Morphology Control of SnS Nanoplatelets Towards Application as a Two-Dimensional Chemoresponsive Gas Sensor

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INTRODUCTION

Motivation: Previous studies have demonstrated that the resulting composite of $Ti_3C_2T_x$ MXene with semiconducting TiO_2 displays more sensitive response to certain volatile organic compounds [1]. In addition to TiO_2, several other metal oxides are known for their superior gas sensing properties with tin dioxide (SnO_2) standing out because of its exceptional characteristics. In order to test SnS-MXene sensing properties, tin sulfide (SnS) platelets must be successfully synthesized. Subsequent attempts at SnS platelet synthesis at the beginning of this project resulted in a variety of incorrect morphologies, most predominant being hexagons.

METHOD

General Procedure 1 mL trioctylphosphine (TOP), 0.4 mL of oleic acid (OA), and 52.9 mg of tin(II) acetate were dissolved in 10 mL diphenyl ether in a vacuum sealed Argon environment. After heating to 75 °C for 2 hours to partially convert tin(II) acetate to tin oleate and remove acetic acid, the reaction was further heated to 230 °C. Once reaction concluded, 19.5 mg of thioacetamide in 0.2 mL dimethylformamide was rapidly injected into the reaction flask. After an additional 5 minutes, the reaction was removed from heat and allowed to cool to room temperature.

To purify nanostructures, samples were centrifuges at 4000 rpm for 3 minutes in toluene. Samples were characterized via transmission electron microscopy (TEM).

Parameters changed: Surfactants doubled with ratio kept the same, duration of heating after addition of TAA doubled, and stir bar added to flask.

REFERENCES

[1] Hanna Pazniak, Ilya A. Plugin, Michael J. Loes, Talgat M. Inerbaev, Igor N. Burmistrov, Michail Gorshenkov, Josef Polcak, Alexey S. Varezhnikov, Martin Sommer, Denis V. Kuznetsov, Michael Bruns, Fedor S. Fedorov, Nataliia S. Vorobeva, Alexander Sinitskii, and Victor V. Sysoev. *ACS Applied Nano Materials* **2020** 3 (4), 3195-3204
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RESULTS

Initially, we observed hexagonal platelet morphology due to unknown issues with our synthesis process. Doubling the surfactants resulted in the synthesis of SnS with platelet morphology, though the small thick hexagonal morphology remained.

