

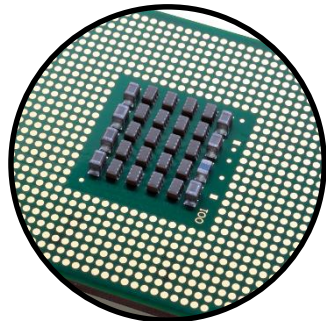
Understanding the Structure of High-K Gate Oxides

Andre Miranda

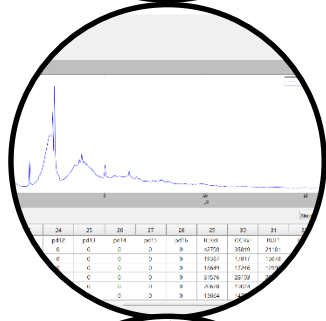
Office of Science, Science Undergraduate Laboratory
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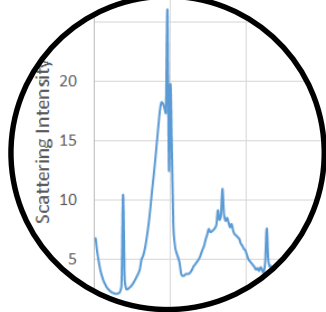
Hafnium Oxide (HfO_2) amorphous thin films are being used as gate oxides in transistors because of their high dielectric constant (κ) over Silicon Dioxide. The present study looks to find the atomic structure of HfO_2 thin films which hasn't been done with the technique of this study. In this study, two HfO_2 samples were studied. One sample was made with thermal atomic layer deposition (ALD) on top of a Chromium and Gold layer on a silicon wafer. The second sample was made with plasma ALD on top of a Chromium and Gold layer on a Silicon wafer. Both films were deposited at a thickness of 50nm. To obtain atomic structure information, Grazing Incidence X-ray diffraction (GIXRD) was carried out on the HfO_2 samples. Because of this, absorption, footprint, polarization, and dead time corrections were applied to the scattering intensity data collected. The scattering curves displayed a difference in structure between the ALD processes. The plasma ALD sample showed the broad peak characteristic of an amorphous structure whereas the thermal ALD sample showed an amorphous structure with characteristics of crystalline materials. This appears to suggest that the thermal process results in a mostly amorphous material with crystallites within. Further, the scattering intensity data was used to calculate a pair distribution function (PDF) to show more atomic structure. The PDF showed atom distances in the plasma ALD sample had structure up to 10 Å, while the thermal ALD sample showed the same structure below 10 Å. This structure that shows up below 10 Å matches the bond distances of HfO_2 published in literature. The PDF for the thermal ALD sample also showed peaks up to 20 Å, suggesting repeating atomic spacing outside the HfO_2 molecule in the sample. This appears to suggest that there is some crystalline structure within the thermal ALD sample.



What Is a Gate Oxide?

