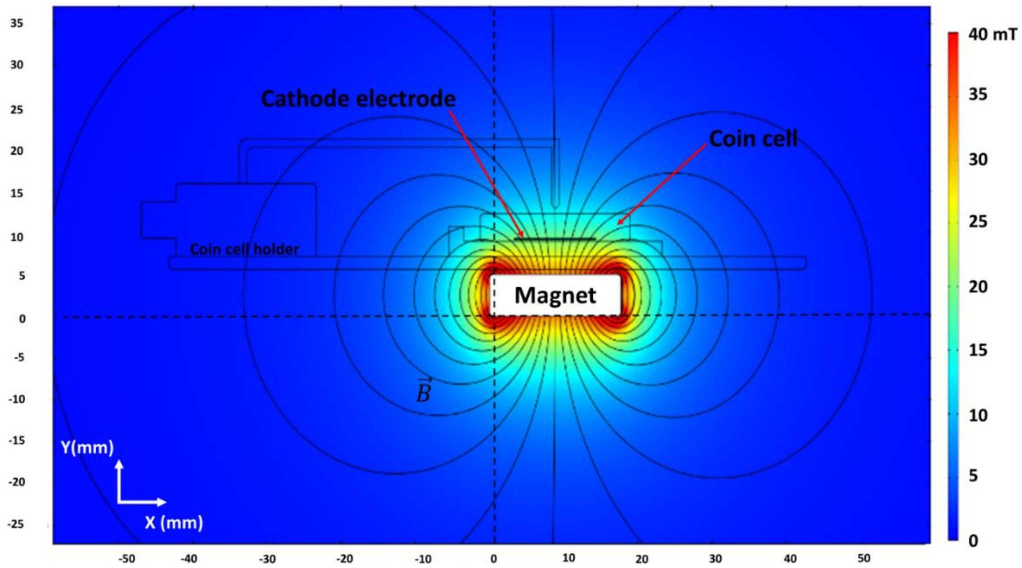
ESI 1: COMSOL simulation of the lines of magnetic field generated by the magnet.



ESI 2: Effect of the magnetic field on the cathode and anode.

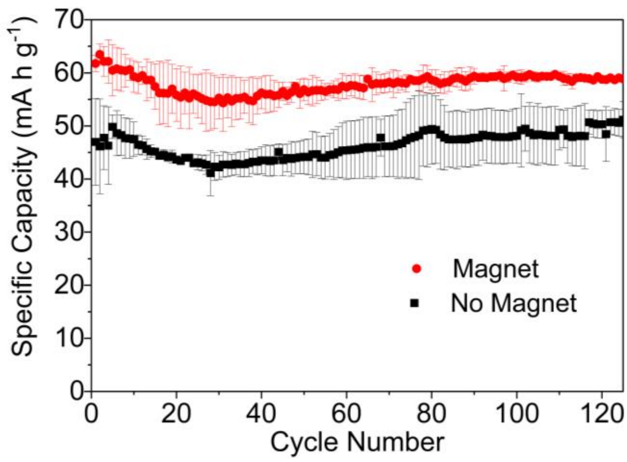


Figure 1 ESI2: Point-to-point standard deviation of the capacity of P,Fe-LMO cells cycled at 2C with and without magnetic field (33 mT).

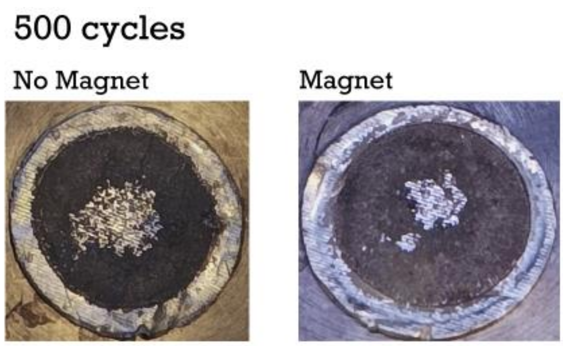
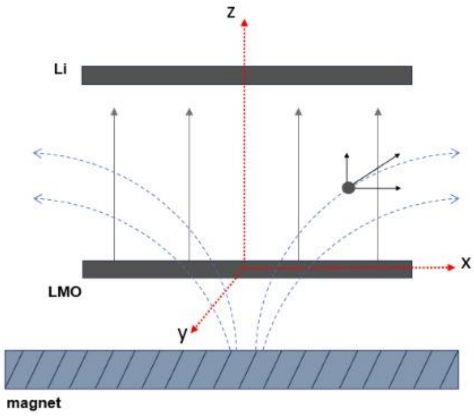