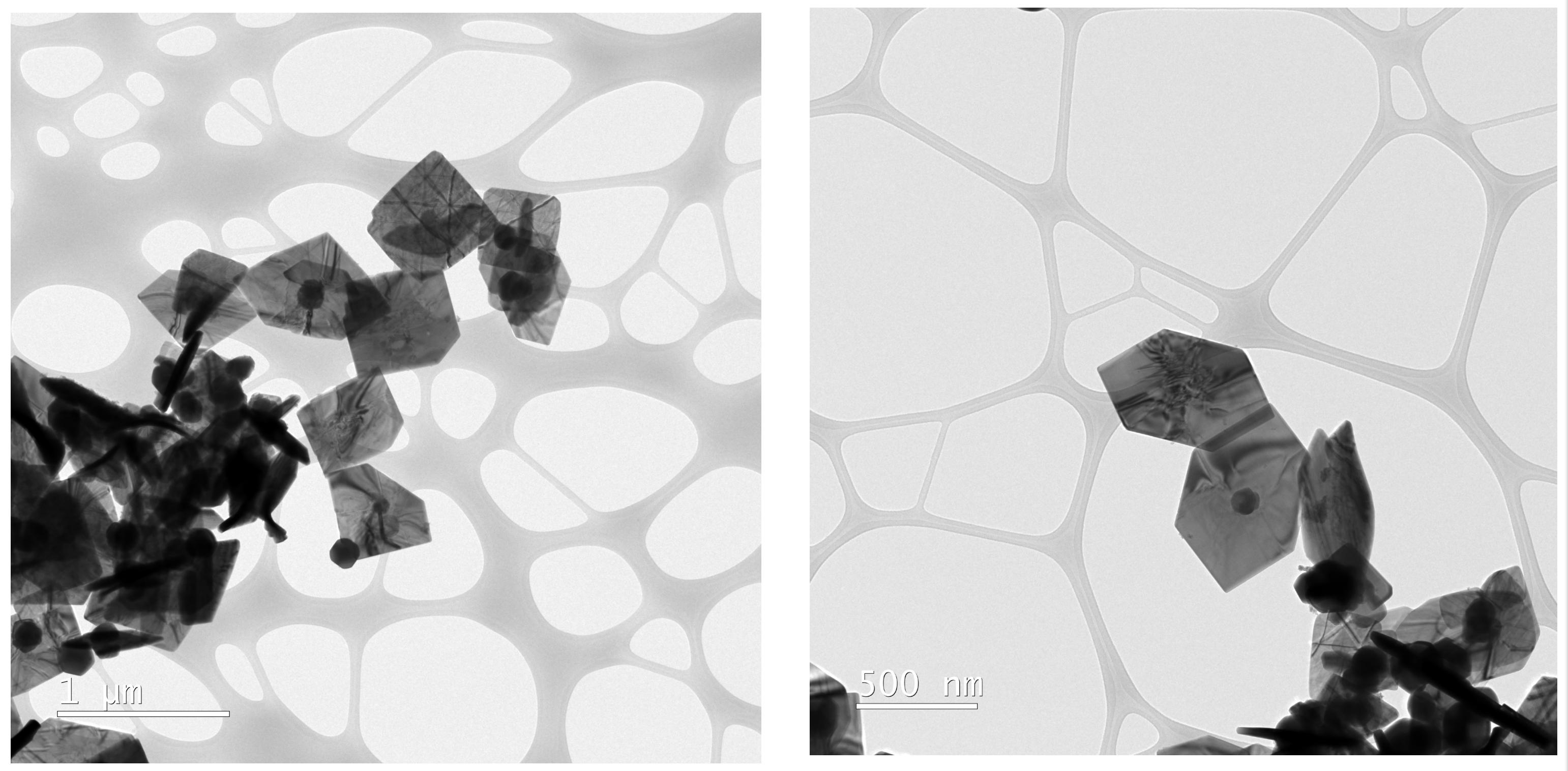

Figure 2: Hexagonal platelet morphology from the beginning of the project

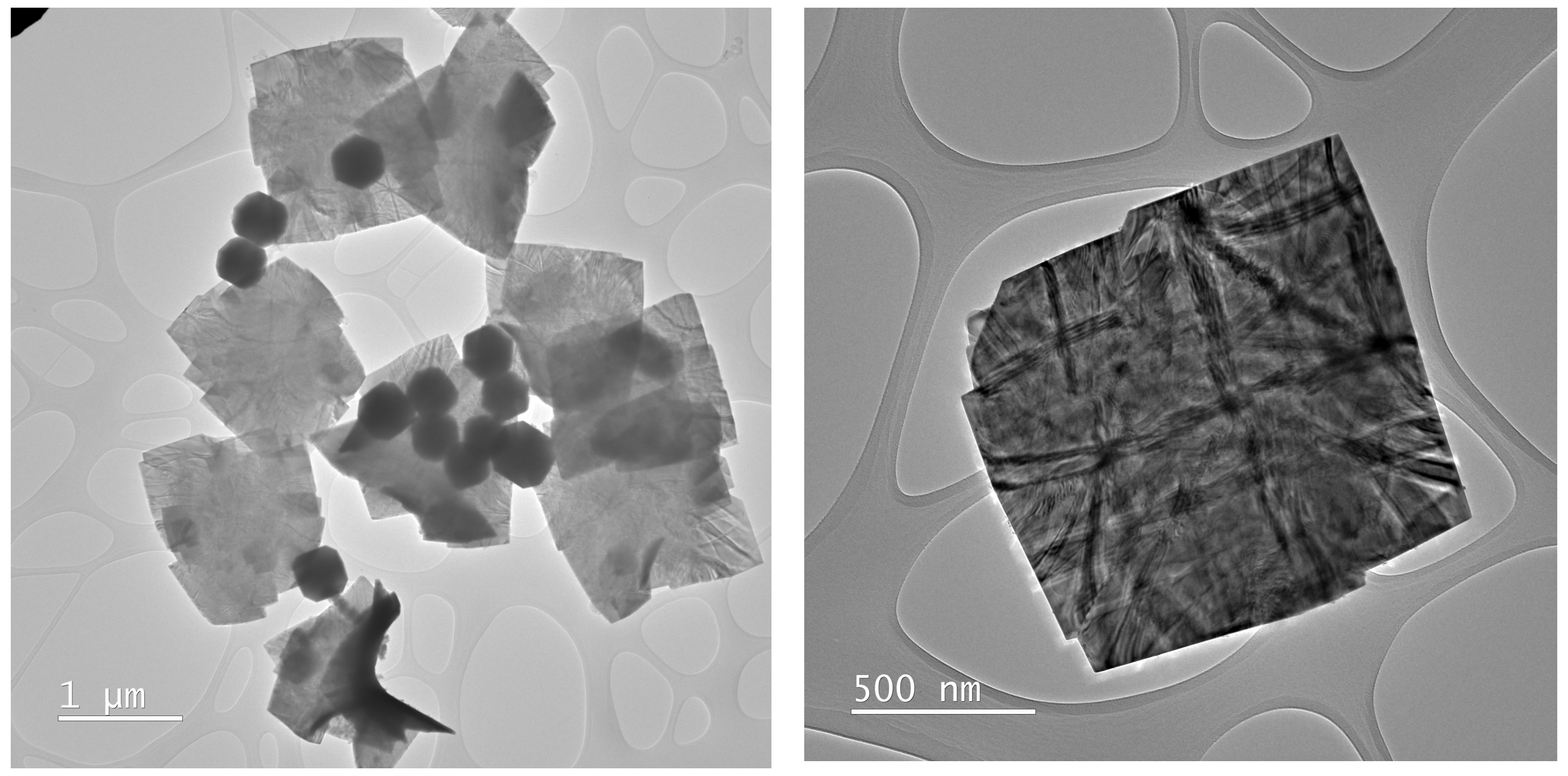

Figure 3: Platelets & secondary hexagonal morphology from doubling surfactants

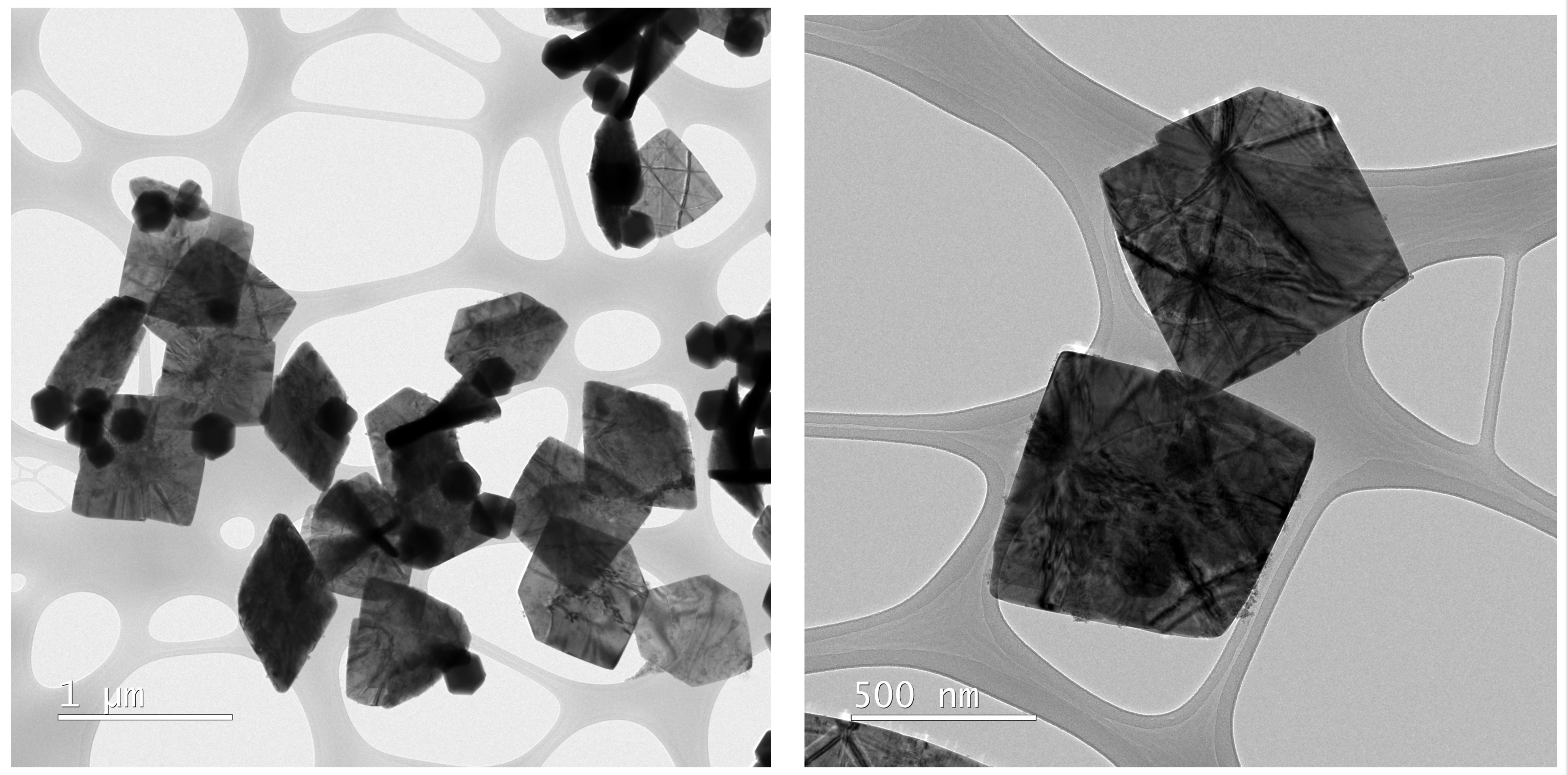

Figure 4: Platelets & secondary hexagonal morphology from doubling surfactants and heating for 10 minutes at the end rather than 5

DISCUSSION & CONCLUSION

The primary goal of tuning our synthesis to produce SnS nanoplatelets was achieved by doubling the amount of surfactants used while keeping the surfactant ratio described in literature the same. While we do have our desired product, a secondary morphology associated with the metastable pseudo tetragonal phase is also produced. This morphology typically dominates when no surfactants are present. Subsequent attempts at this synthesis used double the surfactant