You Will Ru(e) the Day: Developing Area-Selective Processes to Enable Ru-Based Interconnect at the 2 nm Node and Beyond

2022 CNF REU Intern: Elisa Simoni

Intern Affiliation: Engineering Physics and Electrical Engineering, Rose-Hulman Institute of Technology

CNF REU Principal Investigator: Prof. James Engstrom, Chemical and Biomolecular Engineering, Cornell University

CNF REU Mentor: Jay Vishnu Swarup, Chemical and Biomolecular Engineering, Cornell University

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Contact: simoniev@rose-hulman.edu, jre7@cornell.edu, jvs64@cornell.edu

Website: https://cnf.cornell.edu/education/reu/2022

Primary CNF Tools Used: Veeco Savannah, Oxford ALD FlexAL, Oxidation Furnace, Heidelberg Mask Writer - DWL2000, SC4500 Evaporator

Abstract:

For many years, scientists have used photolithography to layer patterns onto wafers. However, the minimum size of the features on the patterns is limited by the wavelength of the light used. Now, as the electronics industry seeks to create single digit nanometer features, photolithography is reaching the limits of its capabilities; a new method for patterning substrates is needed. One such way is through selective deposition of materials in which deposition is determined by the surface chemistry. In atomic layer deposition (ALD), a film is typically grown using half reactions in an AB cycle. First, the precursor (A) binds the substrate. Then, the co-reactant (B) reacts on the surface with the precursor to grow the desired film. Each AB cycle results in a film growth thickness of approximately one angstrom [1]. Because the user controls the number of cycle repetitions, thickness can be tailored with high precision. For area-selective ALD, if a chemical (co-adsorbate) is introduced before and alongside the precursor, the co-adsorbate can attach to certain surfaces and block film growth in order to achieve selectivity [2]. Additionally, the typical material used for electrical interconnects is copper. However, for single digit nanometer features, ruthenium is a better conductor. Overall, the purpose of this project is to create different sized line-and-space patterns of alternating ruthenium and dielectrics (Al_2O_3 and SiO_2) using a lift-off process. These patterns can then be used to test which co-adsorbates provide the best selectivity given the metals and dielectrics used in the patterns.

Summary of Research:

Ten 100 mm silicon wafers were utilized to create the patterns. First, all wafers were cleaned using an RCA clean. A 200 nm film of SiO_2 was thermally grown on five of the wafers using an oxidation furnace. A 50 nm film of Al_2O_3 was deposited via ALD on the other wafers using the Veeco Savannah and the Oxford ALD FlexAL. The negative photoresist nLOF2020 was spun on each wafer at 3000 rpm for one minute, followed by a one-minute bake. A GDSII file containing line-and-space patterns of 100, 30, 10, 3, and 1 µm was created using the gdstk python library and then used along with the Heidelberg Mask Writer - DWL2000 to create the mask pattern. Each wafer was then exposed using the ABM contact aligner, baked on a hotplate for one minute, and developed in the Hamatech wafer processor.

The SC4500 evaporator was used to deposit the metals. Five nm of titanium was first deposited to help the ruthenium stick to the wafer. Then, 20 nm of ruthenium was deposited. After stripping the photoresist, the pattern was then examined using atomic force microscopy (the AFM).

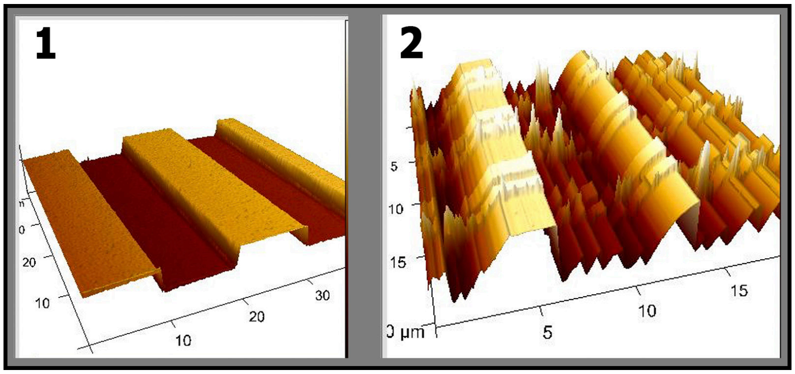

Figure 1, left: 10 µm line-and-space pattern. Figure 2, right: 3 µm line-and-space pattern.

Overall, the 100, 30, and 10 µm lines had good coverage and little surface roughness. However, there were holes and significantly more roughness in the 3 and 1 µm lines. This can be seen in the AFM images of the 10 µm and 3 µm lines as shown in Figures 1 and 2. This is likely due to the wafer not being clean enough before undergoing the photolithography process. Therefore, the 100, 30, and 10 µm lines can now be utilized for area-selective depositions.

References:

[1] S. M. George, "Atomic Layer Deposition: An Overview," ACS Publications, Nov. 2009. https://pubs.acs.org/doi/pdf/10.1021/cr900056b (accessed Aug. 13, 2022).

[2] T. Suh, et al., "Competitive Adsorption as a Route to Area-Selective Deposition," ACS Appl. Mater. Interfaces, vol. 12, no. 8, pp. 9989–9999, Feb. 2020, doi: 10.1021/acsami.9b22065.

PROCESS & CHARACTERIZATION