Novel Germanium Oxide Nanomaterial Synthesis

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Abstract

- The goal of this FURI project is to synthesize thin film germanium oxides. Germanium dioxide has known bulk properties such as infrared light transparency, refractive and optical dispersion properties make it useful for wide-angle lenses and fiberoptics[4], but has not been synthesized in a thin film form. Materials take on vastly different properties when they are on the nano-scale.

- Nanomaterials have been utilized in many ways such as batteries, insulation, medicine, transportation, and optics[1].

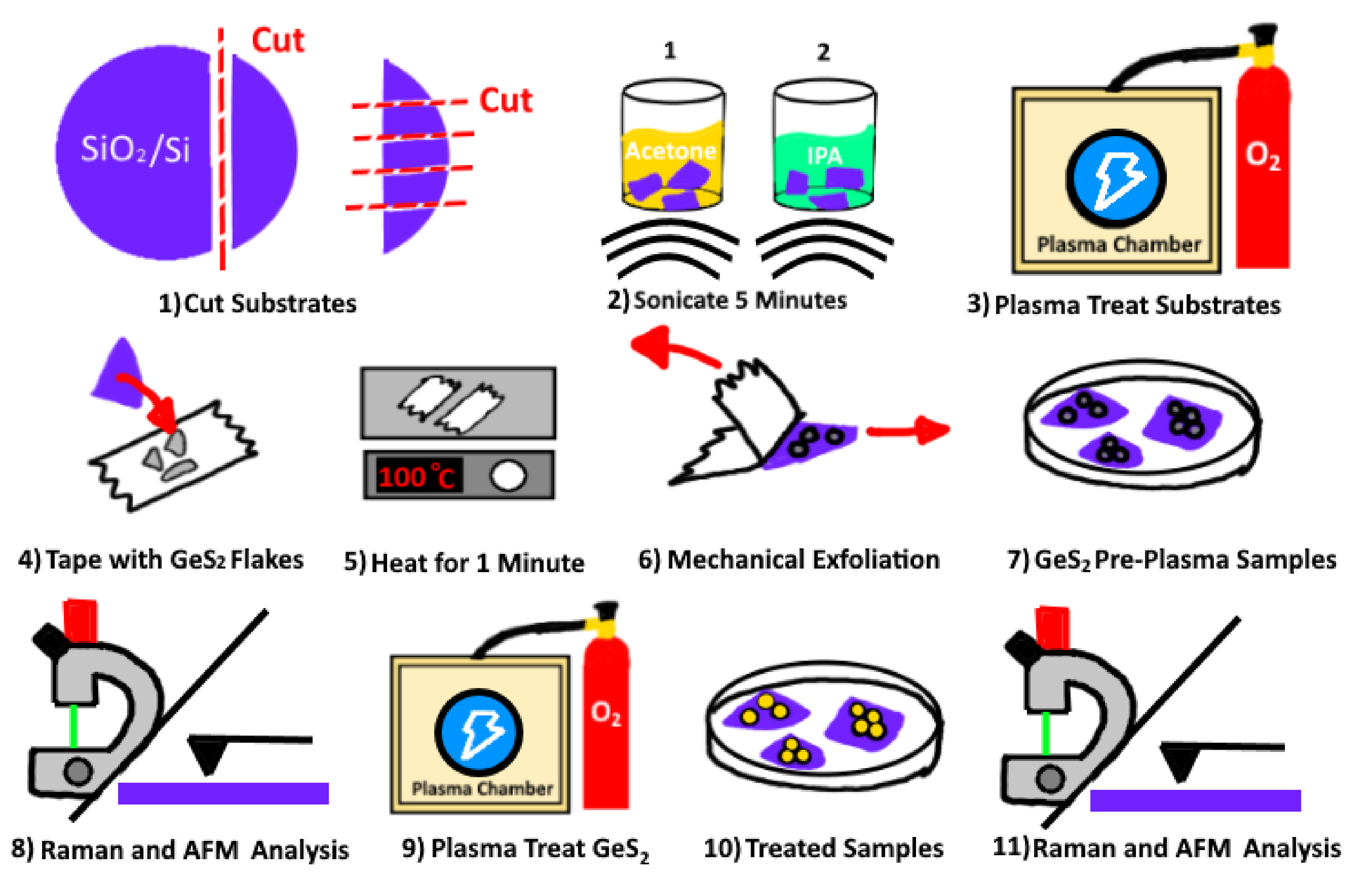
- The hypothesis of this project is that thin film germanium oxide can be synthesized based on previous research by the Wang research group[2]. Their results show that molybdenum trioxide (MoO_3) and tungsten trioxide (WO_3) can be synthesized from their respective sulfides MoS_2 and WS_2 by atmospheric plasma treatment in the form of thin-flake nanomaterials.