Figure 2 ESI2: Photography of metallic Li electrodes after 500 cycles with and without the influence of a magnetic field of 33 mT (330 Oe).

<u>**ESI 3:** Magnetic and hydrodynamic features.</u>



$$\mathbf{E} = (0; 0; E_z)$$
$$\mathbf{B} = (B_x; B_y; B_z)$$

Figure 1 ESI3: geometry for the simulation

Table 1 ESI3: Magnetic susceptibility of the materials used for the simulation at room temperature.

Material	**Magnetic Susceptibility at Room Temperature** (emu mol^{-1} Oe^{-1})	**Reference**
P-LMO	0.0116	https://doi.org/10.1016/j.jallcom.2023.172837
P,Fe-LMO	1.3688	
$LiNi_{0.5}Mn_{0.3}Co_{0.2}O_2$ (NMC 532)	0.0082	Estimated from its theoretical composition and charge of the transition metals

Figure 1 ESI3, shows the geometry used for the simulation. The magnetic susceptibilities of the different materials used for the simulations can be found in **Table 1 ESI3**. Other parameters used for the simulation are exhibited in **Table 2 ESI3**.

Table 2 ESI3: Parameters used for the COMSOL simulations.

Parameters used	**Values**
Lithium concentration (C_{Li+})	1 mol/L
Ionic Conductivity (σ)	0.957 S/m
Volumetric density of charge (ρ)	9.632×10^7 C/m^3
Electrode radii (L)	5.5 mm
Current at 2C	1.63 mA
Electrode voltage where the simulation was performed	3.8 V
Anode-Cathode distance	25 µm

From the expression of the magneto-hydrodynamic effect, the current density vector **J** can be obtained as a function of the components of the electric and magnetic fields.

$$\vec{\mathbf{J}} = \sigma\vec{\mathbf{E}} + \frac{\sigma^2}{C_{Li}F}\vec{\mathbf{E}}\times\vec{\mathbf{B}} \qquad (1)$$

$$\vec{\mathbf{E}}\times\vec{\mathbf{B}} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 0 & 0 & E_z \\ B_x & B_y & B_z \end{vmatrix} = \hat{i}(-E_z B_y) - \hat{j}(-E_z B_x)$$

$$\vec{\mathbf{J}} = \hat{i}\left(-\frac{\sigma^2}{C_{Li}F}E_z B_y\right) + \hat{j}\left(\frac{\sigma^2}{C_{Li}F}E_z B_x\right) + \hat{k}\left(\sigma E_z\right) \qquad (2)$$

The electric field was considered to be perpendicular to the surface. Its module was calculated at a voltage 3.8 V from the expression (E= V/d), where d is the distance between the anode and the cathode (25 µm). The current density vector can also be expressed as a function of the speed of the charge carriers according to the classical Drude-Lorentz conduction model:

$$\vec{\mathbf{J}} = \rho\vec{\mathbf{v}} = \rho\left(\frac{dx}{dt};\frac{dy}{dt};\frac{dz}{dt}\right)$$

Where ρ is the volumetric charge density and **v** is the speed of the charge carriers. Transforming to the cylindrical coordinates and taking θ=wt, we obtain that:

$$\vec{\mathbf{J}} = \hat{i}\left(-\rho w r\sin(wt)\right) + \hat{j}\left(\rho w r\cos(wt)\right) + \hat{k}\left(\rho z/t\right) \qquad (3)$$

Comparing equations (2) y (3):

$$\begin{aligned} -\frac{\sigma^2}{C_{Li}F}E_z B_y &= -\rho w r\sin(wt) = -\rho w y \\ \frac{\sigma^2}{C_{Li}F}E_z B_x &= \rho w r\cos(wt) = \rho w x \\ \sigma E_z &= \rho z/t \end{aligned} \qquad (4)$$

From the results of the simulations in Figure 7 of the manuscript, a linear dependence of the X and Y components of the magnetic field on the distance to the centre of the electrode is assumed, see scheme of **Figure 2 ESI3**.

