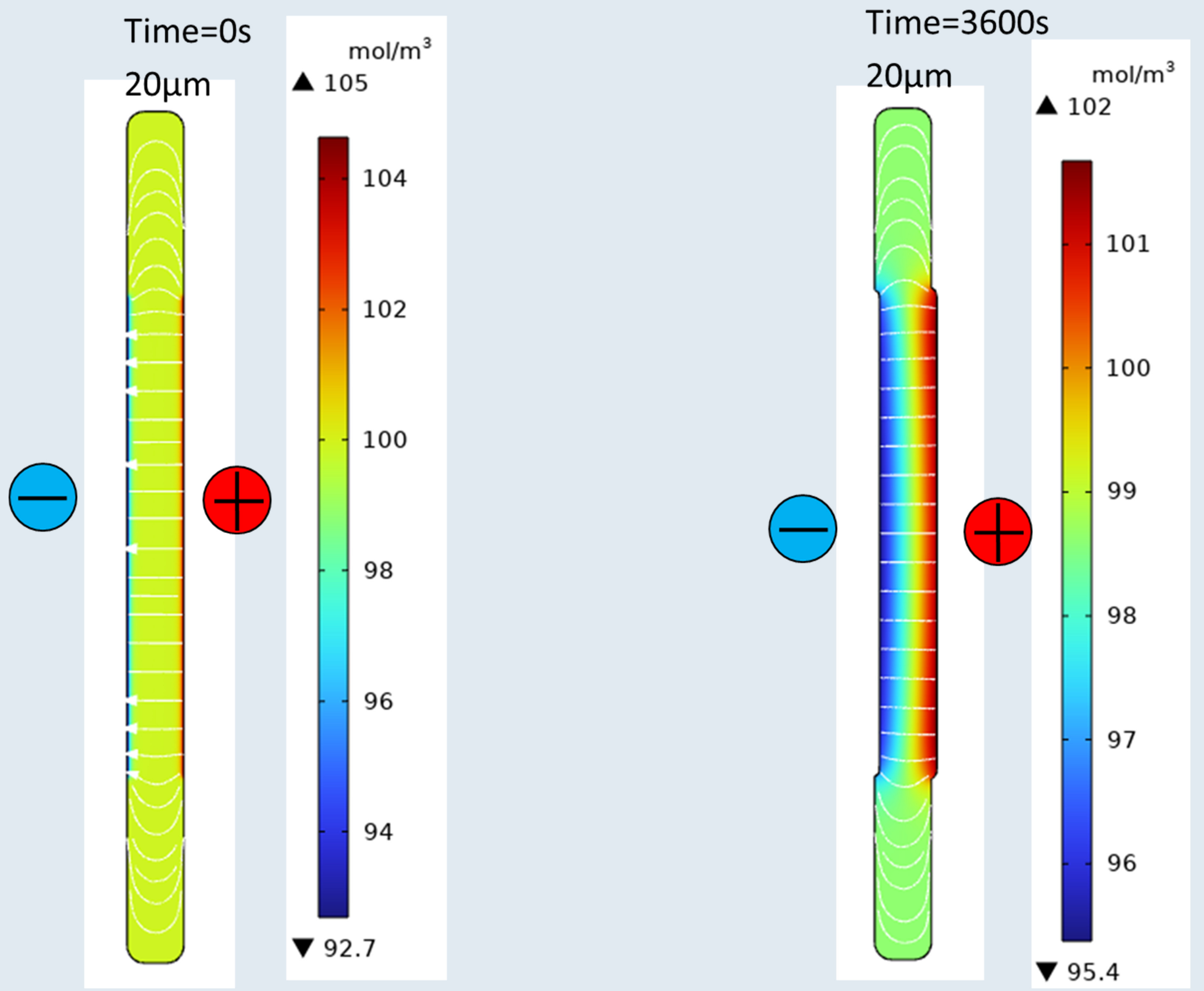


Copper Corrosion Mechanism by Simulation and Experiment Using Small Test Structures

Product lifetime prediction is a crucial task in microelectronics design and fabrication. Among different failures, corrosion resulting in short circuit is investigated in this work.

