Modelling and simulation of micro-galvanic corrosion of Al alloys induced by IMPs

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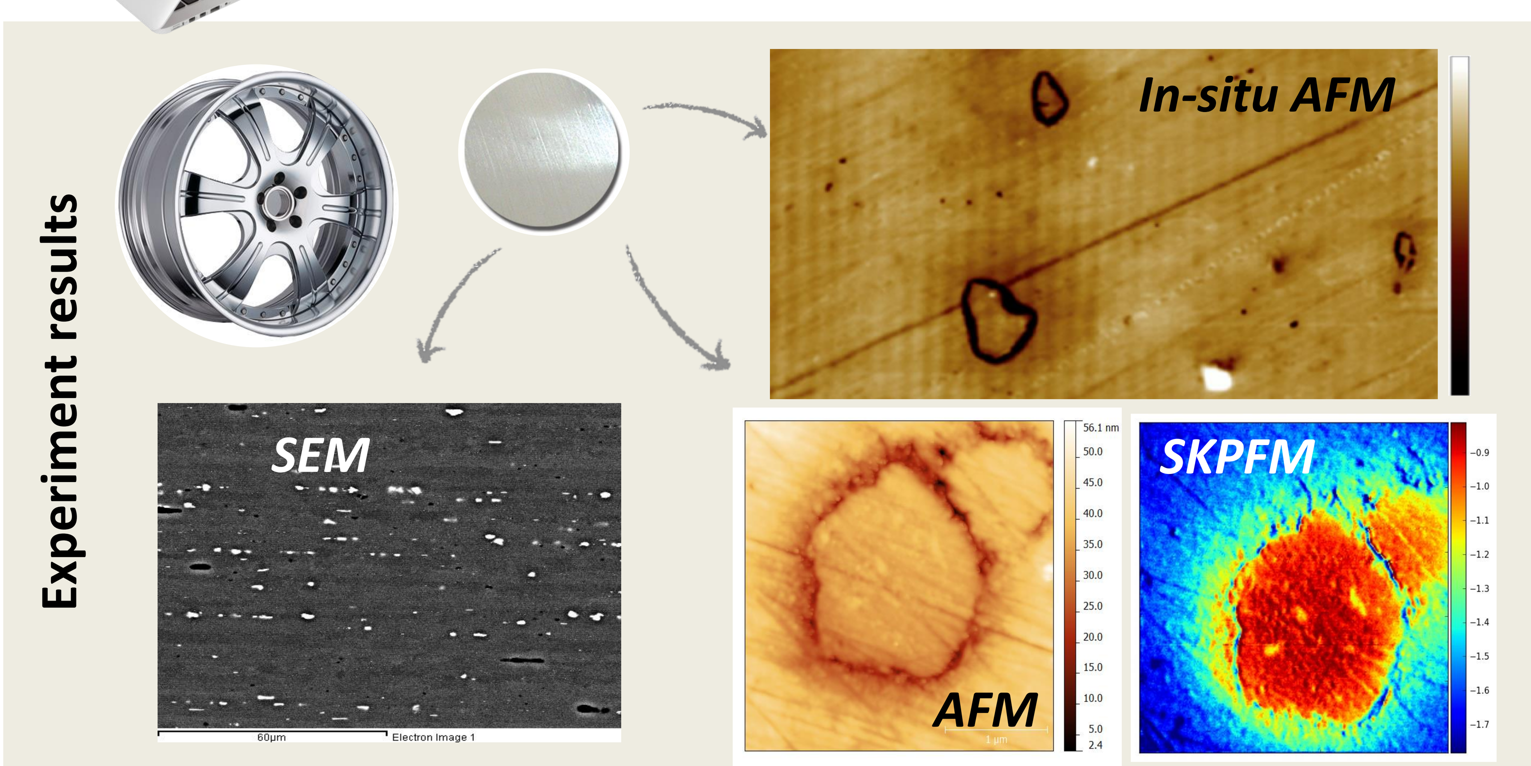
Abstract: FEM model provides a powerful method for corrosion investigation of Al alloys by taking into account the complicate homogeneous reactions, mass transport, kinetic moving boundary, as well as the deposition and blocking effect of $Al(OH)_3$.

