I. Supporting Figures

Figure S1. The optical image of H-type electrolytic cells used for the investigation of Li deposition. Mn ions were only introduced into one side (right, Li anode) of a H-type electrolytic cell. The effect of Mn ions on deposited Li on Cu substrate (left) can be observed. The electrolyte with Mn ions is separated from electrolyte without Mn ions by PP or G@PP separator. The current density of deposition is 0.2 mA cm^{-2} and the capacity is 0.2 mAh cm^{-2} and 1.0 mAh cm^{-2} for nucleation and final morphology, respecitvely. The electrolytic cell was assembled and sealed in glove box, and then tested at 25ºC.

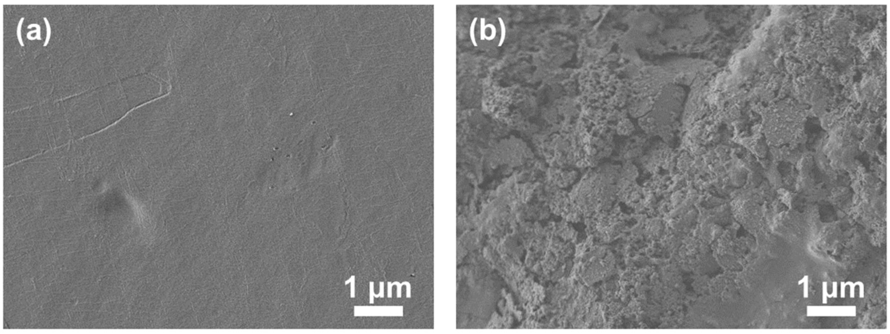

Figure S2. a) The morphology of Li anode after immersing into electrolyte without Mn ion. b) The morphology of Li anode after immersing into electrolyte with Mn ions for 5 h. Mn ions can corrode Li anode by direct chemical reactions, which is much different from the phenomenon on graphite anode. In graphite anode, Li ions were intercalted into graphite forming LiC_6, and Mn ions cannot contact with Li ion directly due to the formaiton of stable SEI. However, Li metal are exposed to Mn ions in the electrolyte of a working Li metal battery.

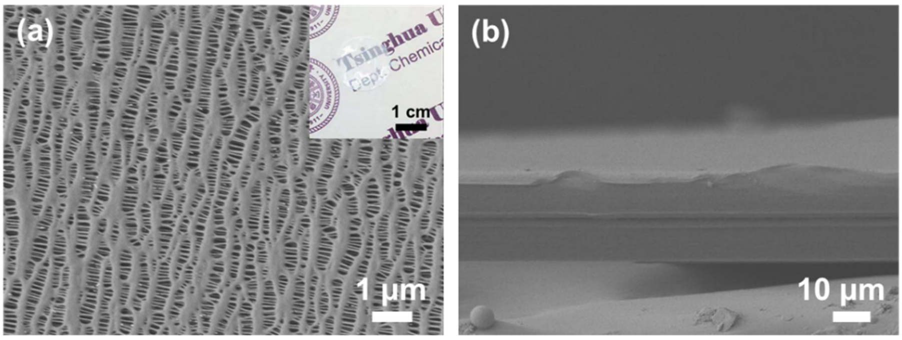

Figure S3. a) The top view of a routine PP separator with through pore. The inset: the optical image of PP seprator. b) The cross-sectional view of PP separator with a thickness of 25 μm. Mn ion can cross PP separator easily due to through pores.