while keeping the ratio of TOP to OA consistent while attempting to increase precursor exposure to surfactants through longer heating durations and the implementation of a stir bar. This was unsuccessful in eliminating the secondary morphology. While a few more attempts at synthesizing isolated SnS nanoplatelets may be made, it is likely that moving forward the two morphologies will be separated through centrifugation so that the nanoplatelets may be used in future projects.

FUTURE DIRECTIONS

Previous studies have demonstrated that the resulting composite of $Ti_3C_2T_x$ MXene with semiconducting TiO_2 displays more sensitive response to certain volatile organic compounds. In addition to TiO_2, several other metal oxides are known for their superior gas sensing properties with tin dioxide (SnO_2) standing out because of its exceptional characteristics. Once SnS with platelet morphology is obtained either through synthesis or through centrifugation, the $Ti_3C_2T_x$ MXenes will be decorated with the SnS (which will then form SnO_2), and their gas sensing properties will be investigated. The SnS-MXene heterostructures will be synthesized into a colloidal solution and drop-casted onto a Si/SiO_2 substrate with patterned electrodes. These substrates will be fabricated into gas sensing chips and will subsequently be used for characterization of electrical properties. Gas sensing measurements will be taken by introducing the chip system to an inert N_2 environment where the sensing film will be introduced to a variety of volatile organic compounds at various concentrations. SnS-MXene response will be analyzed by comparing conductivity found between gasses, concentrations in the ppm range, and temperatures.

ACKNOWLEDGEMENTS

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