Model development

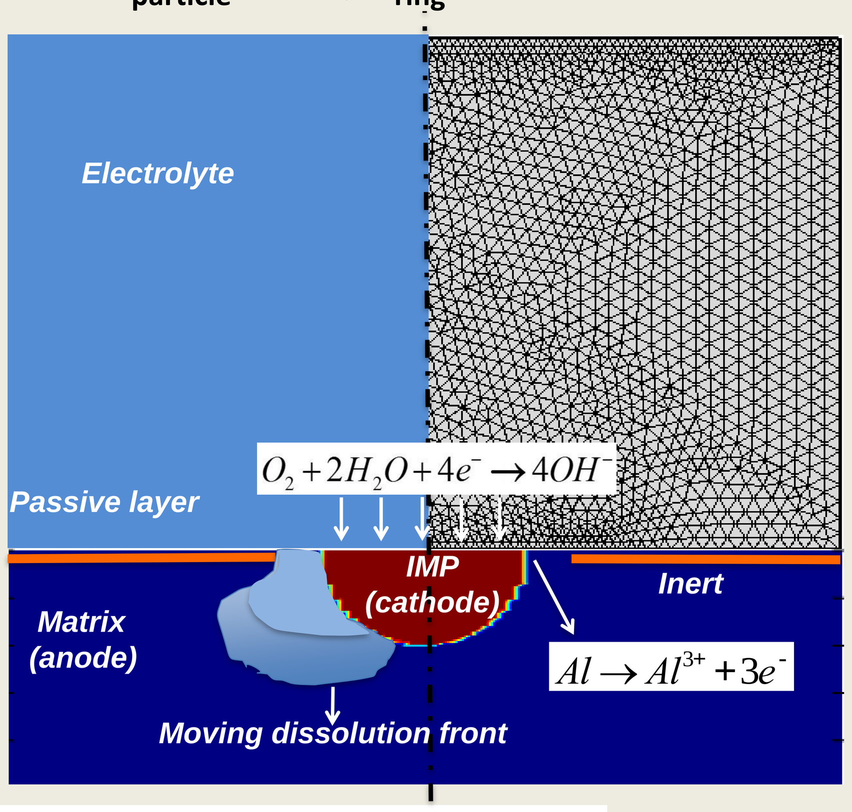


Micro-galvanic couple:

- IMPs (local cathode)
- Boundary (local anode)
- $R_{particle}$=2um, R_{ring}=1um

Main features:

- Moving dissolution front tracing
- Free corrosion at OCP



Homogeneous reactions

✧Hydrolysis and complexion

Mass transport

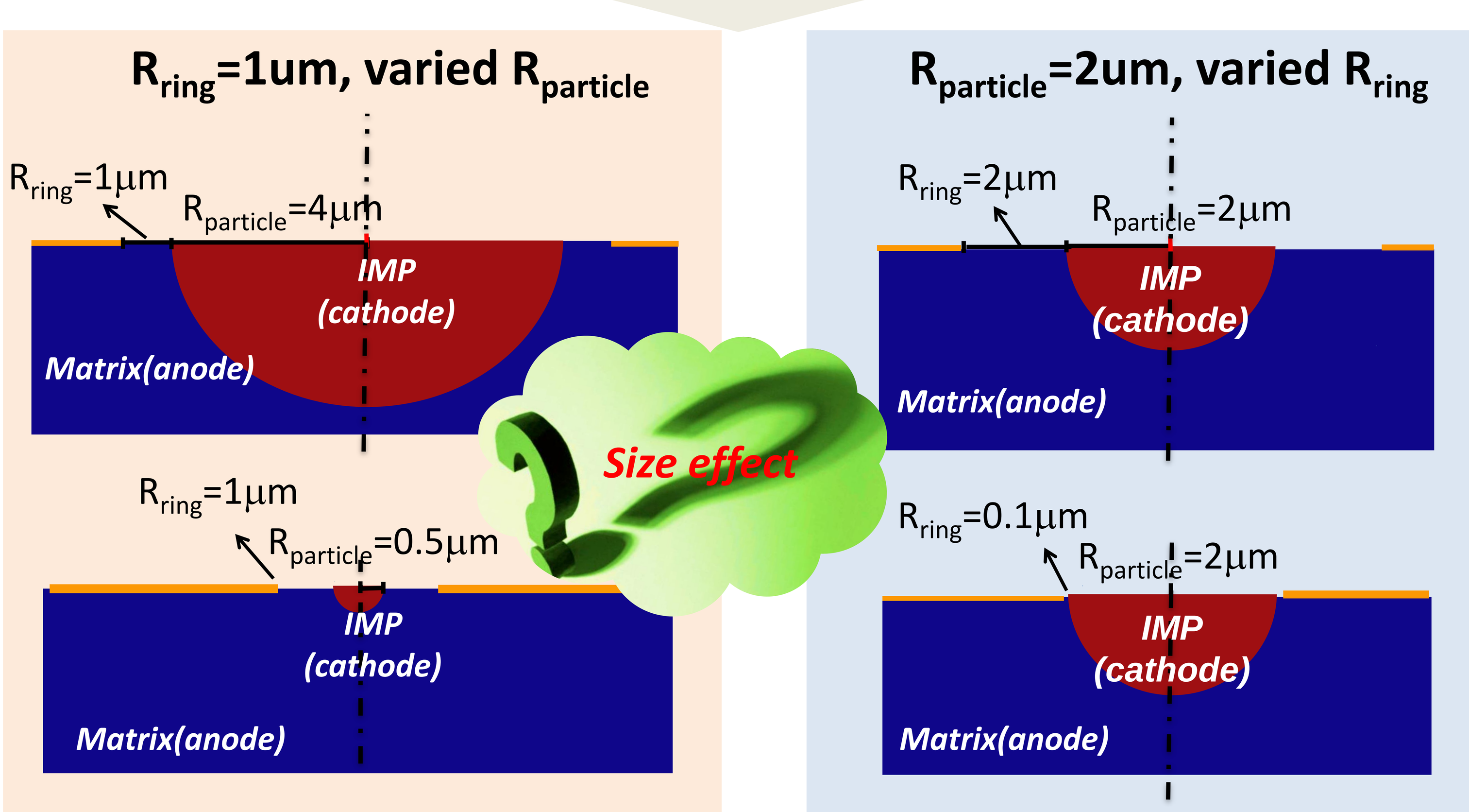
✧Diffusion, migration

Electrochemical reactions

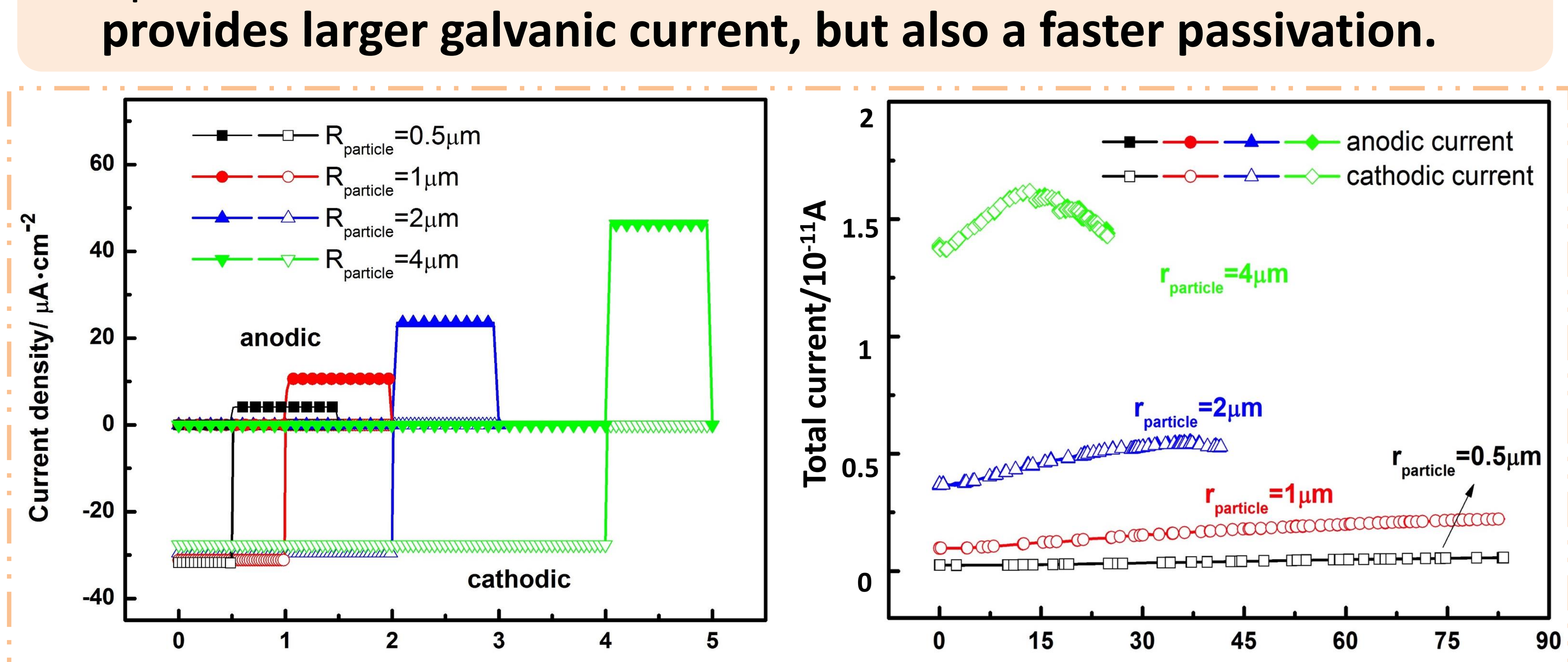
✧Single phase parameters

Precipitation of $Al(OH)_3$

✧Coverage of deposited $Al(OH)_3$



✧ $R_{particle}$ effect: Large IMPs support more cathodic O_2 reduction, provides larger galvanic current, but also a faster passivation.



