Simulation of Current Density for Electroplating on Silicon Using a Hull Cell

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Introduction:

The Hull cell is an electrodeposition tank which has the cathode angled with respect to the anode [1]. The current density varies along the cathode and it is possible to find an optimal distance for plating.
A sample holder was built to allow experiments in the cell with semiconductors which changes the current density. Simulations were done to find an optimal design and a modified cell is proposed.

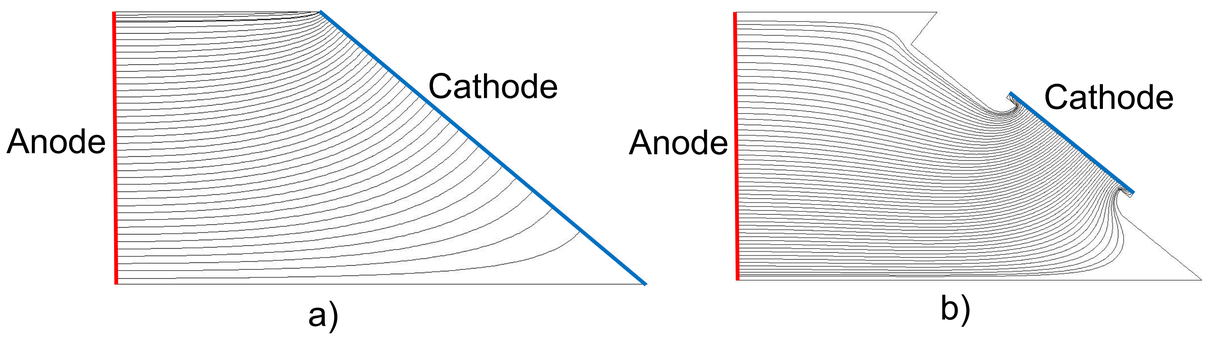

Figure 1. Current density: a) Hull cell, b) cell with sample holder

Computational Methods:

The chemical reactions happening are the following:
on the anode: $Cu_{(s)} \longrightarrow Cu^{2+}_{(aq)} + 2e^-$

on the cathode: $Cu^{2+}_{(aq)} + 2e^- \longrightarrow Cu_{(s)}$

Electrolyte: copper (Cu^{+2}) and sulfate (SO_4^{-2}) ions.
Physics used: tertiary Nernst-Planck interface.
It describes the current and potential distribution in an electrochemical cell taking into account the ions in the electrolyte through the migration and diffusion [2] as it is calculated with the following equation:

$$N_i = -D_i \nabla c_i - z_i u_i F c_i \nabla \varphi_i$$

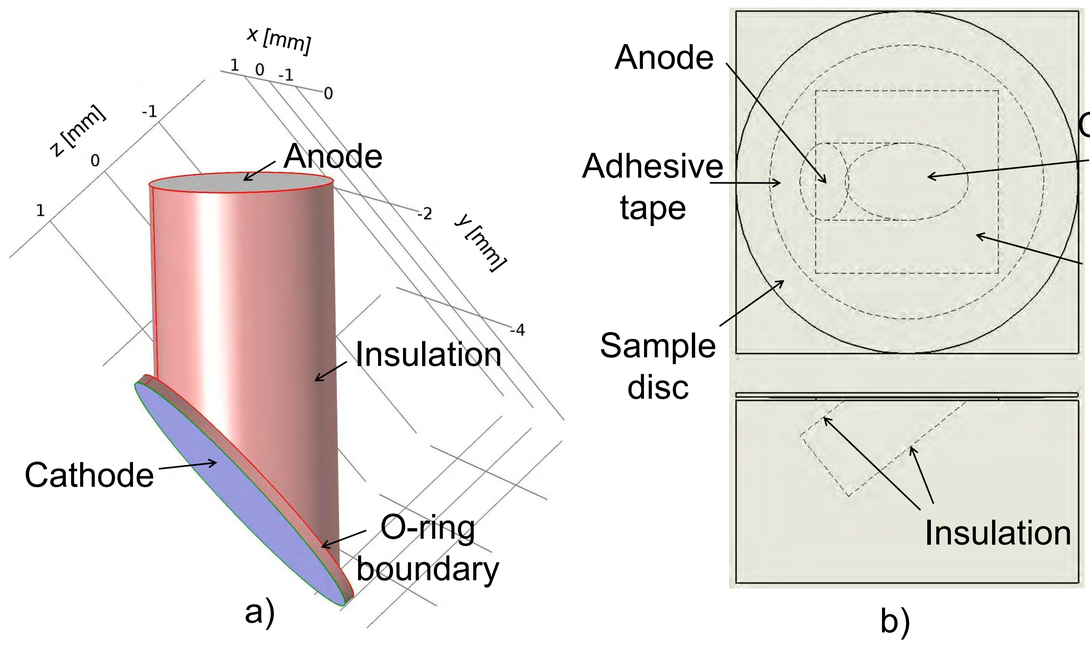

Figure 2. Modified cell model domain and boundaries:
a) with O-ring, b) without O-ring

