PHASE VOLUME FRACTION COMPARED BETWEEN PS-PVD & EB-PVD AFTER THERMAL CYCLING VIA X-RAY DIFFRACTION

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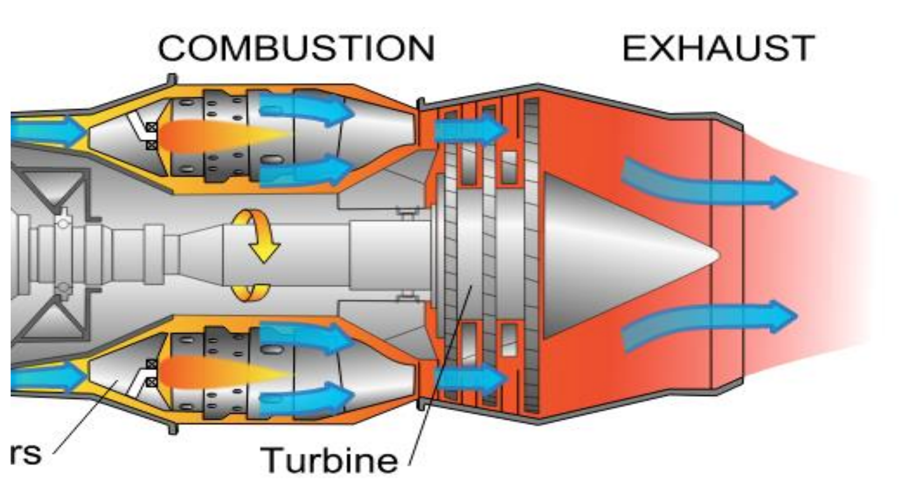
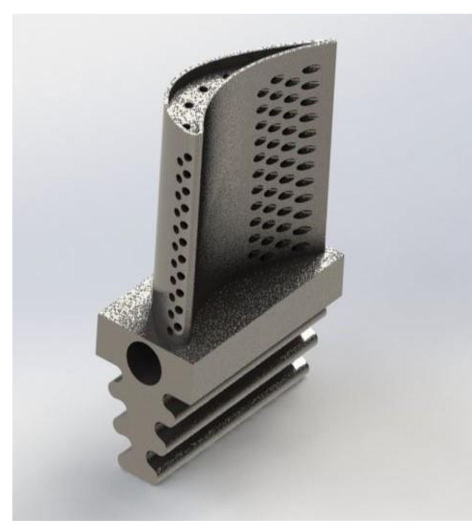
Motivation

Thermal barrier coatings (TBCs) are applied to turbine blades to protect them from operating temperatures up to 1200 °C. The standard application method is electron beam physical vapor deposition (EB-PVD). While effective, this technique is expensive and has a slow deposition rate. Plasma-spray physical vapor deposition (PS-PVD) is a promising technique that offers several advantages over EB-PVD[1], primarily lower cost, faster deposition rate, and non-line of sight deposition. This study investigates the rate of formation of monoclinic zirconia during thermal cycling, which negatively impacts the coating lifetime. If PS-PVD can be shown to have sufficient durability, it will replace EB-PVD for a fraction of the cost.