H. S. Nabi[1] , M. Mayr[2]

1. Infineon AG, Regensburg, Germany

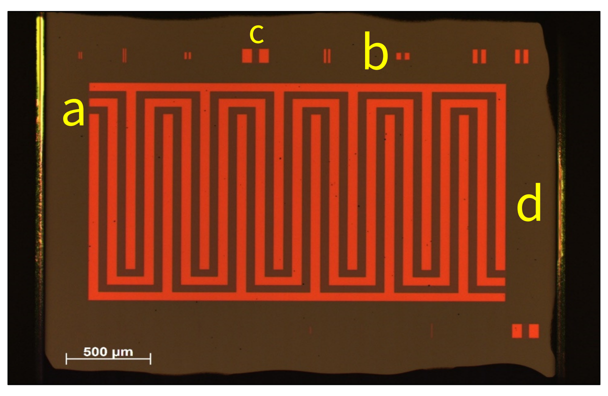
2. TU Wien, Wien, Austria

Abstract

Organic coatings (OCs) are commonly employed to protect microelectronic components from external influences (e.g. bias, humidity), to avoid **corrosion of the metal conductors**. Copper (Cu), widely used as electric conductor, requires such protection to prevent **dendrite growth**, which is driven by **electrochemical migration (ECM)** and can result in unwanted short circuits. However, OCs can degrade over time, making them less protective.

The consequent **ingress of water** to the metal/OC interface is assumed to enable **corrosion** processes at the metal conductors [1].

This work aims to understand the corrosion mechanism along with degradation of organic coatings and electrochemical migration in/on coated structures.



No.	Part
a	Cu comb + meander
b	Flat band Cu electrodes
c	Like b, with "micro-electrodes" in between (not visible)
d	(optional) OC (covering the whole area)
not shown	Cu pads for bonding and electrical contacting

$$Cu^{2+} + 2e^- \leftrightarrow Cu$$
$$2H^+ + 2e^- \leftrightarrow H_2$$
$$2H_2O + 2e^- \leftrightarrow H_2 + 2OH^-$$
$$O_2 + 4H^+ + 4e^- \leftrightarrow 2H_2O$$
$$O_2 + 2H_2O + 4e^- \leftrightarrow 4OH^-$$
$$Cu_2O + 2H^+ + 2e^- \leftrightarrow 2Cu + H_2O$$
$$2Cu^{2+} + H_2O + 2e^- \leftrightarrow Cu_2O + 2H^+$$
$$CuO + 2H^+ + 2e^- \leftrightarrow Cu + H_2O$$
$$2CuO + 2H^+ + 2e^- \leftrightarrow Cu_2O + H_2O$$
$$2H_2O \leftrightarrow H_3O^+ + OH^-$$
$$Cu^{2+} + Cu \leftrightarrow 2Cu^+$$

Figure 1: Test structures used for experiment and implemented electrode reactions in the Simulation model.

Methodology

Test structures are developed and used for **variation of electrolytes** and **application of bias** to 'scan' migration and corrosion mechanisms. **Electrochemical impedance spectra** and **current-versus-time curves** are recorded during the experiments.

COMSOL Multiphysics®, is used for simulations of **diffusion and migration** by solving Nernst-Planck equations as well as **electrochemical and homogeneous reactions** (tertiary current distribution) in an electrolyte.

Parameters for simulation were taken from literature and optimized based on experimental results.

Results

Experimentally, the influence of different electrolytes and their concentrations, as well as applied biases on the corrosion behavior was determined. The **Conditions** in which **dendrites formed** are investigated and determined.

Overall agreement between experiment and simulation is good, but still has to be optimized. **Deviations** are mainly attributed to a **missing implementation of actual dendrite growth**.