Methodology

The nanomaterial synthesis method is to convert thin film germanium disulfide (GeS_2) into thin film germanium oxides (GeO_x) with the following steps:

1. Mechanical exfoliation is used to prepare atomically thin sheets of GeS_2 that are then characterized with Raman spectroscopy and atomic force microscopy (AFM).
2. Subsequently, these samples are exposed to atmospheric plasma with the hypothesis that this will form thin-film GeO_x where x represents the most favorable thin film germanium oxide stoichiometry.

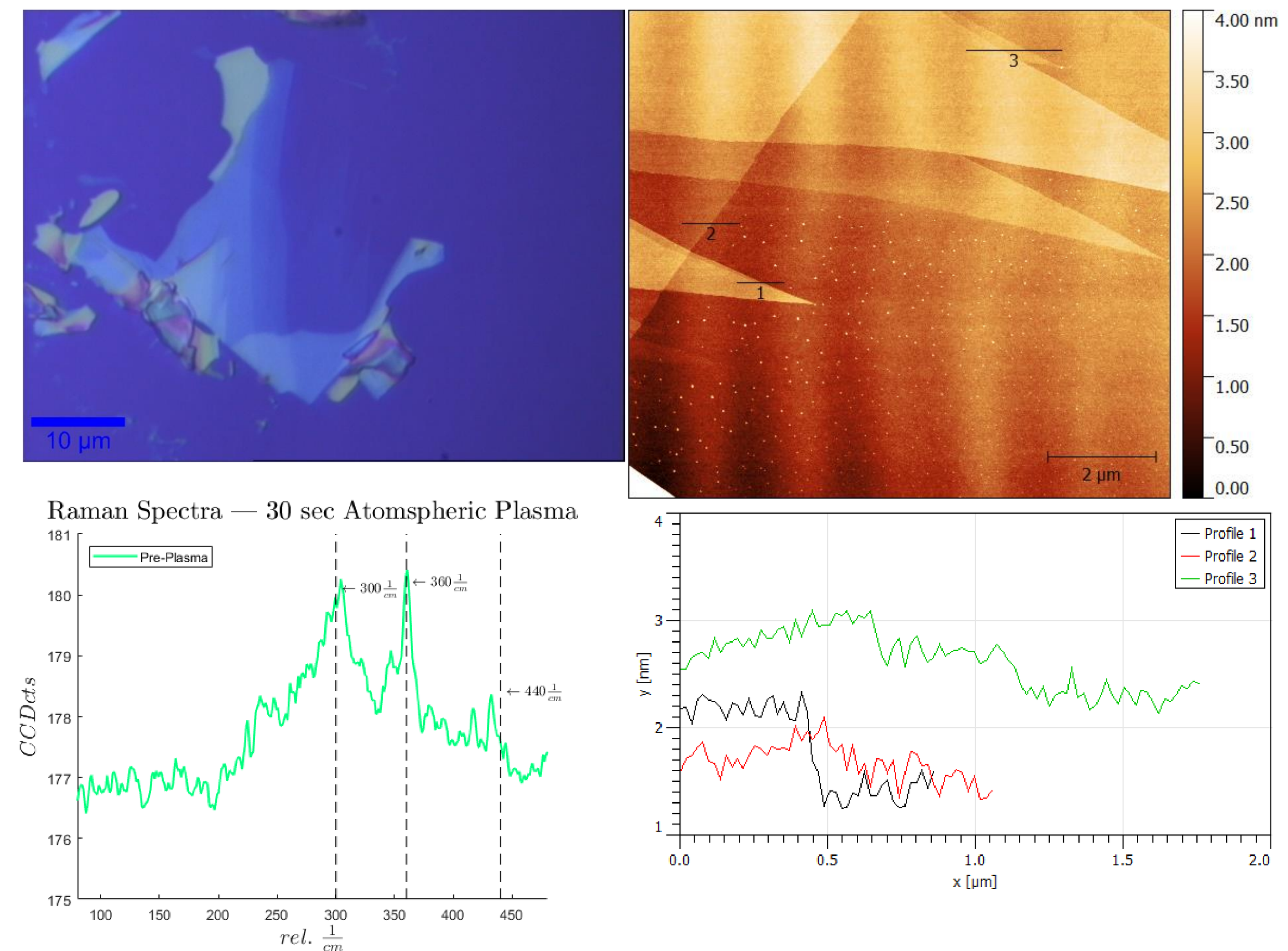
A great deal of effort was put into achieving sufficiently thin GeS_2 exploring different methods used by other scientist to produce nano materials with mechanical exfoliation. The utilization of a hot plate to increase thermal energy and likelihood of atomic planes separating was found to produce thin films in the range of 2 – 10 nanometers thick. The steps are detailed in figure 1.