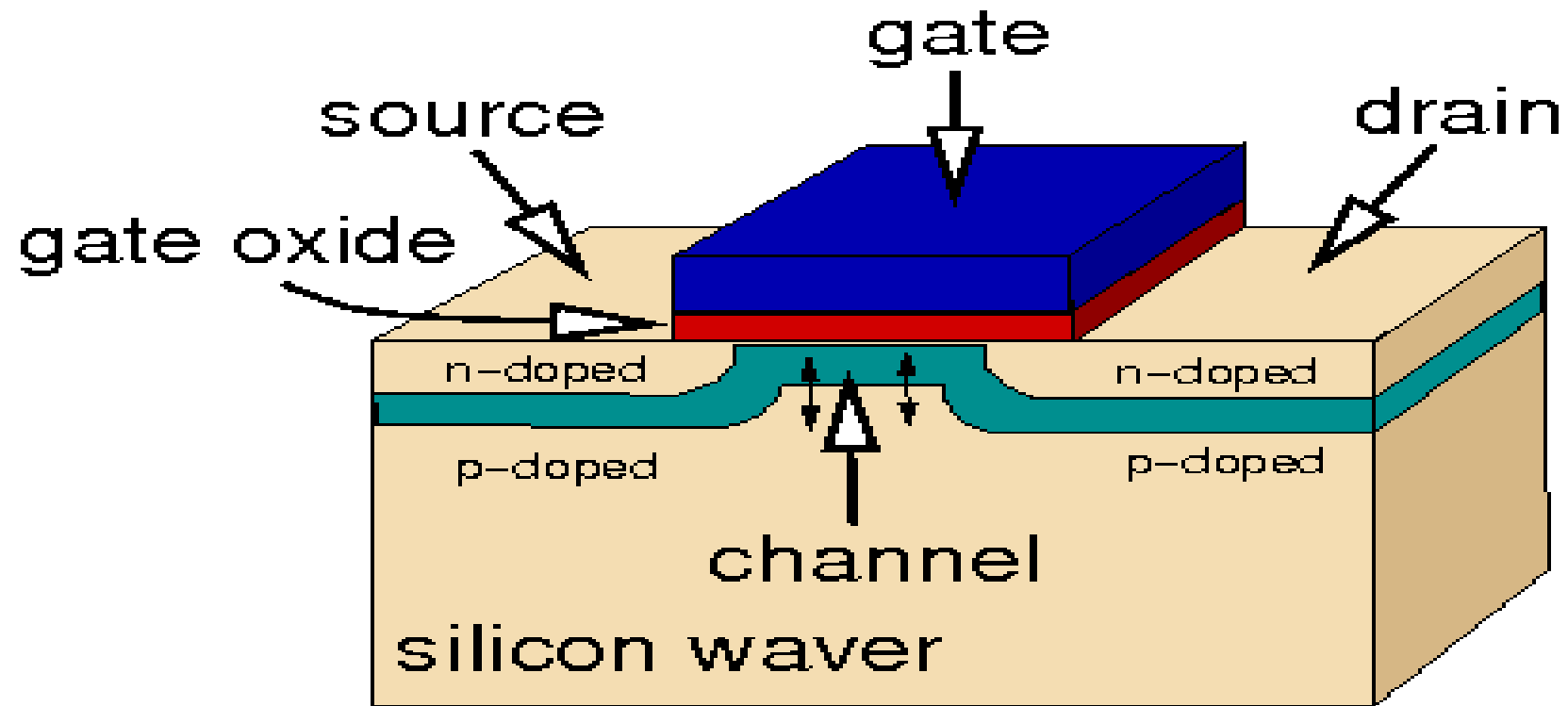


How to get Atomic Structure?



What does the Data Show?

What Makes a Good Gate Oxide?



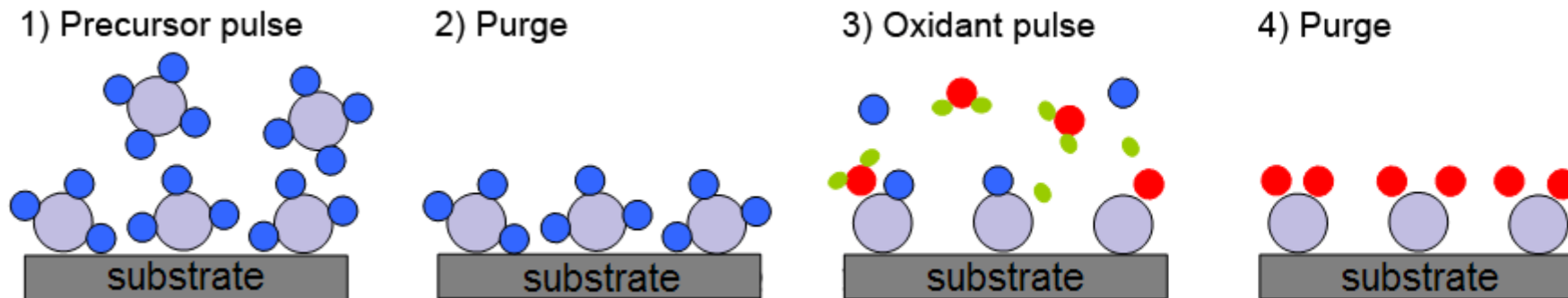
$$C = \frac{\kappa \epsilon_0 A}{t}$$

Metal–Oxide Field–Effect Transistor (MOSFET)

