DIGITAL PROCESSES AND CHARACTERIZATION FOR FABRICATING 3D RF DEVICES

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Dedication

I would like to dedicate this dissertation to my family. For they shaped me into the person I am today with their love and support. I would like to thank all my friends for the great memories we shared that keep me functioning during the lonely nights. And special thanks to Dr Cesar Garcia, David Hsu, and Lizzie Liu who made the extra effort to keep me on track. And finally to my late dear friend Neil Patel, whose early departure has taught me to value each day and to never give up and never surrender.

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Abstract

In this work, co-planar waveguides (CPW) are fabricated and characterized with low temperature 3D printed materials for flexible electronic applications. Laser processing is introduced to reduce heating and cooling times for curing and subtractive manufacturing. CPWs are optimized by varying printing resolution, adjusting curing conditions and shaping conductor profile with a pico-laser. By using acrylonitrile butadiene styrene (ABS) as substrate material and Dupont CB028 as conductive material, a high S21 and low S11 CPW is fabricated. Optimized direct write methods are dispensed onto 3D complex structures to move away from 2.5D style printing and move into true 3D printed antenna devices.

Table of Contents

List of Tables

List of Figures

Chapter 1: Introduction

3D printing has multiple uses in variety of areas including tissue engineering, mechanical structures, textiles, food and even electronics. 3D printed electronic devices are currently challenging to fabricate due to material performance and the lack of process compatibility. Most of the desired materials for electronics are polymer based and have limited post process temperature capability. Additionally, the majorities of printable conductive materials requires higher temperature processing or have inferior performance. Printed electronic devices in the RF regime are especially challenging due to the need for good RF properties of both the dielectric and the conductors. Surface features in RF devices can also negatively affect the performance therefore smooth surfaces and straight conductor edges must be considered. These are issues for 3D printing given the fundamental process of layer by layer printing. The advantages of overcoming these barriers are several, including more functions per volume, reduced weight, reduced time from design to product and ultimately reduced cost.

1.1 Motivation

Additive manufacturing (AM) is a rapidly expanding component of the advanced manufacturing sector that is transforming the product development cycle across a wide spectrum of industries. AM continues to present strong patterns of expansion, with growth rates in the double digits,, thus carrying substantial economic and job growth impact [1]. Among a variety of available AM processes, micro-dispensing and fused filament fabrication (FFF) have perhaps the widest application domains owing to their low process temperatures, dimensional versatility and wide availability of compatible materials. The combination of AM techniques together with other digitally-controlled processes constitutes the more general classification of Direct Digital Manufacturing (DDM).

1.2 Contributions

The main contributions from the work fall within the following categories:

i) Development of harmonic transceivers with novel printing techniques with existing direct write (DW) technology.

   To the best of the author's knowledge, the developed harmonic transceivers have the best overall performance among previously conventionally manufactured published designs, in terms of conversion gain, communication range, and occupied electrical volume. These are achieved through the utilization of novel printing techniques which enable the deposition of conductive material onto complex structures with obstructing features.

ii) Adding value to the study of new DDM techniques for the purpose of 3D printed electronics.

   The simulation and experimental results of 3D printed co-planar waveguide transmission lines have yielded an understanding of the limitations of 3D printed materials. A new approach to the fabrication of electrically improved CPW transmission lines which is compatible with the additive manufacturing process.

iii) Addressing the environmental effects on the electrical performance of 3D printed materials

   Tensile, compressive and temperature cycling tests of 3D printed materials are conducted onto electronic devices with inspection to the changes to their electrical characteristics.

iv) Showing the advantages of the use of multi-material digital additive manufacturing for the fabrication of complex and efficient RF devices

   The digital additive manufacturing technology has been used in the design of 3D antennas, transmission lines, and arrays antennas, while enabling the realization of low-cost, light-weight, robust, efficient, miniaturized RF devices with comparable or improved manufacturing reliability, repeatability and flexibility.