Optimizing Electrode Surface Area by COMSOL Multiphysics®

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Introduction

- Molten salt electrorefining will be used for reprocessing metal fuels from Fast Breeder Reactors
- In the design of electrorefiner, Working electrode and Counter electrode surface areas are very important
- The main aim of this study is to understand the effect of the ratio of Anode to cathode Surface areas on the thickness of deposition on the cathode in an electrorefining cell
- Application of this model to design electrorefiner for metallic spent nuclear fuel is discussed with respect to Uranium recovery
- shaping of real anode surface area is a major issue to be resolved for particularly modeling molten salt electrorefining
- Using Comsol Multiphysics 4.3b, calculated deposition thickness with varying anode surface area.

Molten Salt Electrorefining Process

- In the molten salt electrorefining process, the spent metallic fuel is used as the anode and LiCl-KCl eutectic melt as the electrolyte
- Fuel elements, U and Pu, are selectively electrotransported to a suitable cathode
- When solid inert electrode is used as cathode, Uranium alone is deposited at the cathode leaving Zr and Noble metal fission products in the anode basket, alkali and alkaline earth and lanthanides accumulate in the electrolyte salt phase
- When reactive cathodes such as liquid Cd, liquid Bi, etc.., are used U, Pu and minor actinides are co-deposited

Electrochemical cell Geometry:

- In this geometry Cylindrical Anode is kept at left side and Cylindrical Cathode is at centre
- In this problem two electrodes and electrolyte was meshed with Triagonal elements.

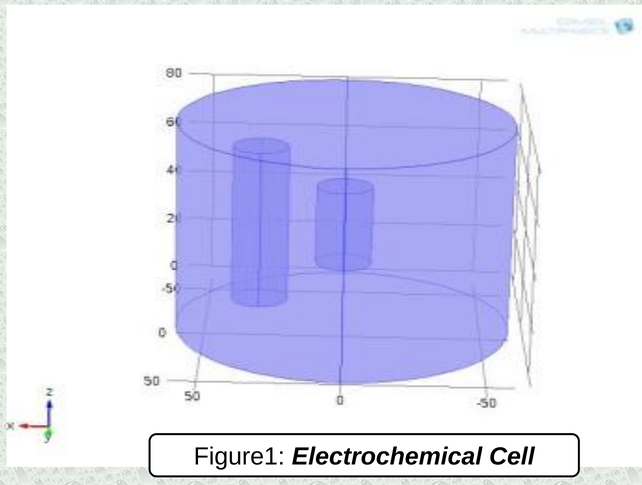

Figure1: ***Electrochemical Cell***

The Equations used in Electrorefiner Modeling

$i_l = -\sigma_l \nabla \phi_l$, $i_s = -\sigma_s \nabla \phi_s$

Where σ_l denotes the electrolyte conductivity and ϕ_l denotes the potential in the electrolyte.

The rate of electrochemical reactions can be described by relating it to the activation overpotential.

$\eta = \phi_s - \phi_l - E_{eq}$ Where, E_{eq} denotes the equilibrium potential

Electrode Kinetics Expression: Butler-Volmer Equation : $i_{loc} = i_0 (\exp(\alpha_a F\eta/RT) - \exp(-\alpha_c F\eta/RT))$

RESULTS & DISCUSSION

Reactions involved:
At cathode:

$$U^{3+} + 3e^- \rightarrow U$$

At anode:

$$U \rightarrow U^{3+} + 3e^-$$

Table1

Variable	Value	Units
Electrolyte Conductivity	1900[3]	S/m
Operating Temperature	773[3]	K
Equilibrium Potential	-1.3	V
Anode Potential	-1.2	V
Cathode Potential	-1.45	V
Exchange Current density	150	A/m^2

Table2

Ratio of Anode to Cathode Surface Area	Deposition Thickness, mm
0.3	0.9
0.6	1.2
1	1.4
1.3	1.5
1.6	1.6
2	1.7
2.3	1.8