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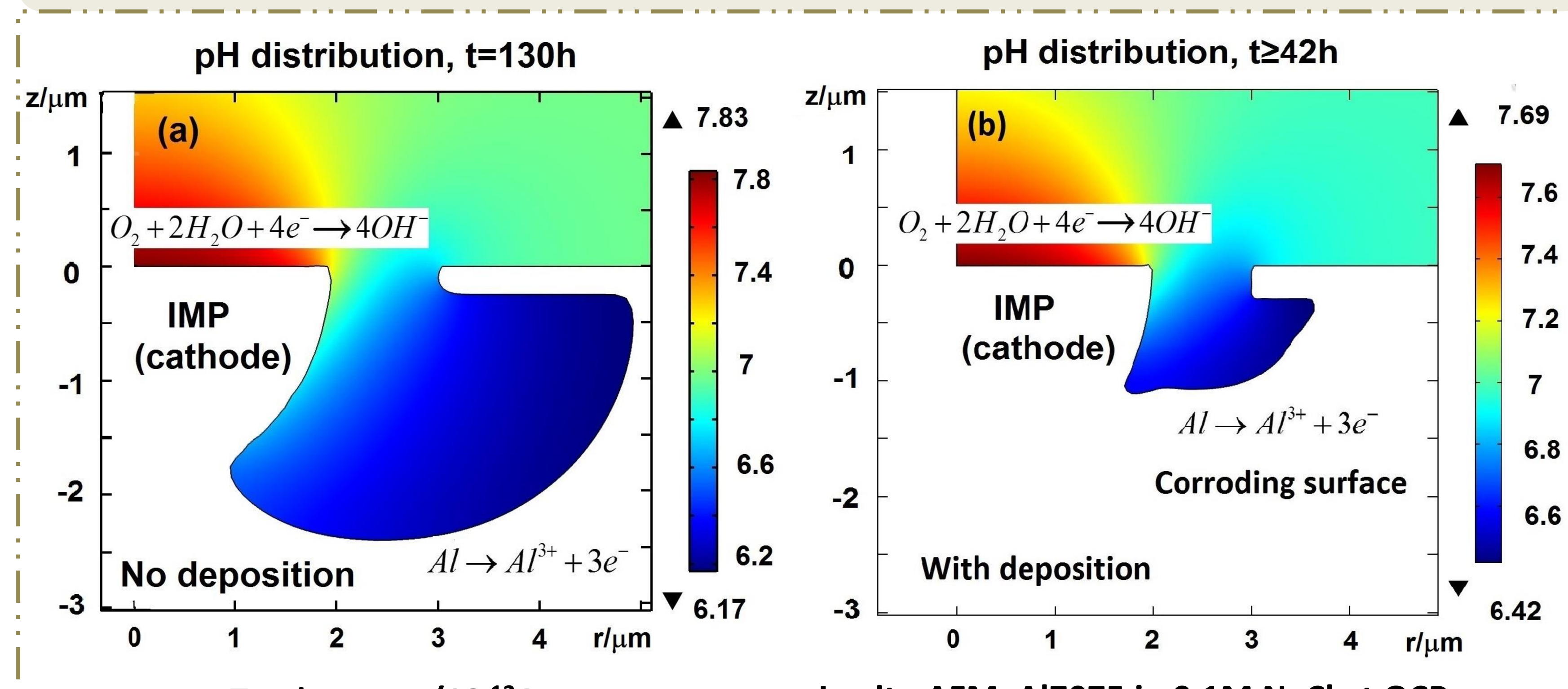
