Field-Assisted Electroplating

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Copper Electrodeposition

Goal

The goal of this project was to understand copper electroplating and test the effects of external fields and pH on the plating process, the surface morphology of the deposited film, and the electroplating efficiency.

Background

Electroplating efficiency and plating quality can be affected by multiple parameters including:

- •Current
- •Electrolyte Concentration
- •pH
- •Gas Sparging
- •External Fields

- In a paper by Hinds et al., changes in plating surface morphology were apparent with the addition of an external magnetic field to a copper sulfate electroplating system
- In a paper by Hinds et al., plating effectiveness was seen to increase deposition rates and mass transport by up to 300% at a pH < 1
- A decrease in pH was seen to enhance plating in Zn and Ni electroplating systems with exposure to magnetic field in a paper by Chouchane et al.

Experiment

The cell is composed of an acrylic cell with 20-25 mL of 0.5M $CuSO_4$ electrolyte solution with two electrodes.

- Platinum wire -anode woven onto a plastic polyvinyl plastic frame
- Silver wire-cathode
  - Masked off to the appropriate cathode area/plating area with clear fingernail polish
  - The wire is cleaned with dilute nitric acid
  - The mass of the silver wire (dry) is taken prior to the experiment
- Solution is sparged for 10 minutes with N_2 gas to remove any dissolved CO_2 in the solution
- The pH of the solution is adjusted with the addition of H_2SO_4
- The current is set to 2 - 5mA
- After approximately one day, the experiment is stopped and deposit allowed to dry. Lastly, the wire (dry) is weighed and the plating efficiency determined.

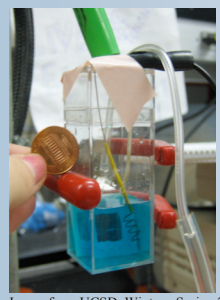
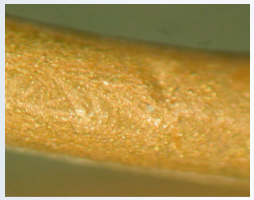


Image from UCSD, Winter - Spring 2007

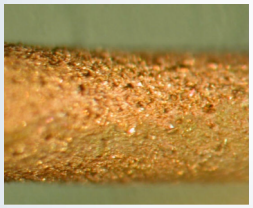
Results

- The photographs below depict the different surface structure of electroplated material without external field addition versus material electroplated with the assistance of an externally applied magnetic field
- When testing different pHs of electroplating solution on a system with and without an applied external magnetic field, the predicted behavior of enhanced plating was not observed (see chart below).

Current (+/- 0.01)	pH(+/- 0.2)	Efficiency (+/- 1.5)	B-Field
2.00	1.5	94.9	N
3.00	0.5	94.5	Y
3.00	0.5	94.1	N
3.00	1.5	90.8	Y
3.00	1.5	94.9	N
3.00	3.0	57.2	Y
3.00	3.0	92.1	N
5.00	0.5	25.3	Y



Copper deposit on wire d=0.7mm (no external field)



Copper deposit on wire d=0.9mm
(external magnetic field of 12,200 Gauss)

Conclusion

- An external magnetic field of 1.2T added to a copper sulfate electroplating system with a current density of 1.27 mA/cm^2 and a 0.5M copper sulfate bath affects the plated surface morphology by making the surface bulkier and rougher (pits and valleys form instead of a smooth surface)
- An external electric field of 6000V added to a similar system does not seem to affect the plated surface morphology of a copper sulfate electroplating system
- No clear trend was established when testing to see if the plating efficiency (of this same system) was affected by pH (ranging from 0.5 to 3) while exposed to a magnetic field
  - The limiting current was calculated to be 2.1 mA without accounting for the B-field and ion drift
  - Our results are not sufficient to disprove the existence of expected trends due to a limitation of data
  - It would be recommended to continue this analysis in greater detail in order to reach a more definite result

Pd/D Electrodeposition

Goal

The goal of this project is to reproduce and evaluate SPAWAR's system for electrodeposition of Pd/D films under external electric and magnetic fields.