Experimental Results

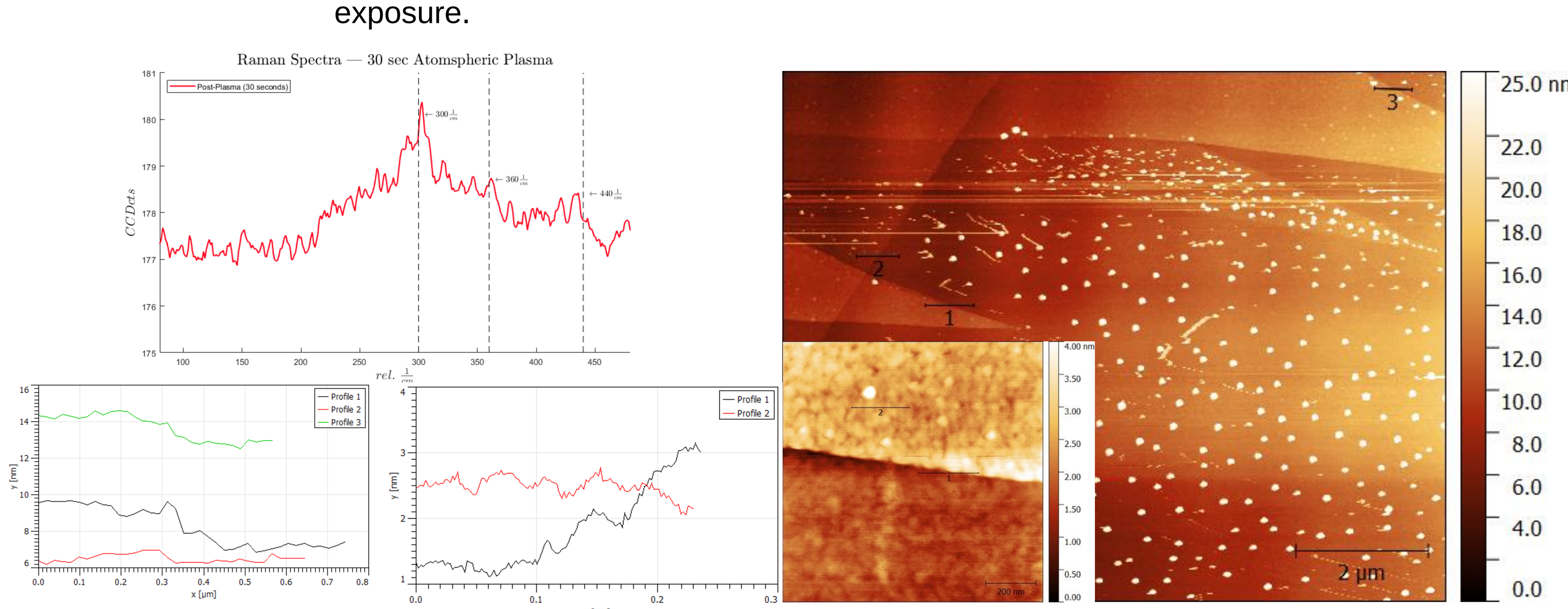
Synthesis of GeS_2 Flakes

- Referencing an article on material synthesis of thin flakes[3] mechanical exfoliation of GeS_2 was found to be most favorable by plasma treating substrates to be hydrophilic and exposing samples to 100 ºC heat for one minute before cleaving. This produced thin flakes that are characterized by Raman spectroscopy and atomic force microscopy.