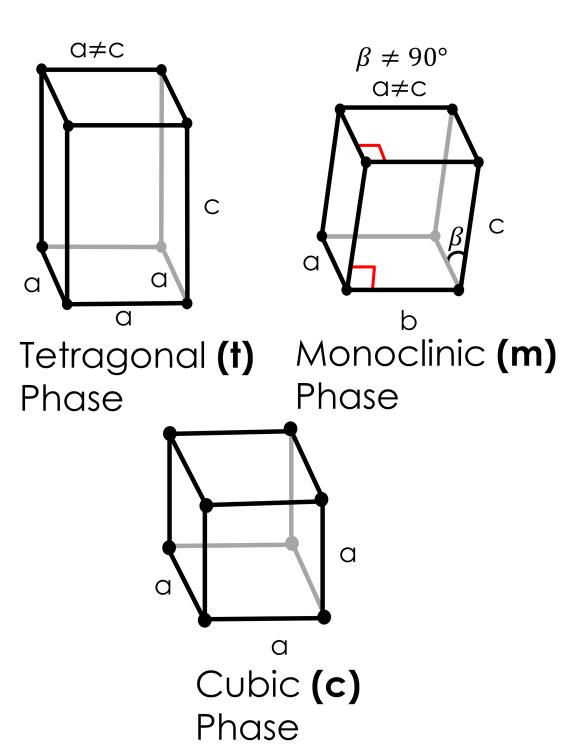


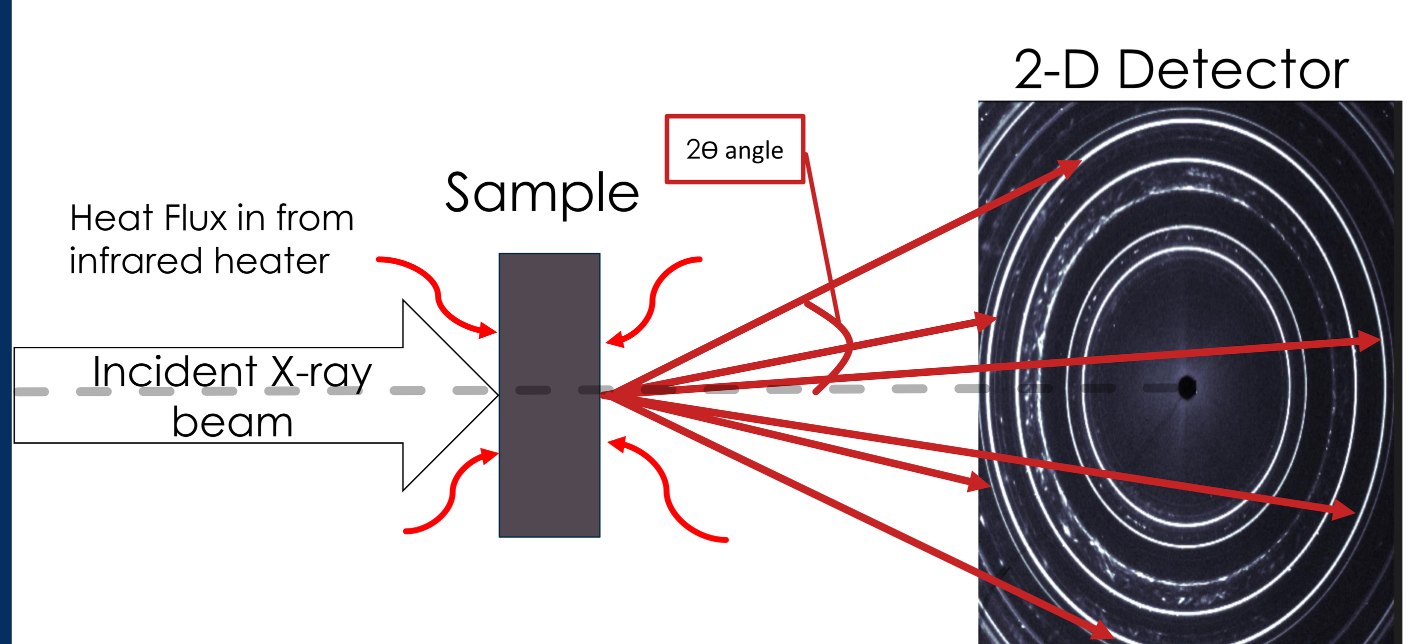
Objectives

- Determine phase volume fraction of tetragonal **(t)**, monoclinic **(m)**, and cubic **(c)** phases present in uncycled, 300, and 600 thermal cycles samples of EB-PVD and PS-PVD.
- Compare rate of monoclinic phase growth between EB-PVD and PS-PVD.

Background

- X-rays diffract off of lattice planes of crystals based on Braggs law.[2]
- From XRD data, the phases present in a sample can be identified and quantified. Based on both intensity and interplanar spacing of peaks. Synchrotron transmission XRD was utilized.
- **(m)** phase has greater volume than the c and **(t)** phases, causing cracking upon transformation.
- To the right are examples of the different unit cell dimensions of the various phases that are found in the yttria-stabilized zirconia (YSZ) of a TBC.

