Plasma Spray – Physical Vapor Deposition

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Motivation

Thermal barrier coatings have a wide range of applications and have been used mainly in the aeronautics industry. These coatings help to lower the temperature of the substrate allowing the engine to burn at higher temperatures and protecting the turbines from these harsh environments. Traditional deposition methods such as Air Plasma Spray and Electron Beam – Physical vapor Deposition have various limitations including their microstructure and other customizable parameters all which effect their performance. PS-PVD coatings offer a bridge between APS and EB-PVD allowing for customization in microstructure among other characteristics at a lower cost.

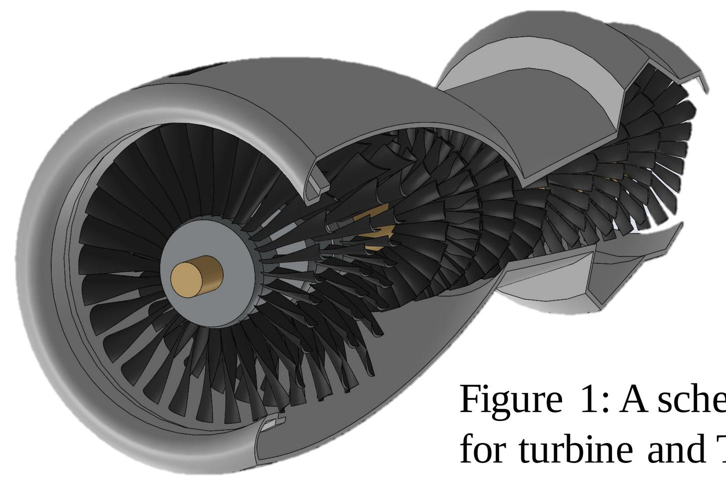


Figure 1: A schematic of an engine for turbine and TBC application

Objective

Characterize the effects of heat treatment, and deposition time on Plasma Spray-Physical vapor deposition coatings through X-ray diffraction and surface roughness.

Background

These coatings are created in a multitude of ways including:
- Air Plasma Spray (APS)
- Electron Beam – Physical Vapor Deposition
- Plasma Spray – Physical Vapor Deposition(PS-PVD)

The PS-PVD process involves a ceramic powder that is dispensed into a plasma beam originating from a torch held inside a vacuum chamber. The ceramic powder is melted and vaporized into the plasma and is then condensed onto the substrate [1]. The final product is a thermal barrier coating that can be used to improve the protection of materials from their surrounding extreme environments.

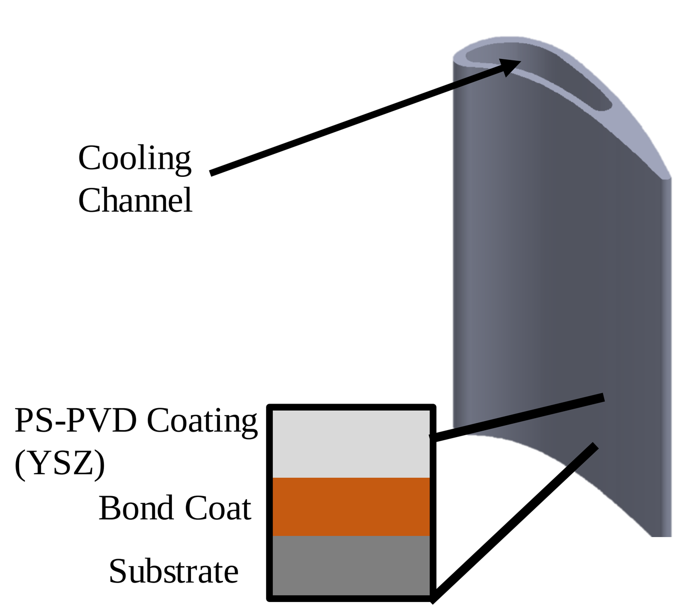


Figure 2

A turbine is made up of three layers of different material including:
- Metallic Substrate
- Bond Coat
  - Typical to help improve adhesion between the metallic substrate and barrier coating.
- Thermal Barrier Coating
  - Deposited using a PS-PVD rig.
  - Coatings are made of a multitude of materials but YSZ(Yttria Stabilized Zirconia) was used for this study.