<https://www2.pt.tu-clausthal.de/atp/projects/high-k.html>

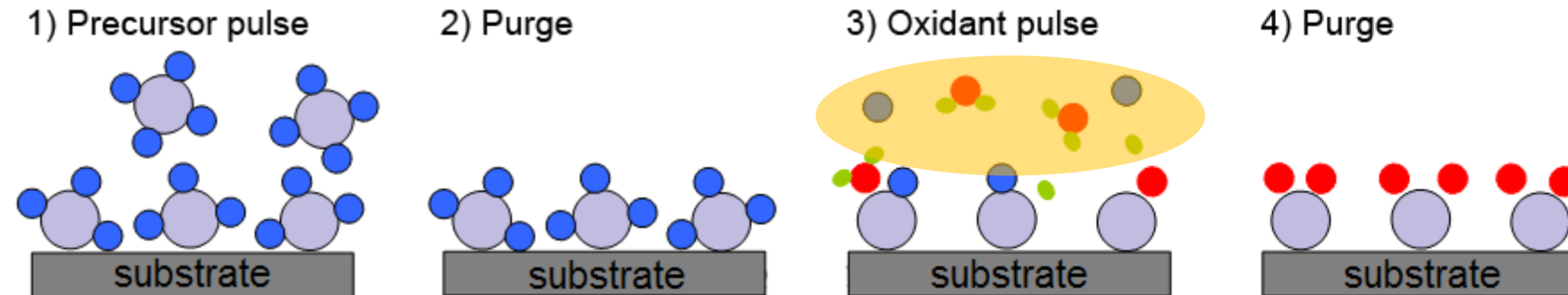
Atomic Layer Deposition

- Thermal ALD

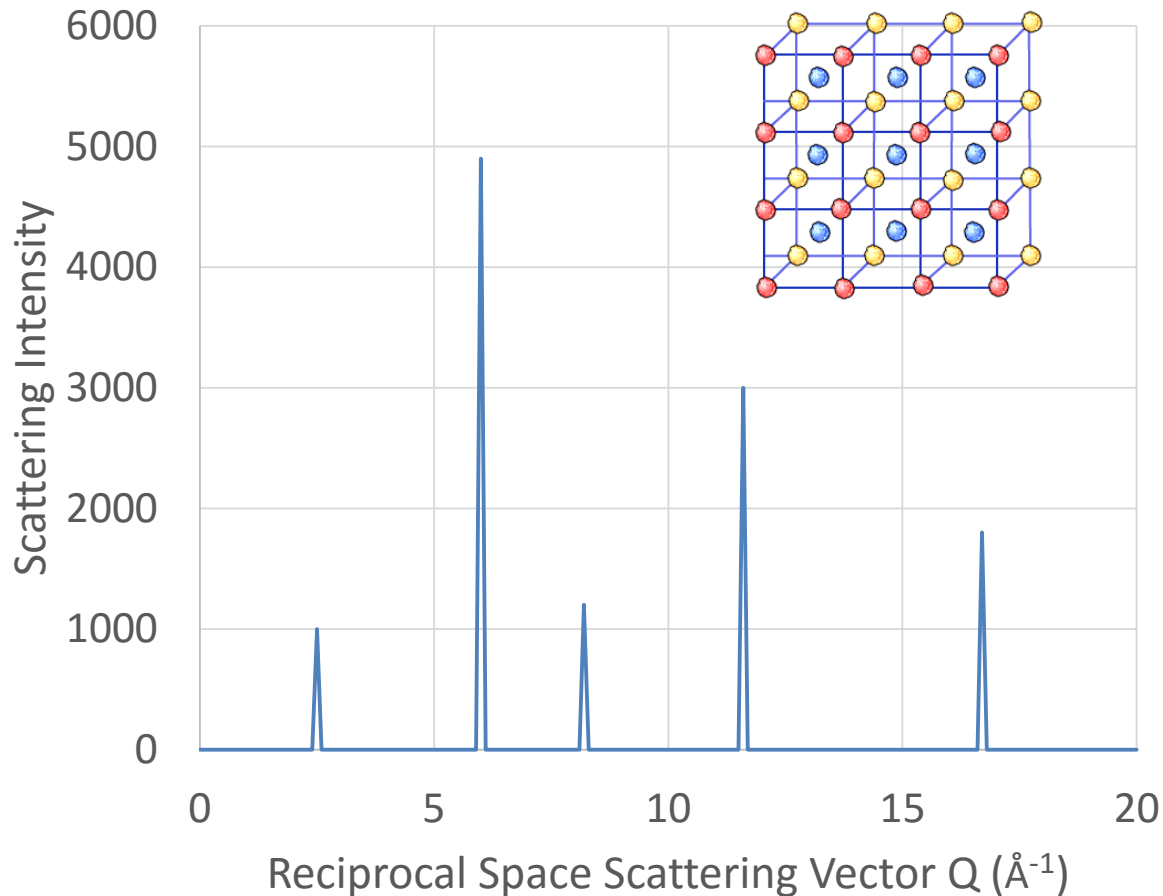