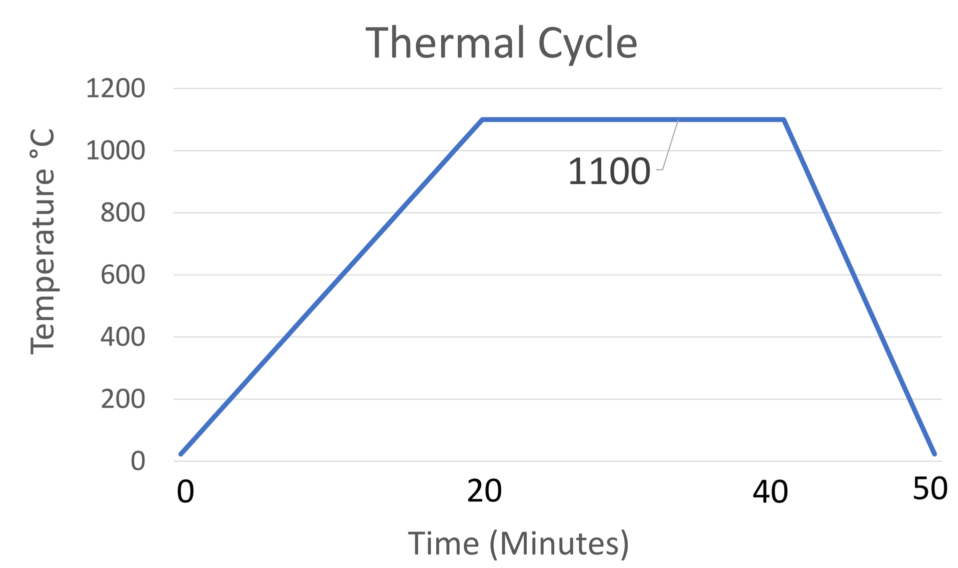


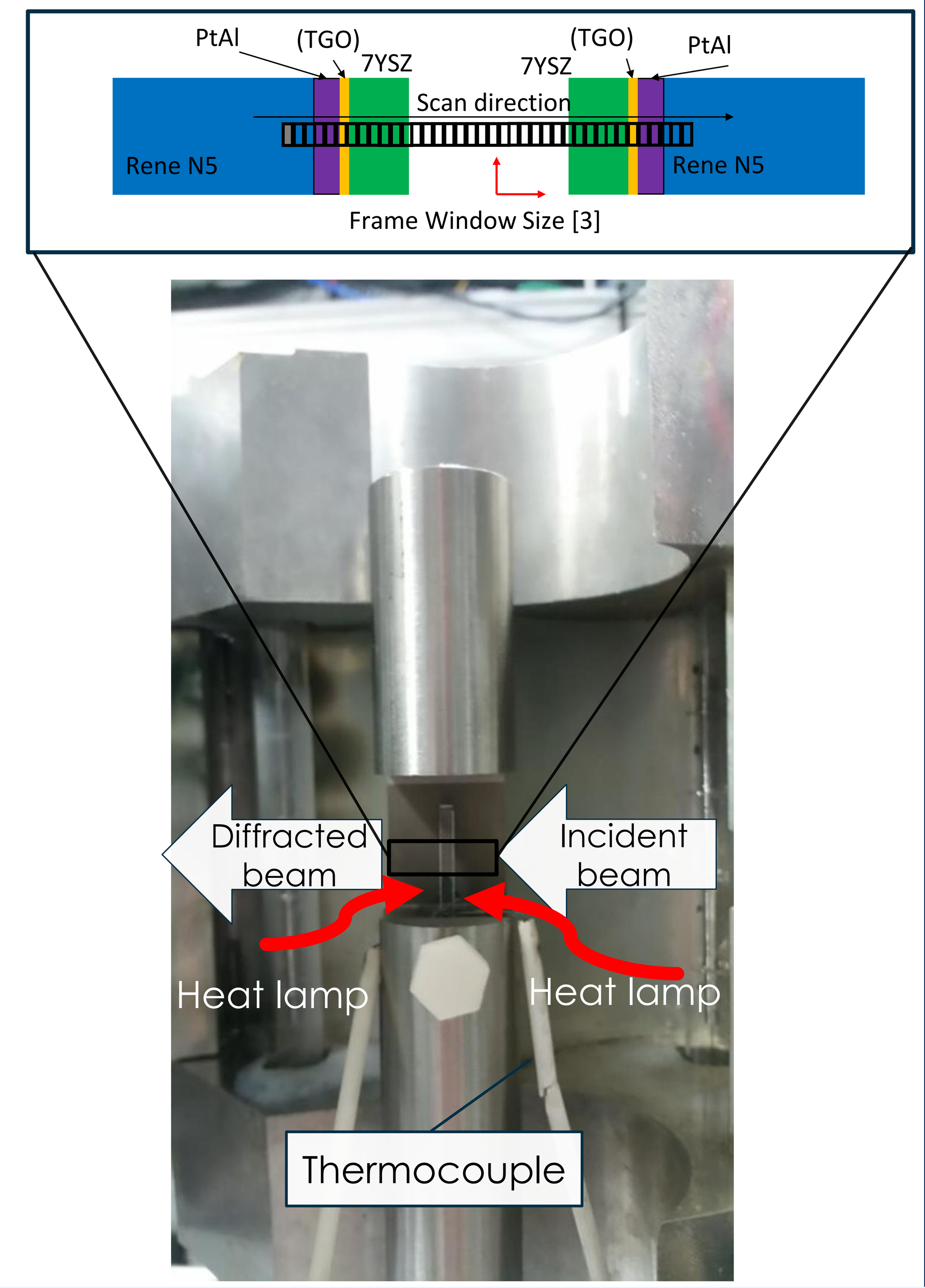


Experiment

- Samples in an infrared heater were thermally cycled (see diagram below) during XRD data collection using a 30 x 300 μm slit size.
- Scans were taken across two samples during a thermal cycle, passing through all layers of the TBC system (see diagram) about once every second).