- The coatings can be characterized through a multitude of different methods including X-ray diffraction.
- X-ray diffraction characterizes the crystal structure of a material. An X-ray is emitted and is then read through a detector which quantifies the intensity at certain angle of emission.
- Bragg's Law can be used to characterize the structure.

$$n\lambda = 2d\sin\theta$$

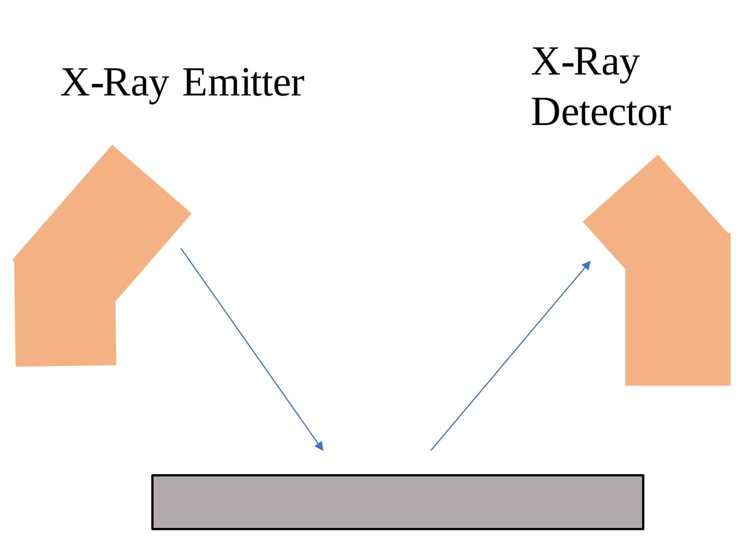


Figure 3

Methodology

Samples were manufactured with controlled manufacturing parameters:
- Amperage: 1800
- Grit Blasted: 60 Psi / Alumina Grit
- Feeder Speed: 150 Rpm
- Pressure: 0.78 torr
- Coating Material: Yttria Stabilized Zirconia(YSZ)
- Deposition time and Heat Treatment: Varied

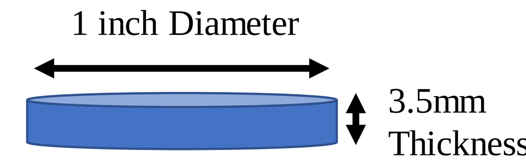


Figure 4

- Surface roughness measurements were taken before and after deposition
- X-ray Diffraction was conducted on each sample
- Heat treated samples were deposited before heat treatment.
- Optical images were taken on each sample after deposition

- Figure 5 shows a screenshot of the surface roughness measurements which were measured using a Zygo NewView 7200.

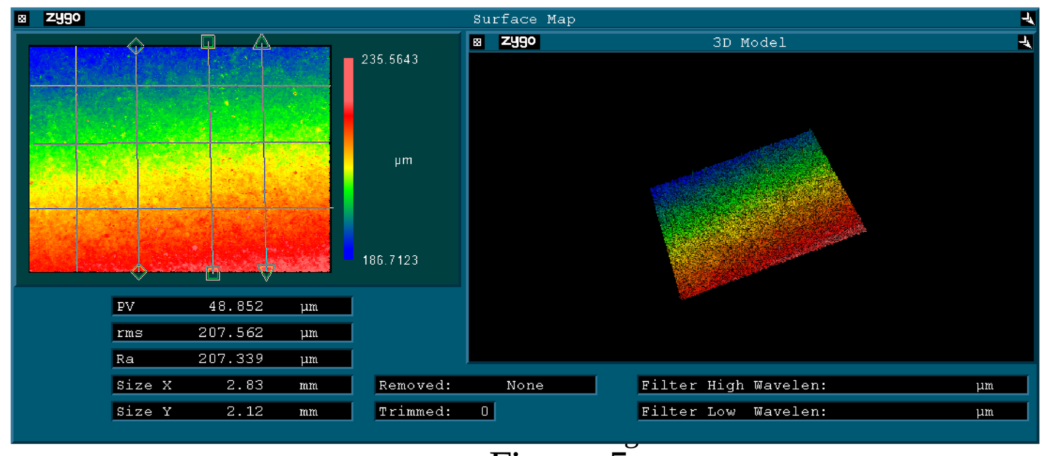


Figure 5

Results

Figure 6

Deposition Time(min)	Coating Thickness	Ra Mean Value(micrometers) (Before Heat Treatment)
5	40-60 microns	2.402
20	160-180 microns	7.052