Atomic Layer Deposition

- Plasma ALD



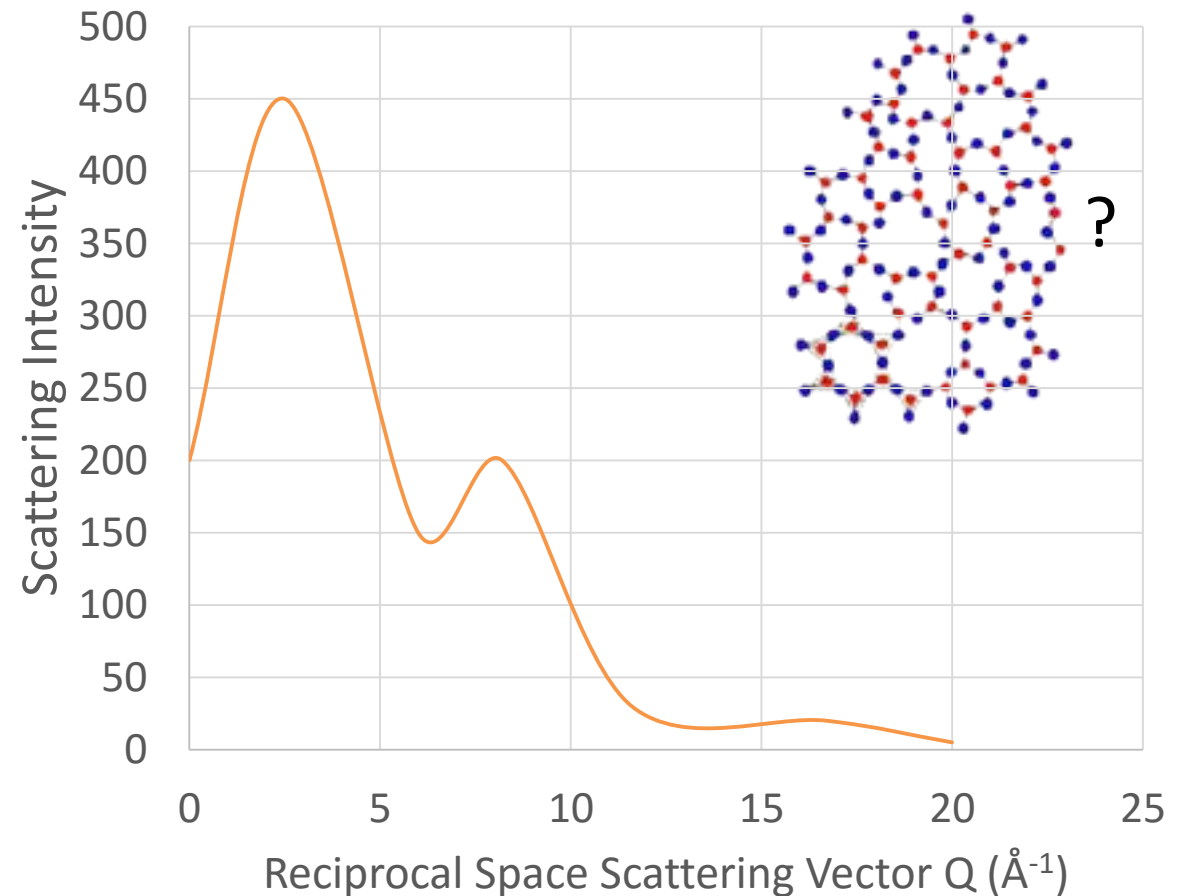
Crystal XRD



<http://chemistry.tutorvista.com/inorganic-chemistry/crystal-structure.html>

