Fabrication of a 35 GHz Folded Waveguide TWT Circuit Using Rapid Prototype Techniques

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***Abstract*—Microfabrication techniques are commonly used to build circuits for millimeter-wave and THz vacuum electron devices. A cost effective solution is becoming available, at least for building prototype circuits intended for cold-testing. Rapid prototyping machines such as 3D printers have advanced to the point that their resolution is below the wavelength of many microwave circuits. This paper reviews the application of this quickly-advancing technology towards waveguide components of vacuum electron devices. The authors use a rapid prototype technique called Direct Metal Laser Sintering (DMLS) to "print" sample 35 GHz circuits in metal. Circuits in two different materials (Aluminum and Chromium Cobalt) are printed and cold-tested. The test data shows good agreement with simulation.**

I. Introduction And Background

Most vacuum electron devices require a slow waveguide structure to propagate electromagnetic waves interacting with an electron beam. Since these circuits scale with wavelength the dimensions become very small and thus the device becomes challenging to build in the millimeter-wave and THz regimes. A number of advanced techniques have been used to microfabricate such components, including electron discharge machining (EDM), photolithography, laser ablation, and deep reactive ion etching (DRIE) in silicon [1]. Such processes are effective, but time-intensive and costly.

Many recent advances have been made with rapid prototyping machines, which fabricate prototype parts directly from three-dimensional computer aided design (CAD) packages. High-resolution 3D printers have been effective in constructing small parts with fine features. Originally considered useful as plastic models and toys, such parts are now commonly found in commercial products, science applications, and even rocket engines.

Rapid prototyping machines may be useful for constructing microwave circuits intended for vacuum electron devices. This technology is investigated for a 35 GHz millimeter wave TWT amplifier.

II. Results

A 3D printing process called Direct Metal Laser Sintering (DMLS) was used to build several circuits. DMLS builds the part layer by layer, fusing metal powder into a solid by melting it locally using a focused laser beam. It uses a CAD model as input, similar to plastic 3D printers.

The waveguide geometry was based on a 35 GHz TWT folded-waveguide structure that was originally made using a lithography process known as LIGA [2]. Four circuits were printed, two units in two different materials, aluminum (Al7075) and chromium cobalt (CrCo, Fig. 1). To simplify the process, only 9 periods of the 30-period original interaction section were printed. Although not necessary, the circuits were printed in upper- and lower-halves and pinned together. An electron beam tunnel was included in the circuit. A transition section was designed to interface the serpentine section with WR-28 rectangular waveguide for testing.

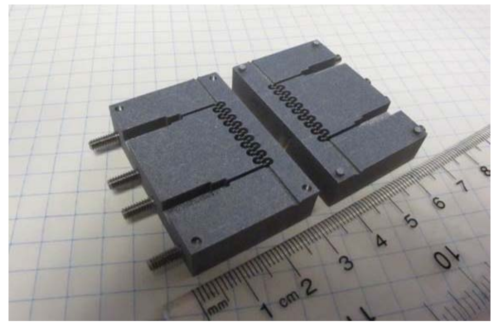

Fig. 1. Two halves of a prototype folded waveguide TWT circuit. The circuit was made in layers of chromium cobalt using an inexpensive rapid prototyping process called DMLS.

The circuits were tested from 30-40 GHz using a network analyzer (Fig. 2). The results were compared with simulations using Ansoft's High Frequency Structure Simulator (HFSS). The measured insertion loss and reflections agree well with the predicted result for the Aluminum circuits. Measurements were also made for the Chromium Cobalt units. Surface roughness measurements were also made for each set.

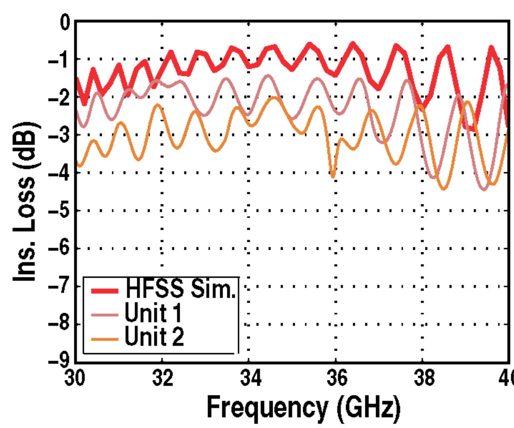

Fig. 2. The insertion loss for two aluminum circuits made using DMLS, compared with the same circuit geometry modeled in HFSS.

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References

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