As expected lower deposition times results in a thinner coating. The difference in deposition times also shows differences in optical images in the sample that was heat treated.

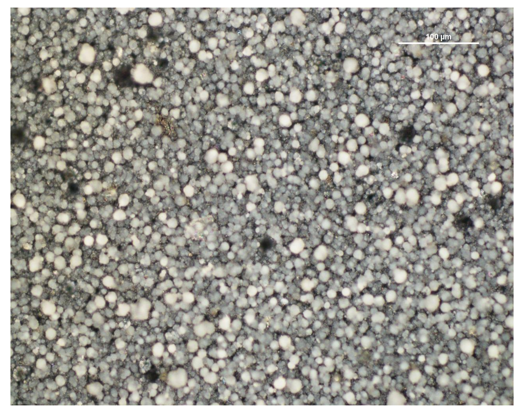


Figure 7: Optical microscopy of thin coated sample after deposition and before heat treatment

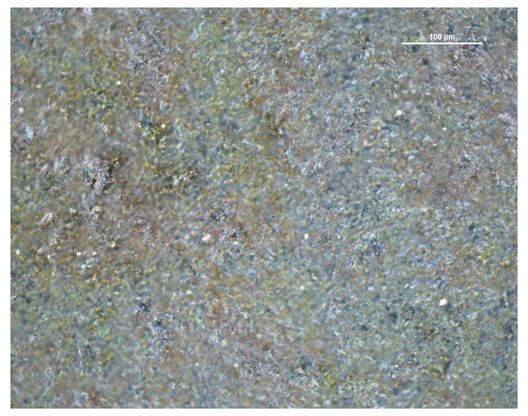


Figure 8: Optical microscopy of thin coated sample after heat treatment

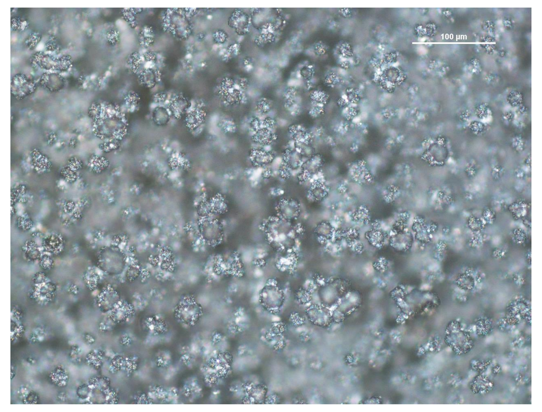


Figure 9: Optical microscopy of thick coated sample before heat treatment

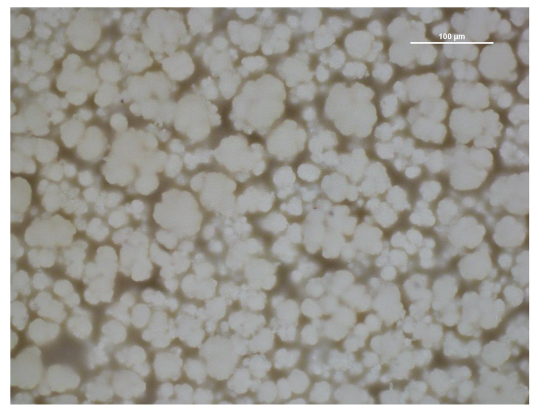


Figure 10: Optical microscopy of thick coated sample after heat treatment

- Heat treated samples showed signs of oxidation which turned the coating from black to the typical white color coating and increased the surface roughness as seen in figure _

