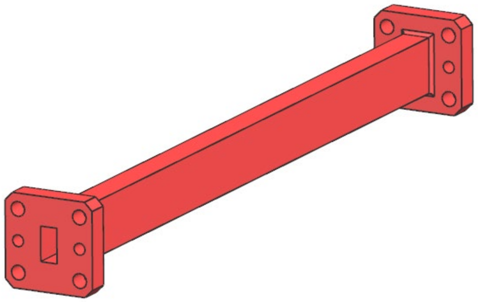
Investigating Polishing and Plating Methods to Improve Additively-Manufactured RF Waveguide Performance for Flight Applications



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Problem Description

- **Waveguide tubes are critical components for JPL spaceborne and airborne missions in applications ranging from telecommunications to science radar.**
- The conventional manufacture of these tubes involves many complex processes including mechanical tube bending, brazing, straightening, and stress relief.
- Currently, qualified waveguides can only be procured by a very limited number of suppliers.
- This situation results in high project risk including:
  - Schedule risk (i.e. long lead times >6 mo.)
  - High costs
  - Low margin for rework due to lead times

An Additively Manufactured (AM) Waveguide could significantly reduce lead time (8 weeks vs. 8 months), cost much less, and can allow iterative development by printing many runs in the time that it takes to produce one set conventionally.

Technological Objective

- Producing waveguide tubes with **AM is an emerging technology**.
- The relatively rough surface produced with AM results in reduced electrical performance compared to the traditional waveguide tube.
- **A critical development is needed to improve the AM waveguide tube interior surface characteristics and thereby allow its use for flight missions.**
- **The objective of this effort to carefully investigate the effect of chemical and mechanical polishing processes on the internal surface finish of an AM waveguide tube, thereby establishing the initial development groundwork for using this technology in flight applications.**

Workflow

1. Develop Requirements
2. Design Waveguide Coupons / Release Fabrication Drawings
3. Additively Manufacture (3D-Print Coupons) on Build Plate
4. Remove from Build Plate
5. Heat Treat and Hot Isostatic Press (HIP)
6. Polish
7. Silver Plating (Optional)
8. RF Performance Testing
9. Mechanical Testing (Surface Roughness, Profile, Wire EDM Inspection)
10. Deliver Data & Recommended Process Parameters

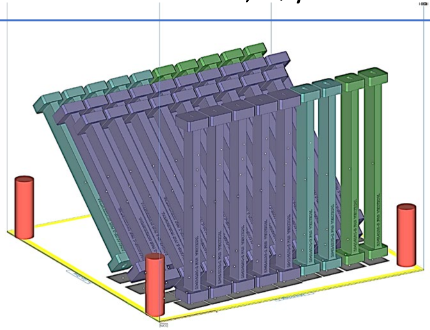
Cochrane, C. *et al.* Vectorized magnetometer for space applications using electrical readout of atomic scale defects in silicon carbide. *Sci Rep* **6,** 37077 (2016). https://doi.org/10.1038/srep37077

Results – Additive Manufacturing of Test Waveguides

<u>Volunteer Aerospace Fabrication</u>

- Printed over 3 builds, in an EOS M290
- Material: AlSi10Mg
- Parameters are custom VAI settings

Vertical Orientation:
10414101-1-A-FAB, Qty 12
10414101-2-A-FAB, Qty 4
10414101-3-A-FAB, Qty 4
45 Degree Orientation:
10414101-1-A-FAB, Qty 54
10414101-2-A-FAB, Qty 12
10414101-3-A-FAB, Qty 12



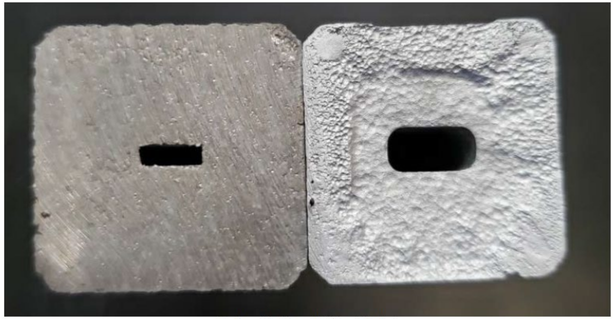
Vendor Build Setup: Purple -1, Blue -2, Green -3

Incoming Surface Evaluations

- Wave guide test coupons were manufactured in both vertical and 45 degree orientations to capture variability in surface finish with build orientation effects
- Al-10Si-Mg was used with JPL specified post process “T6” heat treatment

Results – Post print surface finish enhancement processing

Final Surface & Dimensional Evaluations



Before (left) and After (right)

Note recessed area where Chemical Polishing (CP) tooling connected; heavily textured area surrounding the recessed zone was impacted by CP solution leakage (but was understood to be sacrificial)

Before (left) and After (right) Port Dimensions

Note circular pores on waveguide faces consistent with either subsurface voids that were circularized by the HIP process or (potentially) locations of precipitates formed during the HIP process

- Two surface finishing methods were identified for post print surface finish improvement:
  - Flow through chemical – conducted via proprietary process at REM
  - Flow through abrasive slurry– conducted by Extrude Hone
- Although evaluation is still in progress, preliminary data suggest promising results may be obtained by a combination of both processes for bulk removal followed by planarization
- **Typical Surface Roughness Improvements:**
  - **As-printed waveguide: 12µm**
  - **After REM Chemical Polish: 3µm**

Work-To-Go

- To finish this investigation (which incurred significant delays due to the COVID and fire-related laboratory shutdowns) the following additional work is required:
  - Complete electrical/RF testing to examine waveguide performance in comparison with both the control additive sample and with a similar conventionally-produced waveguide.
  - Mechanical evaluation of the process effectiveness should be performed using CT-scanning and/or surface roughness profilometry.
  - Selected samples should be sectioned via wire EDM process to fully investigate the internal surface properties.