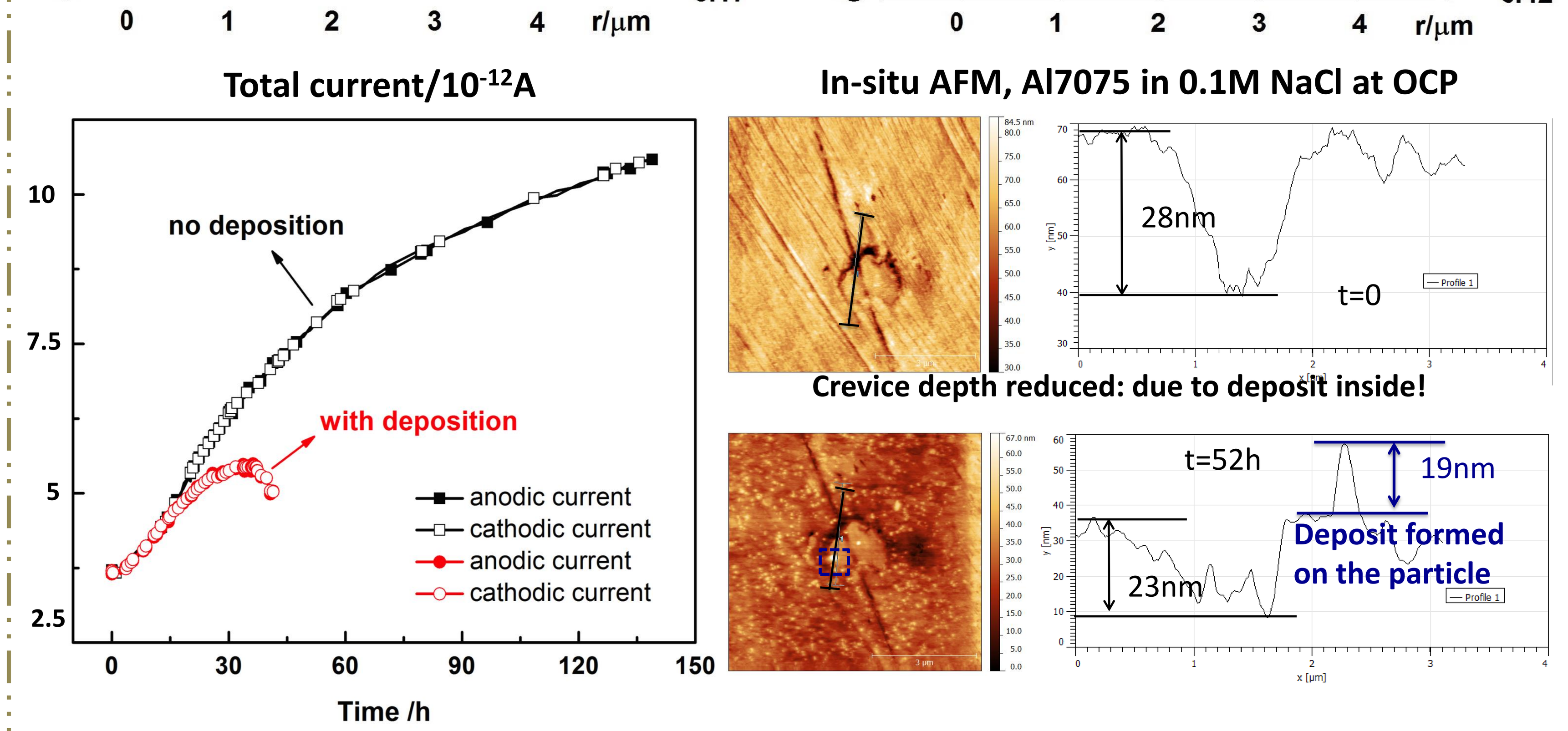
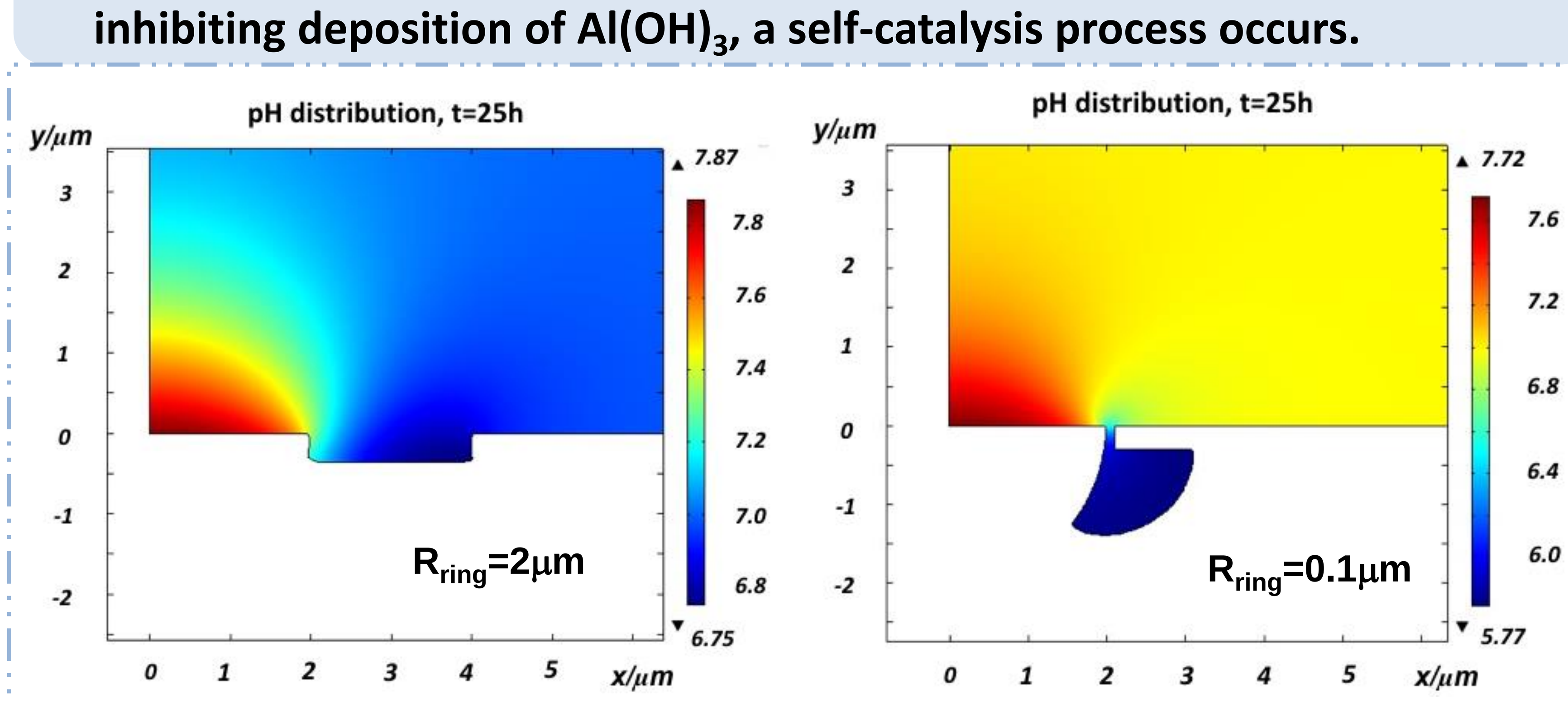
Results and conclusions