Sample	Ra Mean Value(micrometers)
Thin Coating before Heat Treatment	2.402
Thin Coating before Heat Treatment	9.273
Thick Coating before Heat Treatment	7.052
Thick Coating after Heat Treatment	7.179

Figure 11

Figure 12

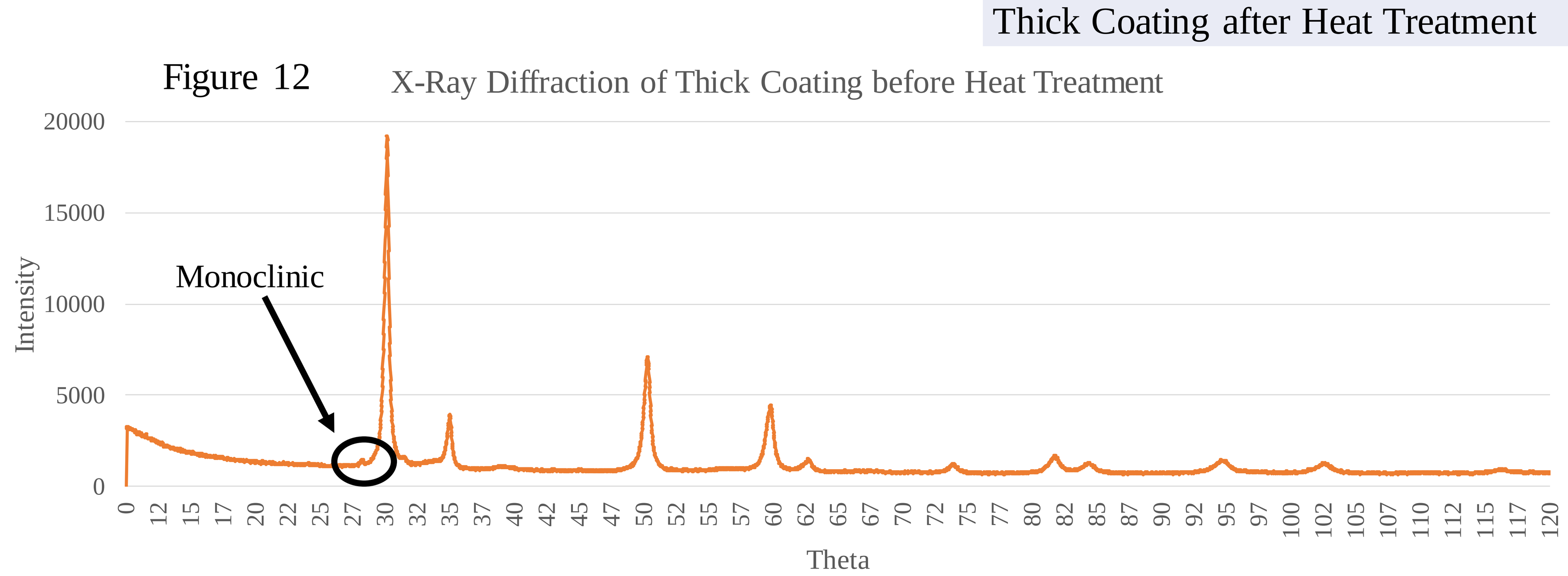
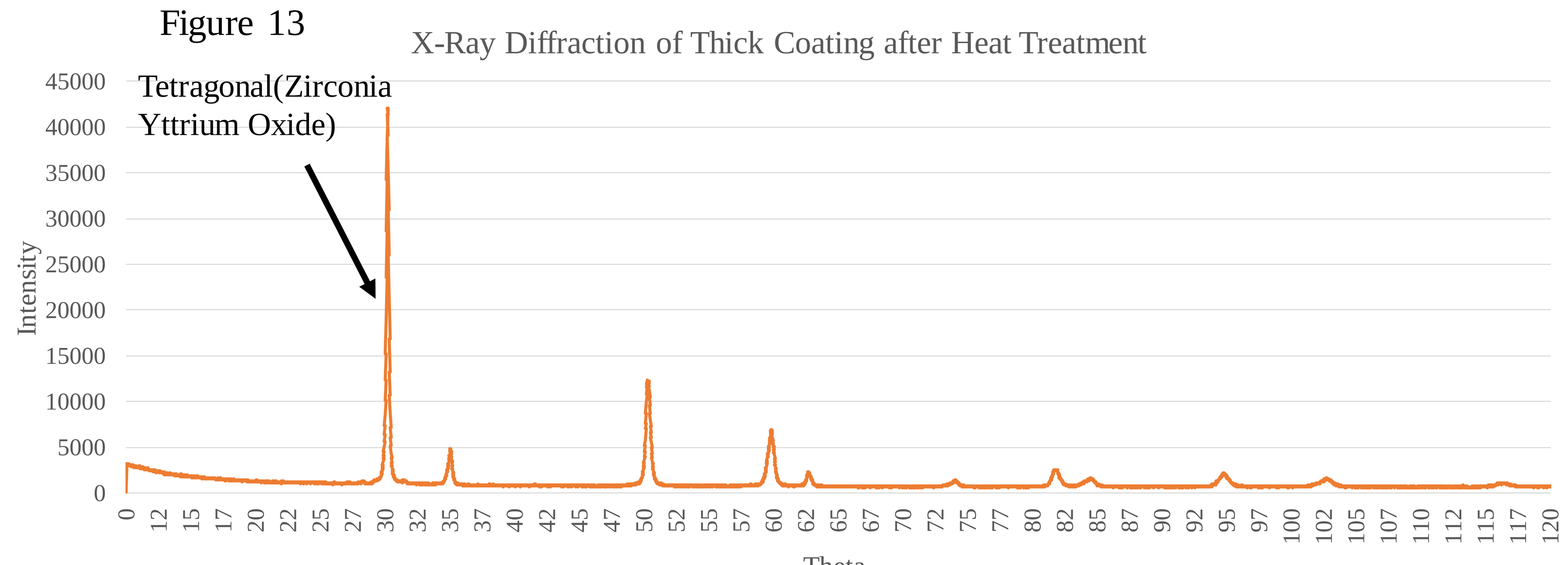