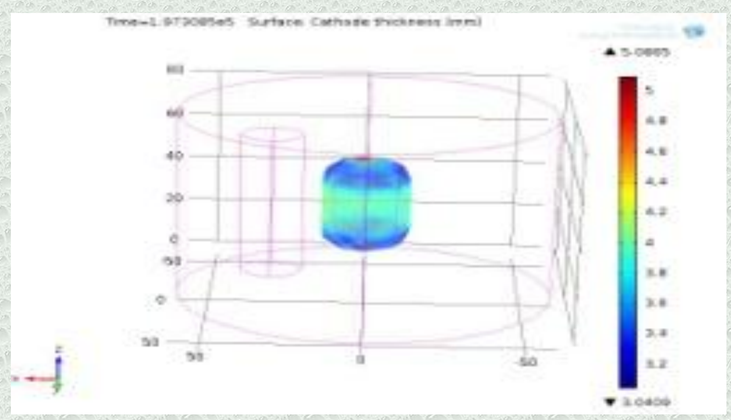

Figure2: Deposition Thickness (mm) after 54 hrs

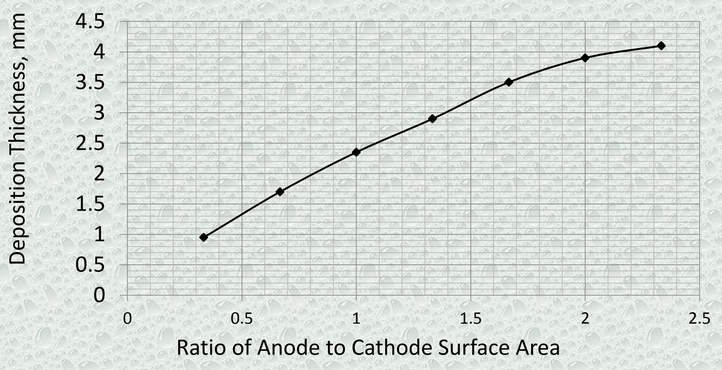

Figure3: Ratio of Electrode Surface Areas Vs Deposition Thickness

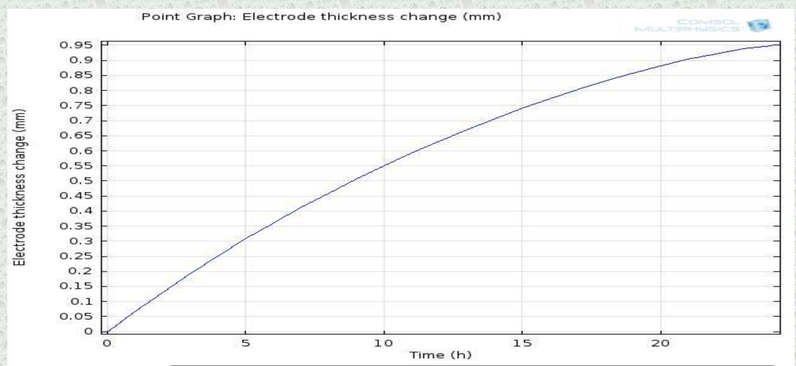

Figure4: Deposition Thickness Vs Time, Ratio 0.3

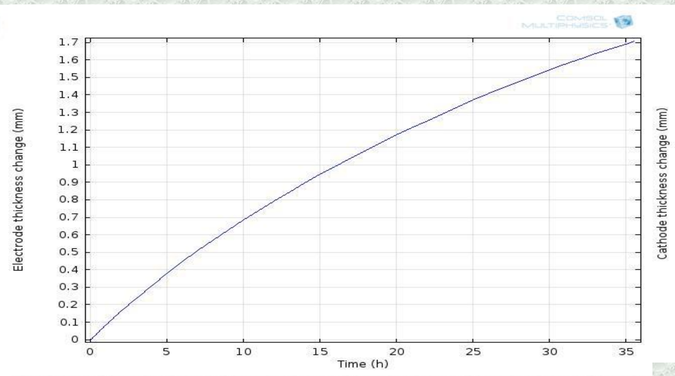

Figure5: Deposition Thickness Vs Time, Ratio 0.6

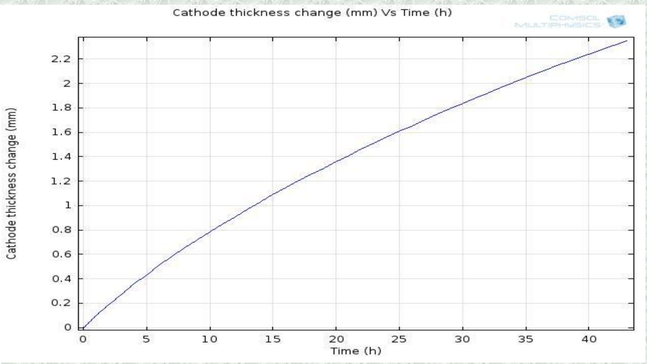

Figure6: Deposition Thickness Vs Time, Ratio 1

Future Direction

- Optimize the Cathode Surface Area For a Electrochemical Cell
- Modeling of Multi electrode system for a electrodeposition using comsol Multiphysics
- Comparison of model developed by the Comsol Multiphysics with Experimental results

Conclusion

- Increasing the Ratio of Anode Surface Area to the Cathode Surface Area, increases the thickness of deposition that means that the rate of deposition increases

References

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