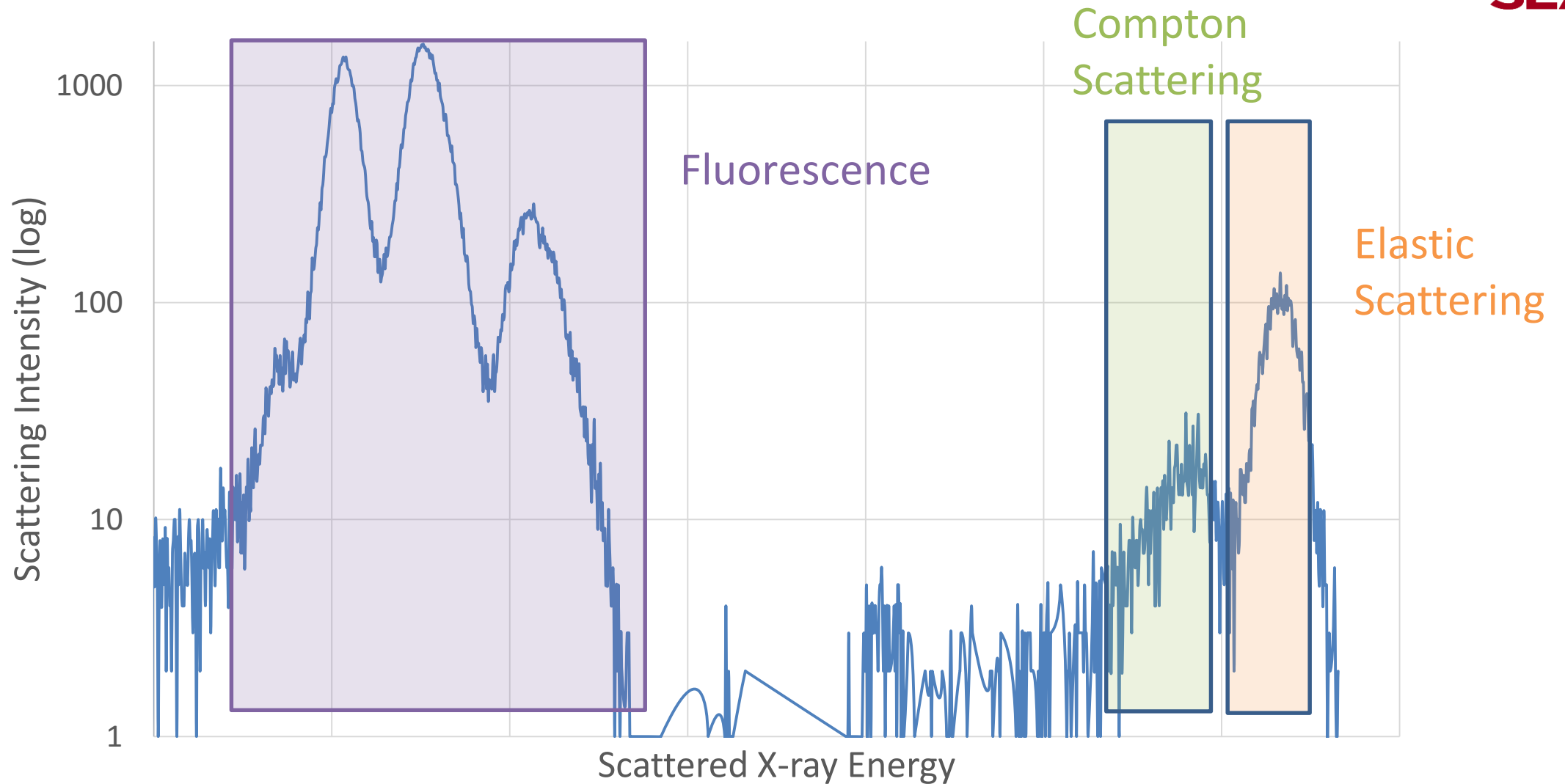
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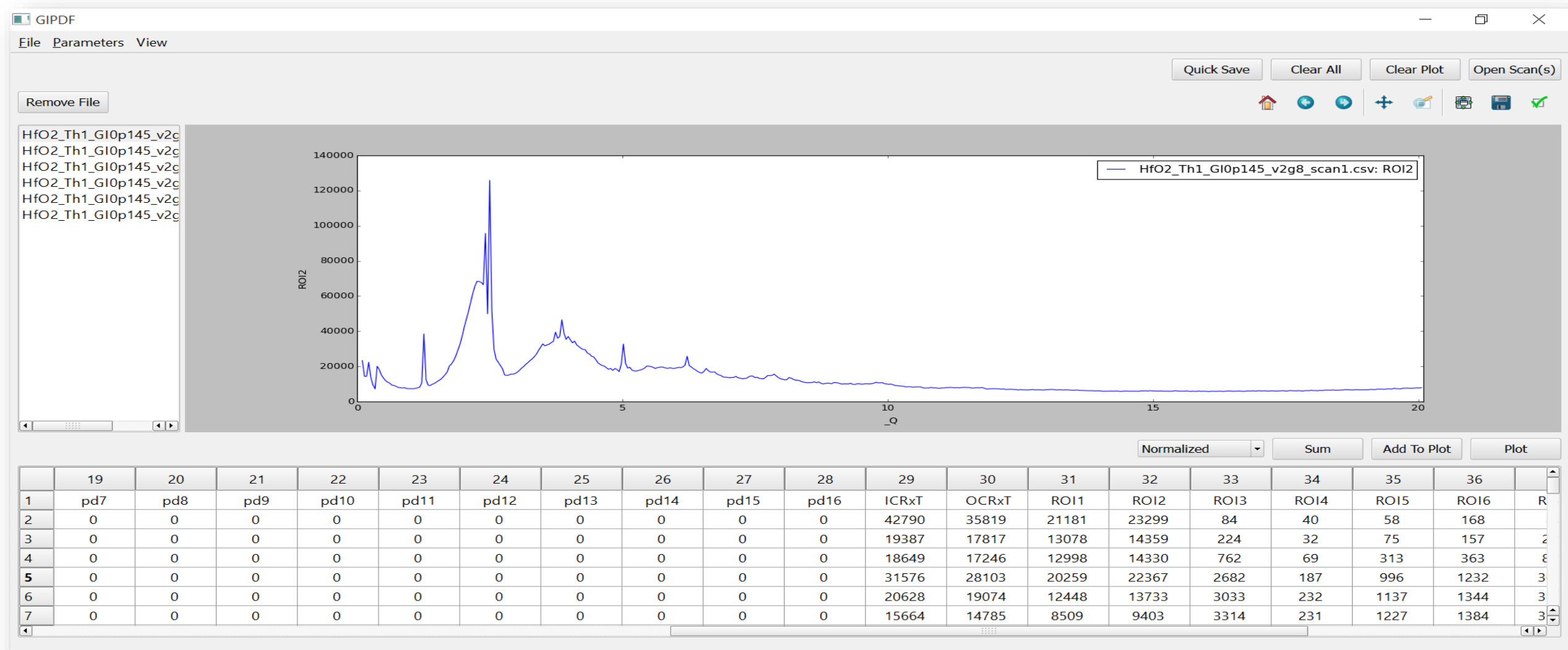
Amorphous XRD