The current density is calculated according to the equation:

$$i_{ct} = i_0 exp\left(\frac{1.5F\eta}{RT} - \frac{c_{Cu^{2+}}}{c_{Cu^{2+},ref}} exp\left(-\frac{0.5F\eta}{RT}\right)\right)$$

The Hull cell dimensions according to the DIN 50957 [3] and the modified miniaturized cell can be seen in the following Table 1.

Table 1. Hull cell and modified cell dimensions

DIN 50957 [mm]	Modified [mm]
102	5.4
48	2.54
64	3.39
127	6.72

Results:

The simulation shows the impossibility of using a holder with an O-ring as the one in Fig. 3a. Similar results to the Hull cell were obtained with a setup like in Fig. 2b (results shown in Fig. 3b).

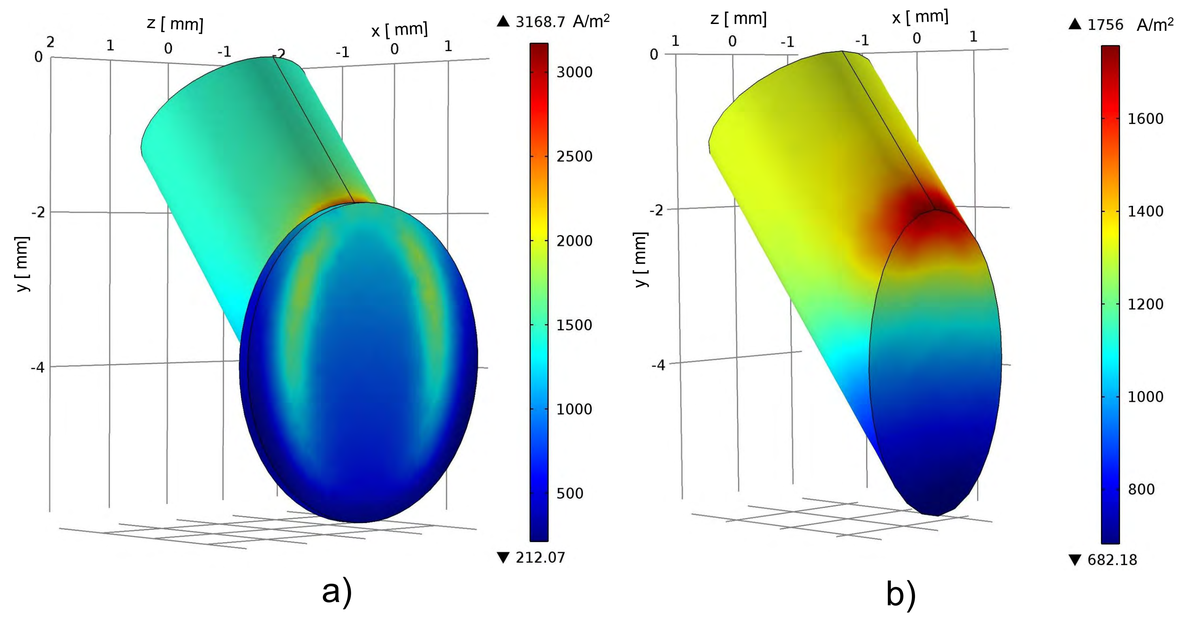

Figure 3. Current density along the cathode for modified cell:
a) with O-ring, b) without O-ring

Conclusions:

A miniaturized modified Hull cell sketch was presented and simulated in Comsol. The results are satisfying but a current density profile equation still has to be defined. The design shown considers a circular anode. It would work for rectangular shaped anodes. The design presented works if there is no production of gases during the electroplating process.

References:
1. N. Kanani, *Electroplating: Basic Principles, Processes and Practice*, 1st Edition, Elsevier (2006)
2. COMSOL, Electroposition Module User's Guide, Version 4.2a (2011)
3. Deutschen Normen, Galvanisierungsprüfung mit der Hull-Zelle, *DIN50957*, 1-6 (1978)

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