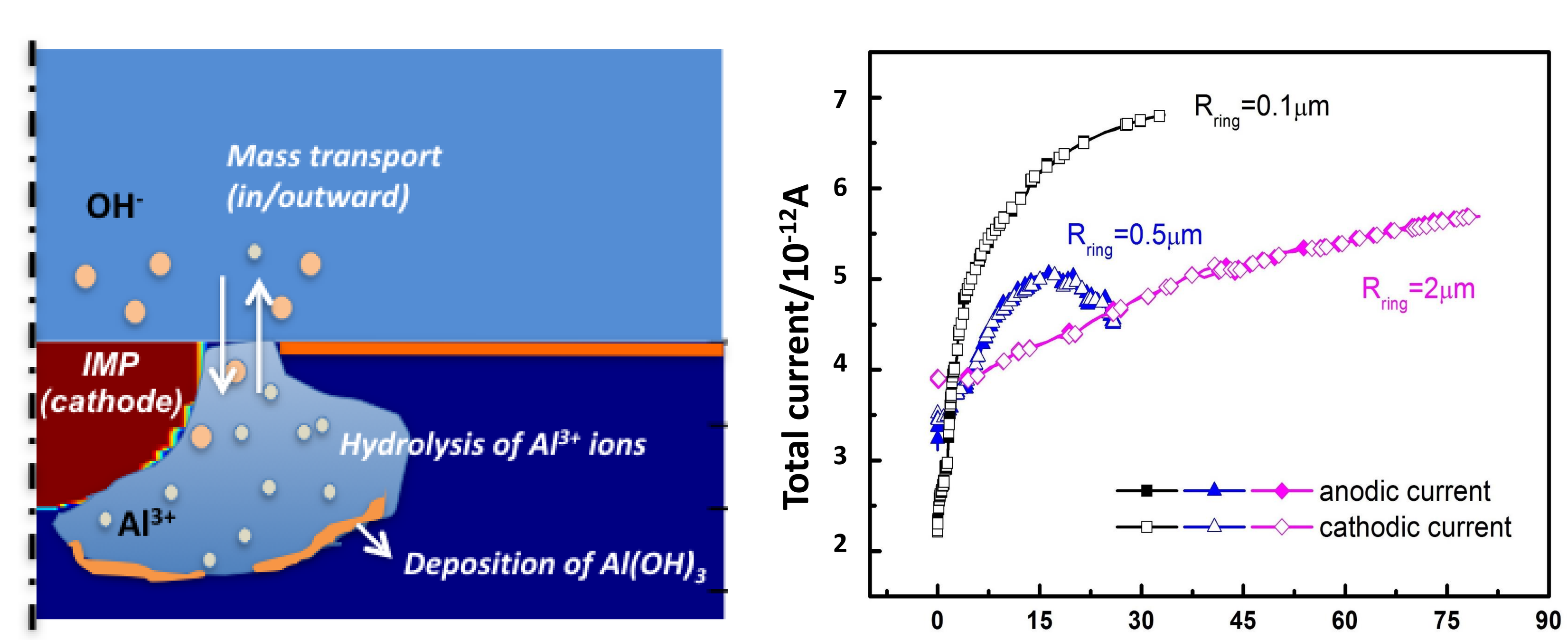
✧ pH distribution shows possibility for $Al(OH)_3$ depositing, block effect of deposited $Al(OH)_3$ leads to a much slower and shorter corrosion process.





✧ R_{ring} effect: Small R_{ring} (pit mouth) limits inward mass transport of OH^-, leading to localized acidification inside the dissolution volume, in turn inhibiting deposition of $Al(OH)_3$, a self-catalysis process occurs.





Conclusions:

✧ The developed FEM model provides a deeper insight into the relationship between microstructure and micro-galvanic corrosion of Al alloys.

✧ Using a coverage parameter, the deposition of $Al(OH)_3$ and subsequent blocking effect on surface reactions can be described quantitatively and kinetically.

✧ The blocking effect leads to a reduced local corrosion rate, and eventually to a static corrosion frontier corresponding to a completely blocked active surface.

✧ Decrease of R_{ring} enhances local acidification inside corroding volume resulting from the limited mass transport of OH^- ions into the volume, furthermore, this would slow down the deposition of $Al(OH)_3$, leading to pits stabilization and propagation.

✧ Smaller IMP with $R_{particle}$ = 0.5 and 1 μm can not provide enough drive force for active dissolution.