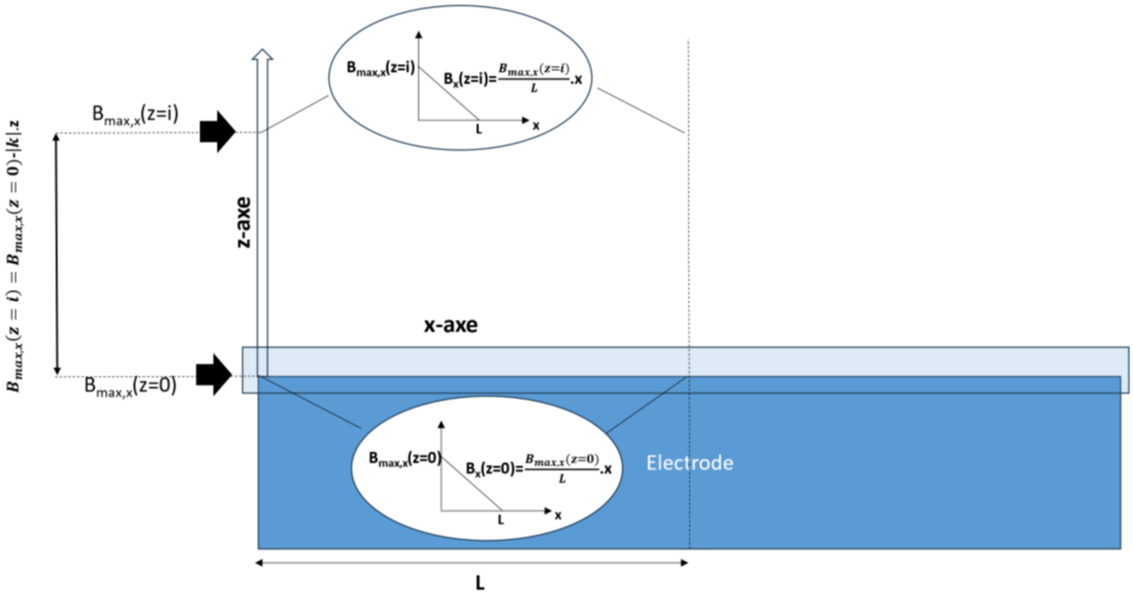


Figure 2 ESI3: Schematic representation of the assumed mathematical dependencies of the Bx component of the magnetic field along x for different highs (z-axe) above the electrode surface. In the scheme, only Bx is represented given that because of the symmetry of the system around the z-axe, the modules of Bx and By are equals.

$$B_x = \frac{B_{\max,x}(\mathrm{z=i})}{L} x = \frac{B_{\max,x}(\mathrm{z=i})}{L} r\cos(wt)$$
$$B_y = \frac{B_{\max,x}(\mathrm{z=i})}{L} y = \frac{B_{\max,x}(\mathrm{z=i})}{L} r\sin(wt) \qquad (5)$$

$B_{max,x}$ (z=i), $B_{max,y}$(z=i) are the maximum values of Bx and By for a given z-coordinate, respectively. L is the radius of the electrode. An example of the suitability of this linear fitting of the X and Y components of the magnetic field is provided in **Figure 3 a,b and c ESI3** for electrodes made of P-LMO, NMC 532 and P,Fe-LMO materials. The graphics were created using Bx,y components along x (or y) for z= 0 (surface of the electrode).