- Uncycled PS-PVD samples had a 1 hour heat treatment.
- Samples had been thermally cycled for either 0, 300, or 600 cycles, with 20 min hot time at 1100 °C and 10 min of cooling per cycle.
- Phase volume fraction was calculated using XRD intensities; equation for **(m)** phase shown below.

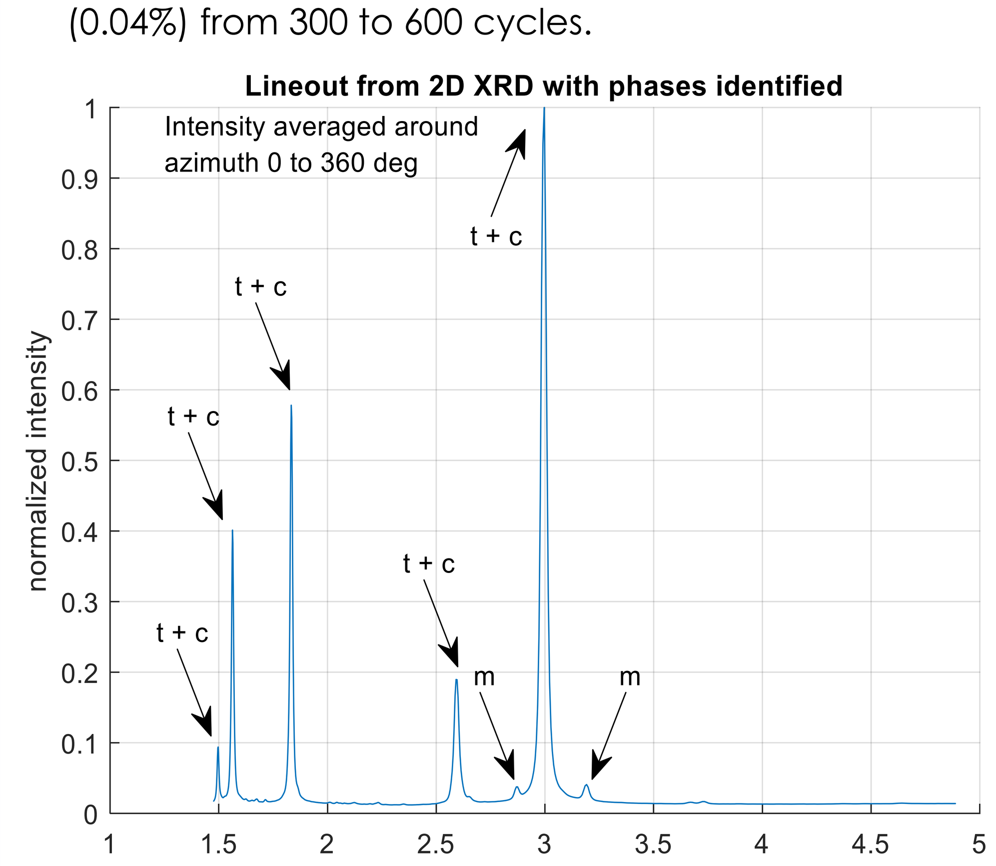
$$x_m = \frac{I_m(\bar{1}11) + I_m(111)}{I_m(\bar{1}11) + I_m(111) + I_t(101)}$$