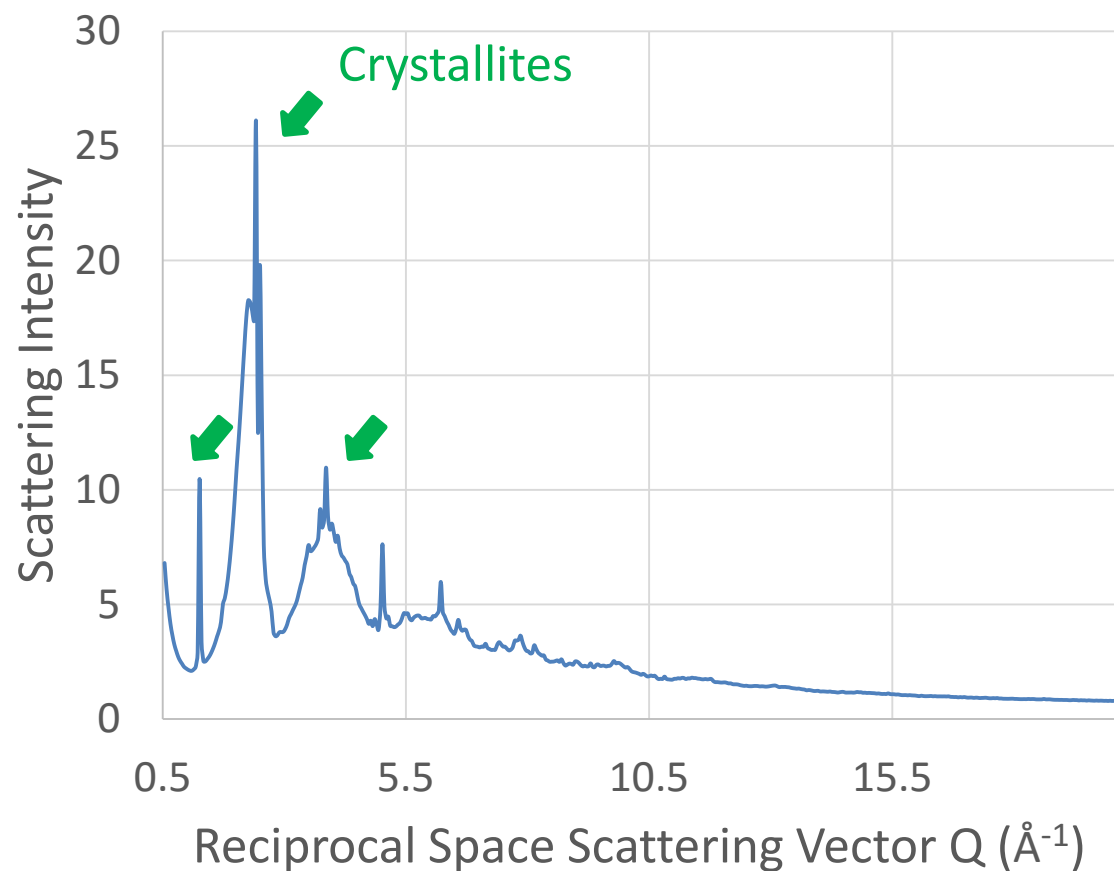
<http://www.eoearth.org/view/article/155223/>