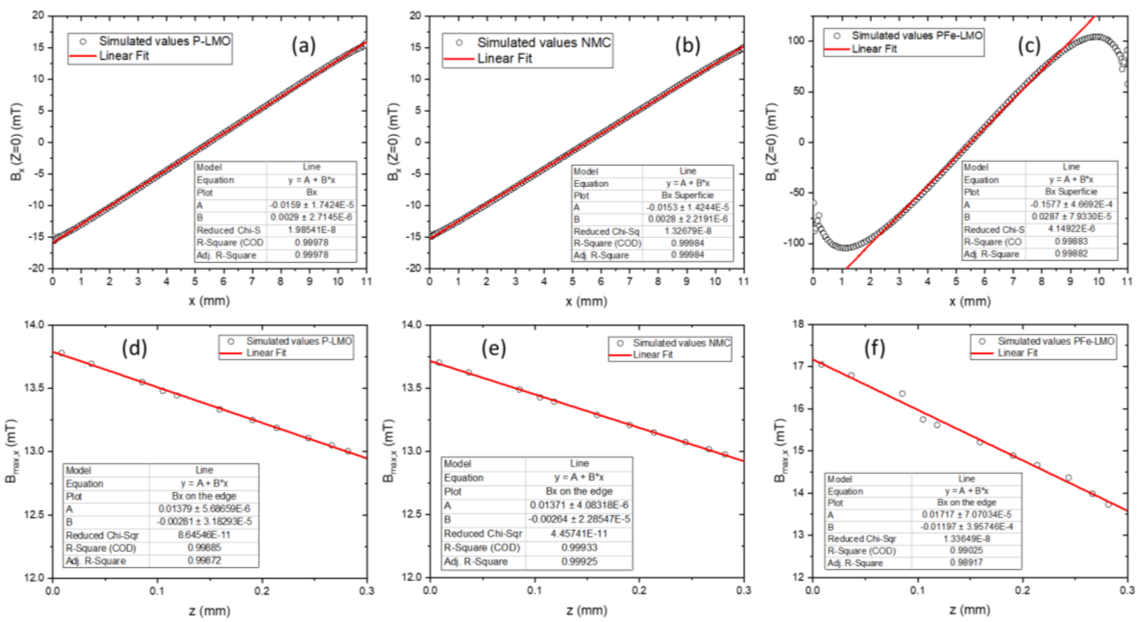


Figure 3 ESI3: (a, b, c) B_x along the x direction at z= 0 mm; (d, e, f) $B_{max,x}$ along the z direction.

Because, $B_{max,x}$ (z=i) and $B_{max,y}$(z=i) also change between z=0 and z= i, a linear dependency is also assumed for $B_{max,x}$ (z=i), $B_{max,y}$(z=i) along the z-axe, equations 6. This allows us to finally parametrize the dependency of Bx and By above the electrode surface for any desired z vale.

$$B_{max,x}(z=i) = B_{max,x}(z=0) - k \cdot z \qquad (6)$$

$$B_{max,y}(z=i) = B_{max,y}(z=0) - k \cdot z$$

where $B_{max,x}$ (z=0) and $B_{max,x}$ (z=i) are the maximum value of Bx on the electrode surface and a z= i distance from the surface, respectively. *k* is the rate of change of B_{max} from the button up to a high z= i.

The fitting of $B_{max,x}$ (z=i) for the LMO, NMC 532, and P,Fe-LMO electrodes can be seen in Figure 3d, e, f ESI3.

By substituting (5) and (6) in (4) and clearing the Cartesian coordinates, the parametric equation of the cathode-anode trajectory of a Li^+ ion starting at a distance r from the centre of the electrode is obtained. The form of the equation shows a trajectory in the form of a conical helix, where t (associated with the time) is the independent parameter.

$$\begin{cases} x = (A + B \cdot t) r \cos(wt) \\ y = (A + B \cdot t) r \sin(wt) \\ z = C \cdot t \end{cases} \qquad (7)$$

where $A = \dfrac{\sigma^2 E_z B_{0,\max}}{\rho w C_{Li} F L}$, $B = \dfrac{\sigma^2 E_z k}{\rho w C_{Li} F L}$ and $C = \dfrac{\sigma E_z}{\rho}$

The parameter w (associated with the angular velocity) can be easily determined from the current imposed during cycling by the expression:

$$w = \frac{I}{\pi L^2 \rho r} \qquad (8)$$