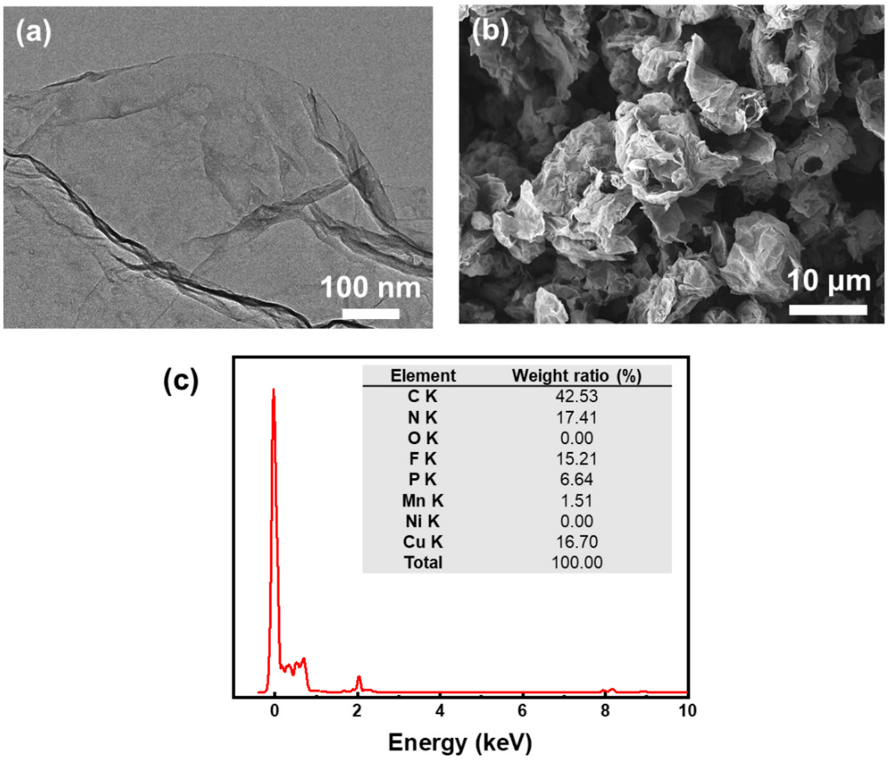

Figure S4. a) The TEM image and b) SEM image of graphene coated on PP separator after cycled in Li | NCM523 batteries. c) The corresponding EDS spectra. The signal of Mn element is detected though the amounts of Mn is much low, proving the adsorption of graphene in blocking the crosstalk of Mn ions.

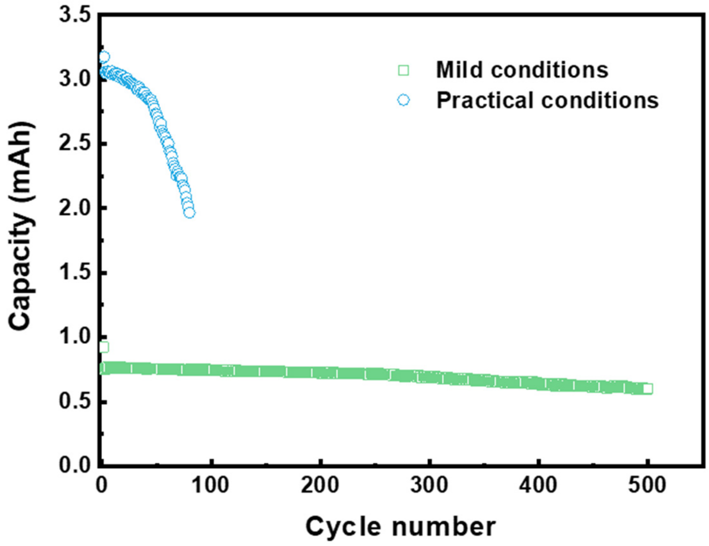

Figure S5. Cycling performance of Li | NCM523 batteries under mild and practical conditions. The mild conditions include a thick Li anode (500 μm), a low cathode loading (~1 mAh cm^{-2}), and a lean electrolyte (50 g Ah^{-1}). The practical conditions include an ultrathin Li anode (33 μm), a high loading NCM523 cathode (2.5 mAh cm^{-2}, measured value), and a lean electrolyte (7.7 g Ah^{-1}). The much-decreased cycle life (nearly one of tenth) under practical conditions compared with mild conditions demonstrated that practical Li batteries are faced with huge challenges and issues. Therefore, fresh and effective strategies towards to promoting the developments of practical Li batteries are in the spotlight.

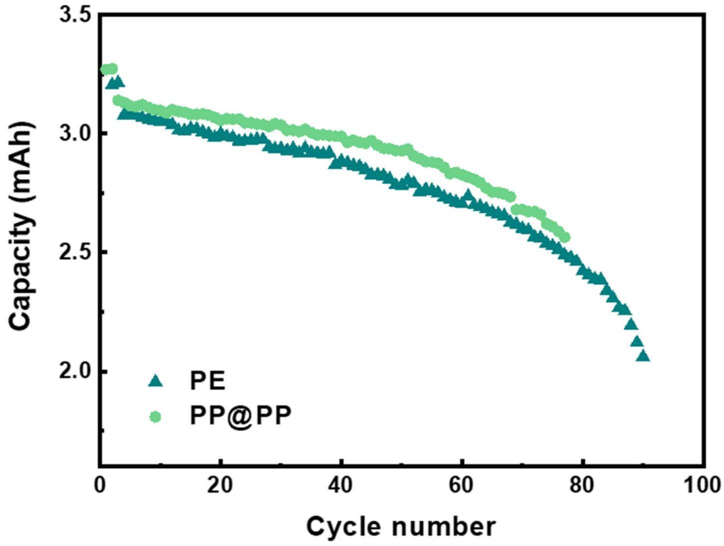

Figure S6. Cycling performance of Li | NCM523 batteries under practical conditions with PE and two layers PP separator. The types of separator almost have no obvious impact on the cycling performance of batteries although the pore structure of PE is much porous compared with PP. In addition, the layers of PP separator also do not contribute to increasing cycle life significantly. Therefore, the role of graphene in blocking Mn ion is specific due to its large surface area and plenty of pore.