Spectrum



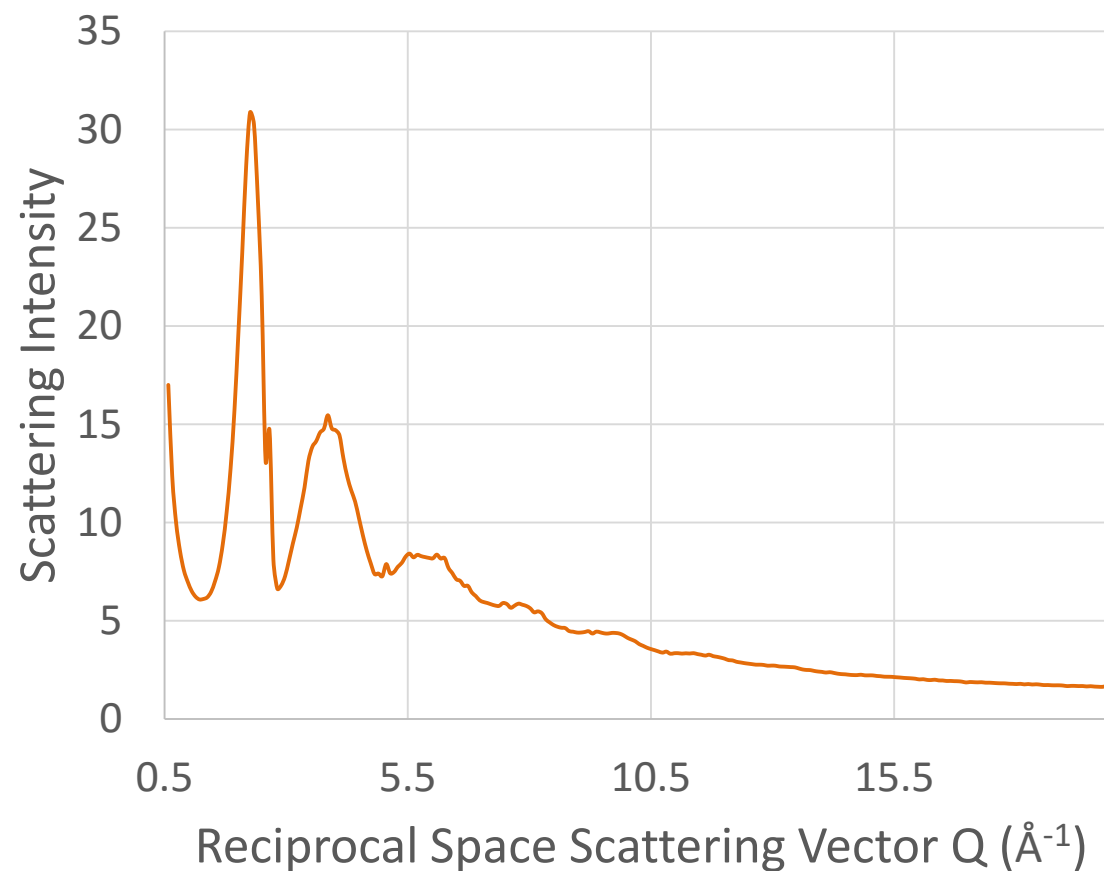


Thermal

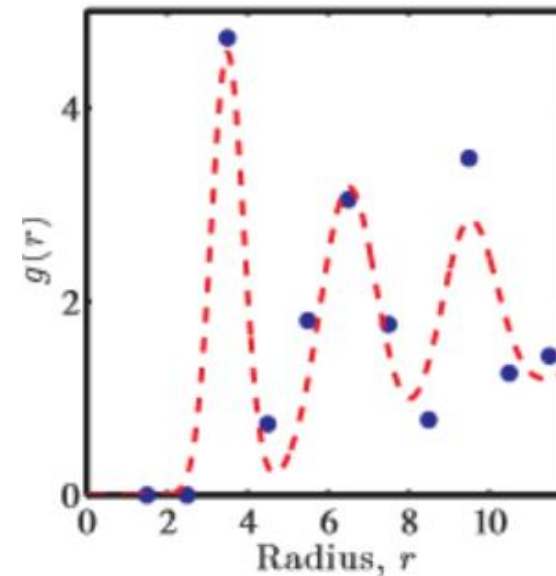
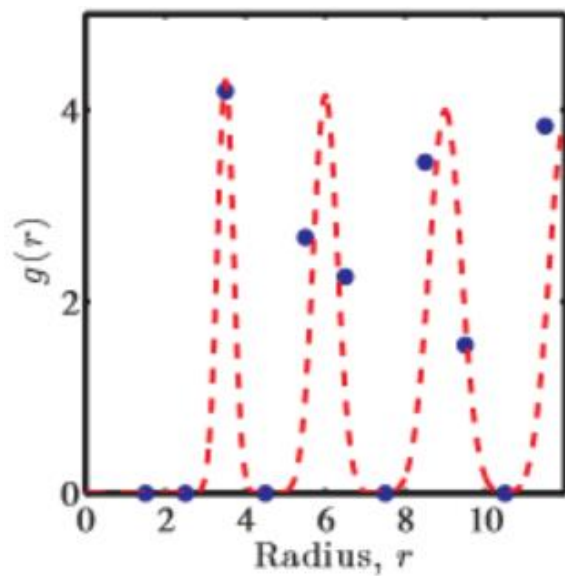
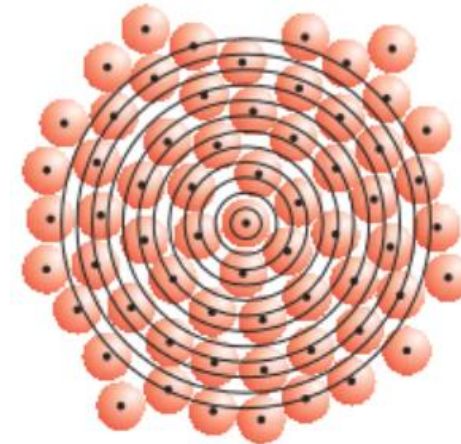
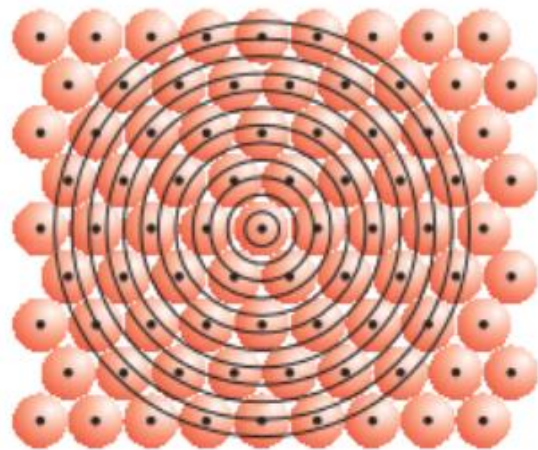


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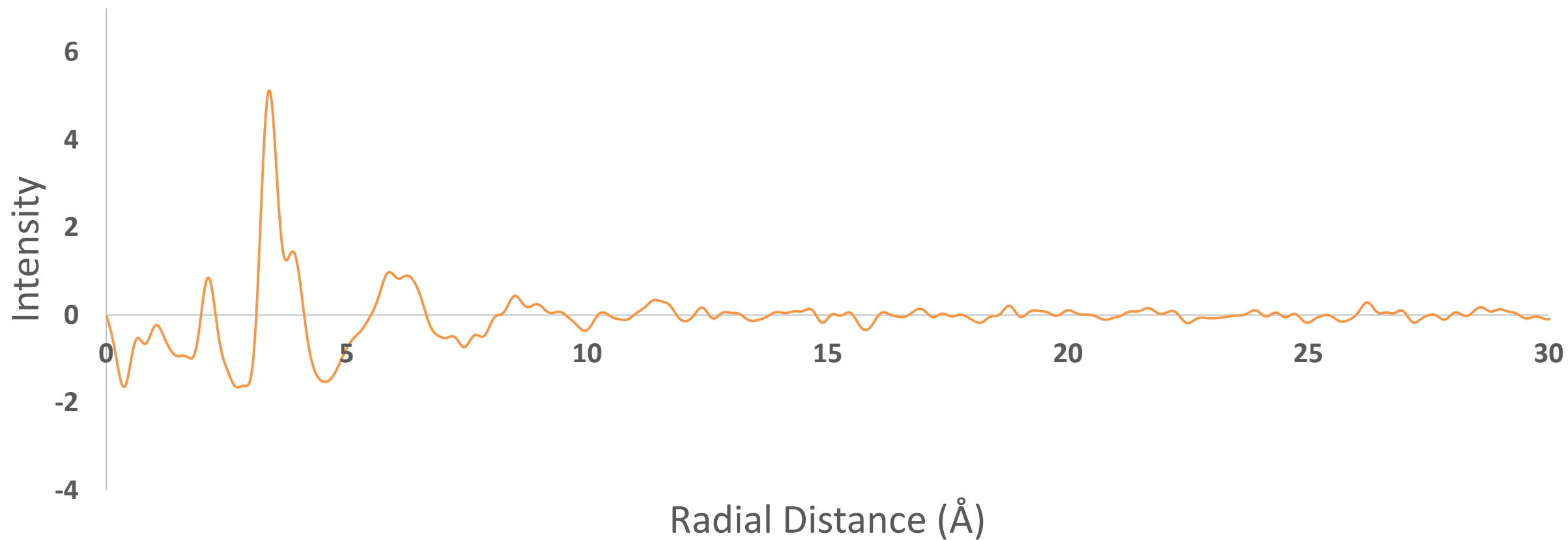
Plasma