Background

San Diego's SPAWAR has electroplated Pd/D under both external magnetic and electric fields and has observed evidence of nuclear fusion activity. Based on their experimental findings, the objective of this project is to replicate their setup and determine if their results can be reproduced by and independent research group.

Experiment

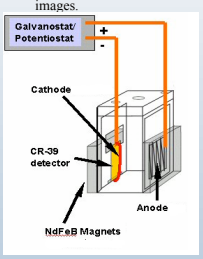
The cell is composed of an acrylic cell with 20-25 mL of 0.03M $PdCl_2$, 0.3M LiCl, and is made with D_2O (deuterated water) electrolyte solution with two electrodes.

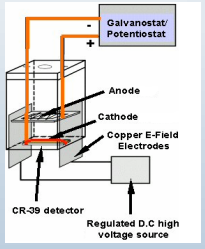
- •Platinum wire -anode woven onto a plastic polyvinyl plastic frame
- •Silver wire-cathode woven into a plastic polyvinyl plastic frame but otherwise prepared the same way as for the copper experiment
  - •The wire holds a piece of CR-39 plastic (for detection of high energy particles) against the polyvinyl plastic frame.

Day #	Current Duration	Current
Plating Phase Procedure		
1	24+ hours	-0.1mA
2	24 hours	-0.2mA
3-14	3, for about 10-14 days until you completely plate out the Pd	-0.5mA
Charging Phase Procedure		
1	24 hours	-1mA
2	24 hours	-5mA
3	24 hours	-10mA
4	24 hours	-25mA
5	24 hours	-50mA
6-7	48 hours	-100mA

Table from The Galileo Project

Once the plating and charging phases are complete, the plastic is removed and etched with 6.5N NaOH to remove the damaged plastic to reveal the "pits" as seen in the images.





Images from SPAWAR c/o Pamela Mosier-Boss

Results

- "Pits" or track marks were found on both the Pd/D codeposition experiments with external electric and magnetic fields applied
- Photographs below depict two different examples of calibrated CR-39 plastic as well as the results obtained in our experiments

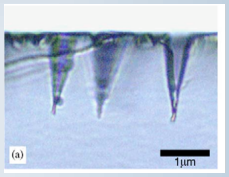


Image from T. Yoshioka et al.

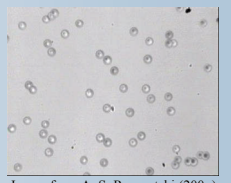
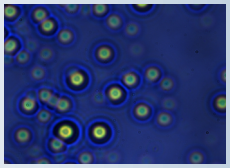


Image from A. S. Roussetski (200x)



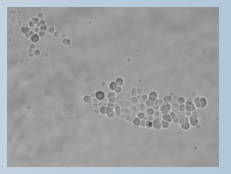
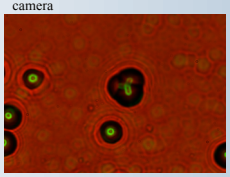


Image from UCSD, Winter - Spring 2007 c/o SPAWAR microscope & camera



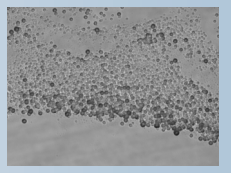


Image from UCSD, Winter - Spring 2007 c/o SPAWAR microscope & camera (Left 1000x, Right 200x)

Conclusion

- There is evidence of alpha particle emissions in the Pd/D codeposition electroplating system with a 0.03M $PdCl_2$ and 0.3M LiCl electrolyte solution in heavy water when external fields of 6000V electric or 1.2T magnetic are applied, and charged as in the chart (see Experiment Section).
- The results of track marks seen in CR-39 plastic are comparable to the results obtained by SPAWAR because of the high amount of pitting across the length of the CR-39 in the area next to the wire (not scattered like the calibration plastics).
- The results of track marks seen in CR-39 plastic are comparable to results obtained calibration methods because of the conical shape of the track marks present on the experimental CR-39 plastic.
- The results were positive for high energy particles in *both* applications of an external
electric field of 6000V and an external magnetic field of 1.2T.

We would like to give a special thanks to the following groups & individuals:

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