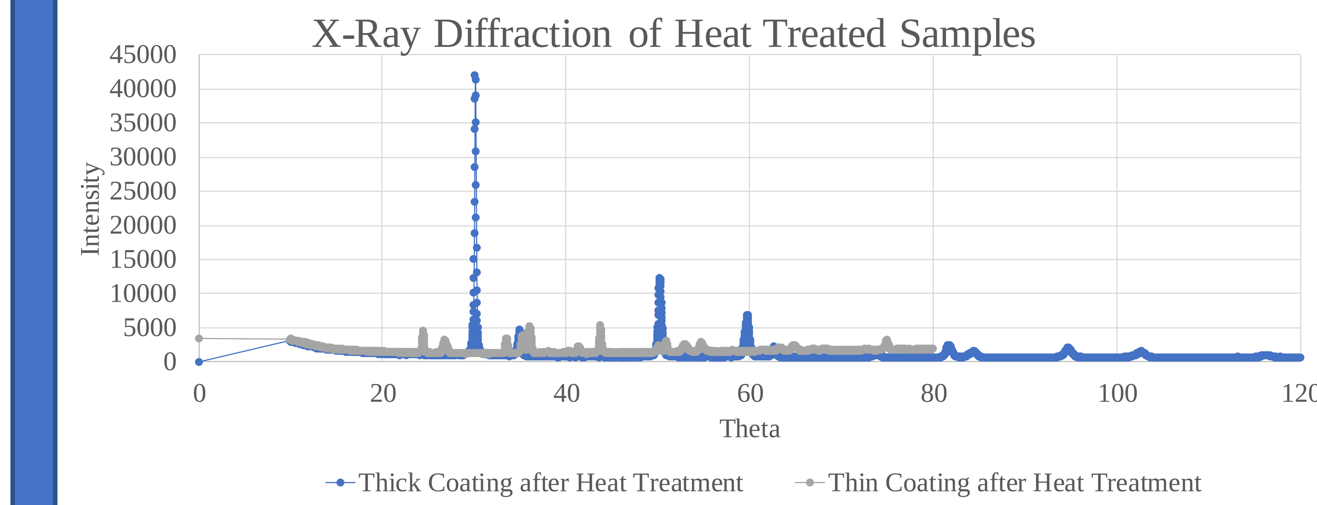
Figure 13



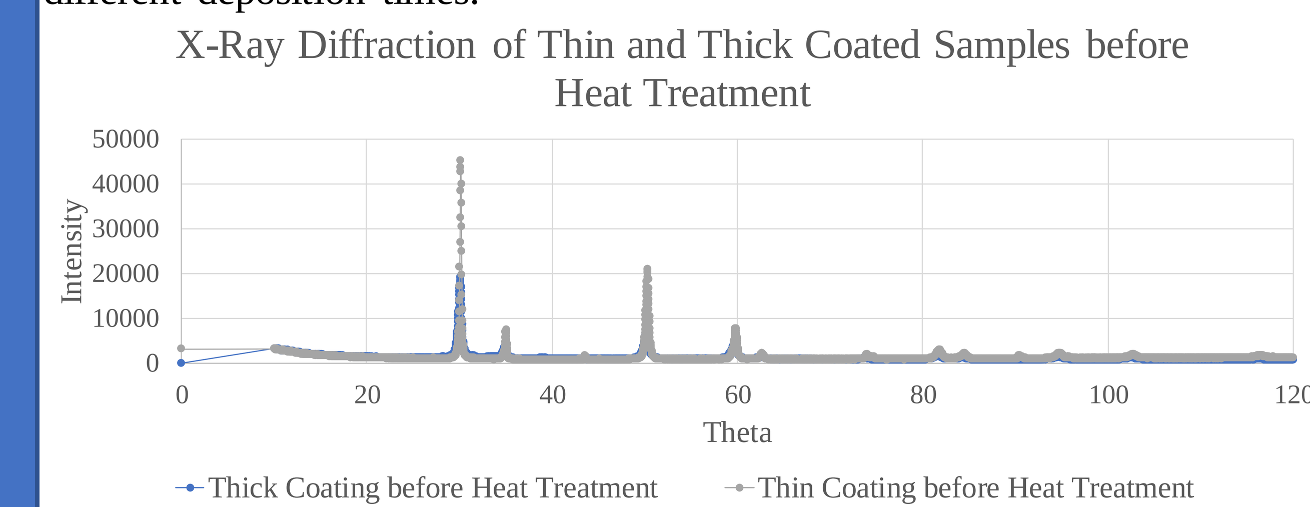
- The two X-ray diffraction patterns compare the same sample before and after heat treatment.
- The heat treated sample has sharper peaks
- Heat treated sample data has smaller peak width and fewer monoclinic peaks

Analysis

When comparing the diffraction of samples before and after heat treatment the peaks are sharper when compared to before heat treatment. In addition, several monoclinic peaks have disappeared.



The diffraction patterns from the samples with different deposition times all have similar peaks translating to similar material composition despite different deposition times.



Conclusion

X-ray Data shows the similarities in composition across all samples. The shorter deposition times resulted in a thinner coating which spalled completely after heat treatment. However, it is important to keep in mind that there was no bond coat on these samples which could help to improve adhesion between the substrate and coating. In addition, heat treatments seemed to increase gaps between columns in the thicker coating.

Future Work

Future work will involve conducting Raman Spectroscopy on the described samples to receive depth resolved strain of the coatings. In addition, we will be creating samples using Electron Beam – Physical Vapor Deposition to compare traditional methods to PS-PVD. The proposed substrate will be Rene N5 and CMSX-4 with a NiCrAlY or Platinum Aluminide. Work will be done at Argonne National Laboratories using high energy synchrotrons to characterize the samples during thermal and mechanical load. The samples will have various manufacturing parameters and will have a bond coat to improve adhesion.

Acknowledgements and References

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[1] "Plasma Spray - Physical Vapor Deposition (PS-PVD) Facility." *NASA*. NASA, 22 Sept. 2015. Web. 10 Mar. 2017.