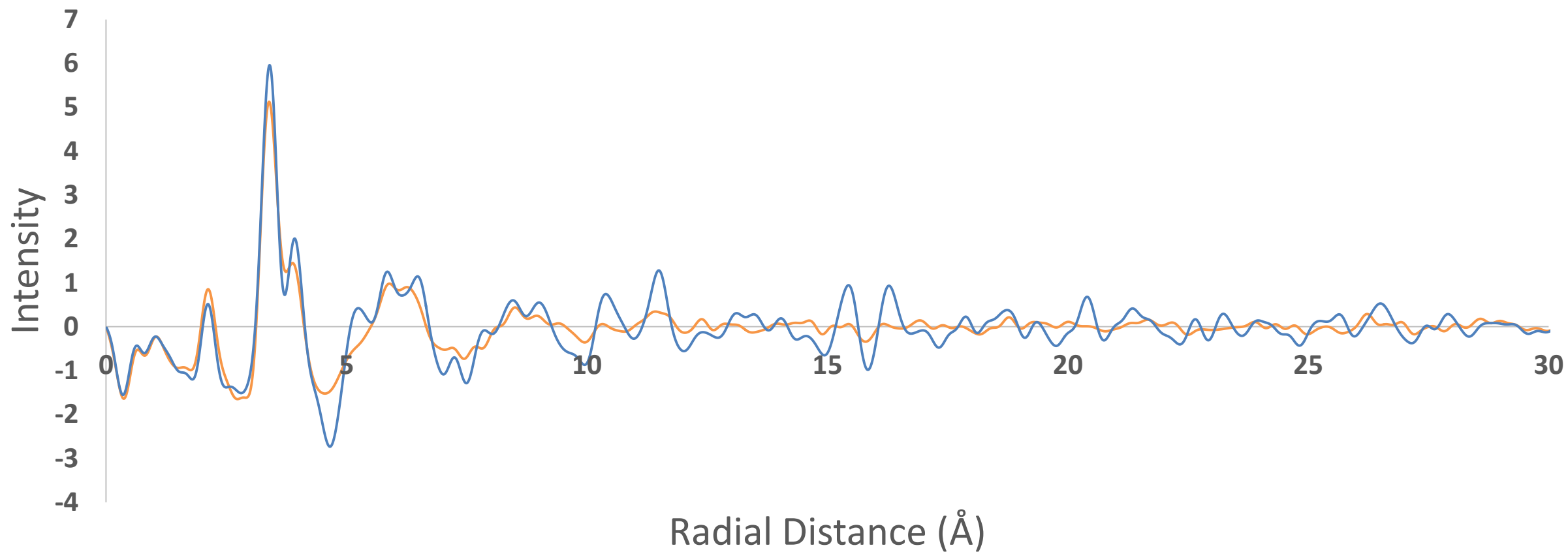
Pair Distribution Function



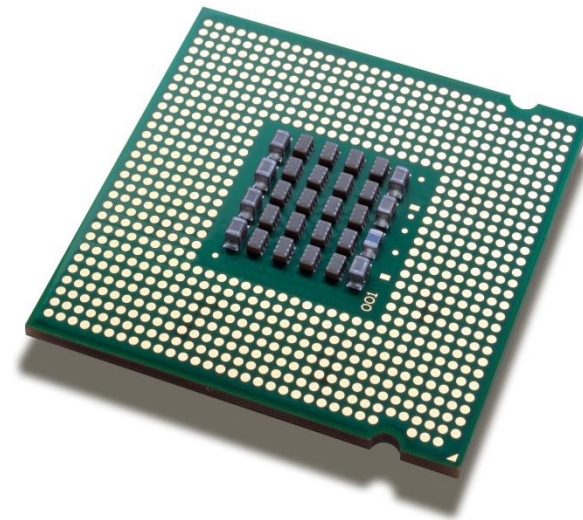
Thermal vs. Plasma



Thermal vs. Plasma



- Using the standards created to study HfO_2 thin films made with ALD technique appear to suggest structural differences.
- Measurements planned for this week will show whether this structural difference is significant or not.



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