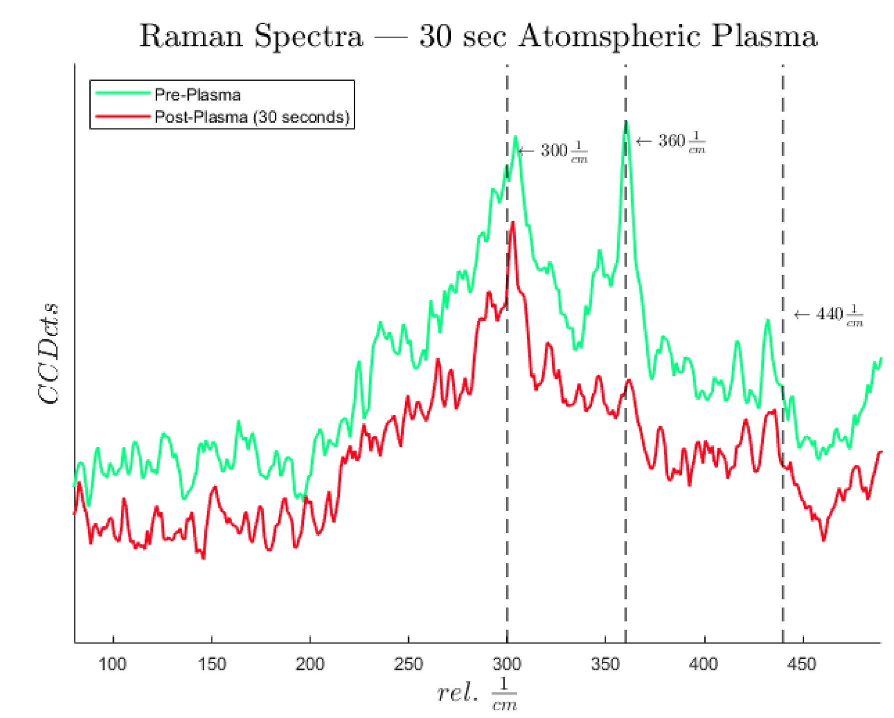
Oxidation by Air-Plasma

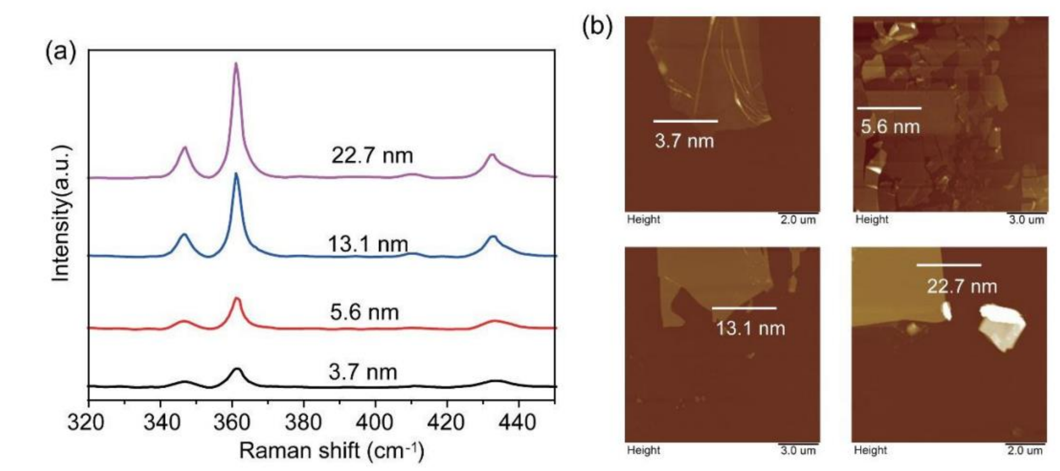
- These flakes are then placed in a plasma chamber and exposed to an atmospheric gas flow with a base pressure of 85 mTorr and a working pressure of 885 mTorr. The chamber outputs 18 Watts of power for 30 seconds for this sample. Exposure times are still being experimented with. The following figures list the results of a 30 seconds atmospheric plasma exposure.



Conclusion

- Successfully exfoliated GeS_2 using the hot plate method[3]
- Characterized thin germanium disulfide using Raman and atomic force microscopy (AFM)
- Air plasma treated flakes exhibit some surface activity. It is observed in this treatment (see change in 360 1/cm peak) but with a lack of reference material and supporting characterization methods to determine or verify the chemical composition and bonding of the materials, no conclusions can be confirmed yet. An article by Jin-Song Hu demonstrates that as GeS_2 becomes thinner the Raman peaks become shorter[4].





[4] Jin-Song Hu et al. Adv. Funct. Mater 2019

Future Focus

Characterization and/or Density Functional Theory

Given the consistent Raman peaks for pre-plasma treated GeS_2 and post-plasma treated GeS_2 activity can be confirmed for the GeS_2 flakes. The results of experiments thus far need to be verified by other methods that will be explored in the Spring Semester of 2021.

Sources

[1] Nano Technology Initiative 2000, accessed September 26th, 2020, <https://www.nano.gov/you/nanotechnology-benefits>

[2] Chu, X. S., Li, D. O., Green, A. A., Wang, Q. H. (2017). Formation of MoO_3 and WO_3 nanoscrolls from MoS_2 and WS_2 with atmospheric air plasma. *Journal of Materials Chemistry C., Vol.*(5) pg 11301 - 11309. DOI: 10.1039/c7tc02867a

[3] Yuan, Huang, et al, (2015). Reliable Exfoliation of Lare-Area High-Quality Flakes of Graphene and Other Two-Dimensional Materials. Journal of ACS NANO, Vol. (9), NO. 11, 10612–10620.

[4] Jin-Song Hu et al. Adv. Funct. Mater 2019