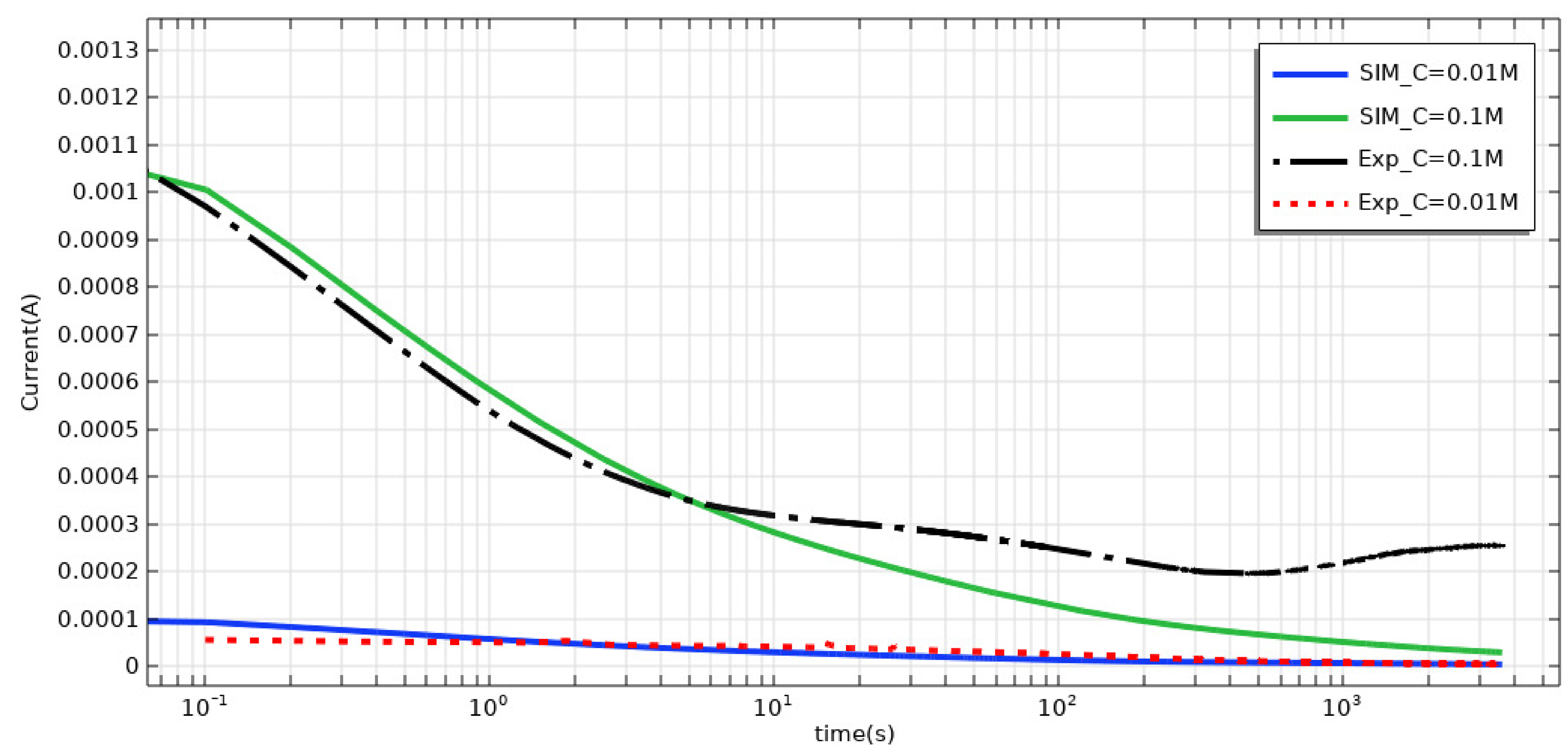


Figure 2: Current Vs. time: correlation of simulation and experiment for different concentration (c=0.1 and 0.01 M, electrolyte:$CuSO_4$)

REFERENCES

[1] Lyon, S. B., Bingham, R., & Mills, D. J. (2017). Advances in corrosion protection by organic coatings: What we know and what we would like to know. Progress in Organic Coatings, 102, 2-7.

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