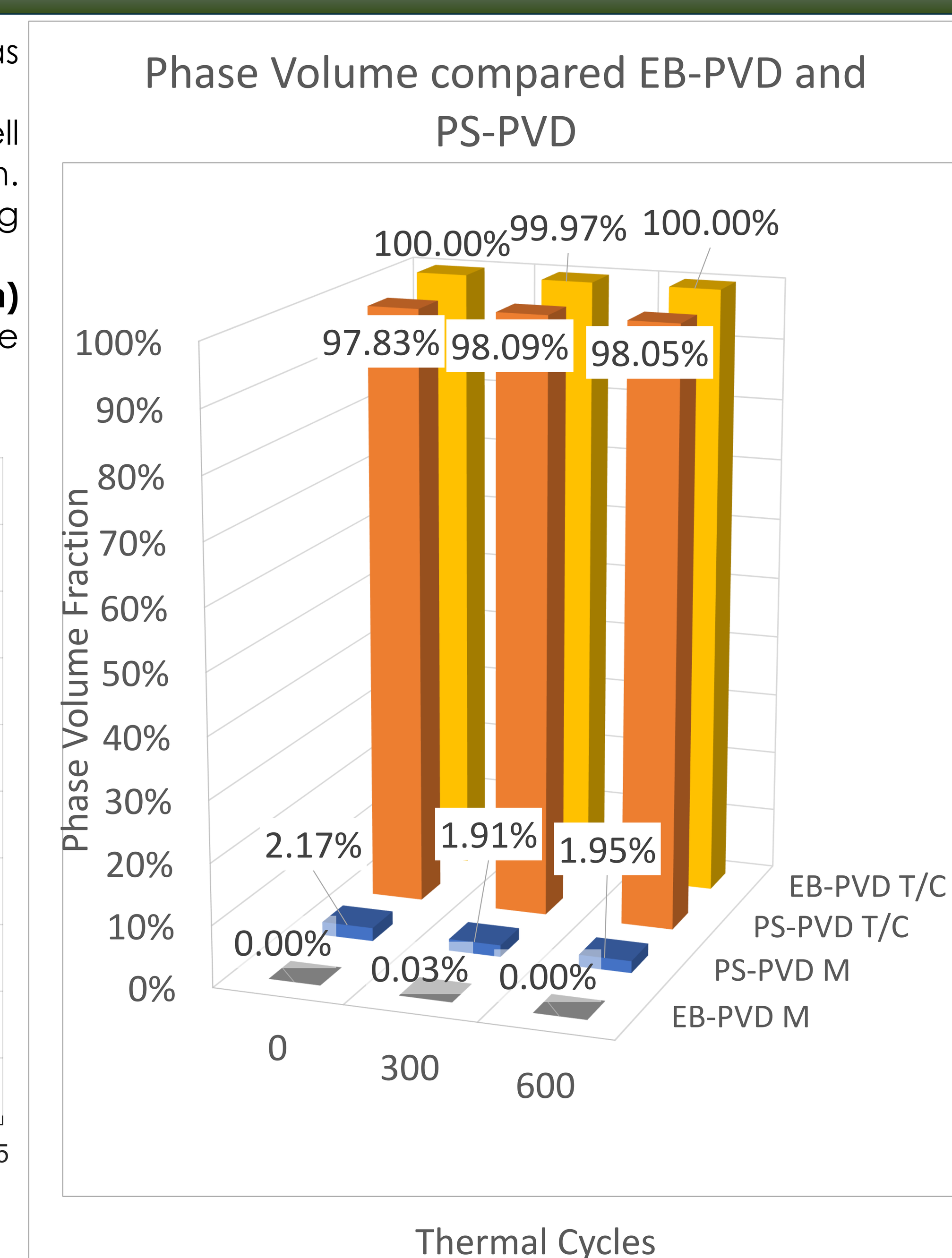




Results and Discussion

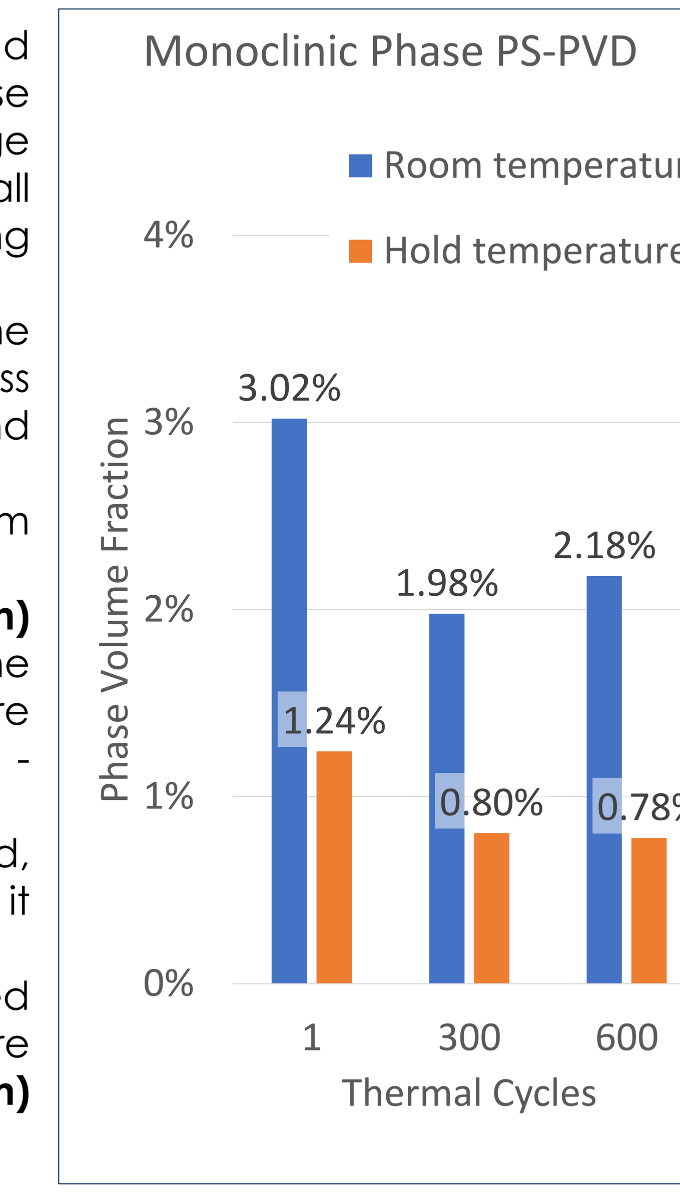
- 100% **(t)** and **(c)** PVF was detected in EB-PVD as expected.[4]
- The **(c)** and **(t)** phases have similar unit cell dimensions, causing overlap in the spectral pattern. Their PVF results have been combined pending deconvolution.
- Overall the PS-PVD showed a decrease(-0.26%) in **(m)** phase formation from 1 to 300 cycles and increase (0.04%) from 300 to 600 cycles.





Conclusions

- EB-PVD samples had negligible or no **(m)** phase and PS-PVD has on average 2% more **(m)** phase in all samples at all thermal cycling steps.
- The associated volume increase contributes to stress that can lead to cracking and failure.[5]
- All PS-PVD samples had m phase, in contrast to EB-PVD.
- Initial high fraction of **(m)** could be a result of the relatively low temperature during deposition (650 - 800°C).
- After cycling with 1100°C hold, the **(m)** PVF reduces as it transforms to **(t)** phase.
- At 600 cycles extended exposure to high temperature caused formation of the **(m)** phase.[6]



Future Work

- Deconvolution of the **(t)** and **(c)** phases should be done to separate their effects.
- Another important area of comparison between PS-PVD and EB-PVD is their response to infiltration of CMAS, a lab-made mix of silicates that simulate the dust that enters aircraft engines and causes coating damage.

References and Acknowledgements

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