Innovative Components in Substrate Integrated Waveguide (SIW) Technology by 3D Printing

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***Abstract*—This final project report presents the main results obtained by the awardee in the frame of the 2018 IEEE MTT-S Graduate Fellowship Educational Program. The research activity of the candidate was focused on the development of novel devices and systems operating in the microwave and mm-wave frequency regions, exploiting the novel potentialities of the additive manufacturing procedures. The authors investigated three different methodologies to 3D-print RF and microwave components. First, the Fused Deposition Modeling (FDM), that allows to print standard plastic filaments and to vary selectively the infill percentage of the deposited material, enabling tunability of the electrical properties just modifying the quantity of the deposited material and the implementation of totally three-dimensional structures. Broadband interconnects, like SIW and SISW waveguides, have been designed, manufactured and experimentally validated through this procedure. Subsequently, the Binder Jetting technique, that allows to create totally three-dimensional shapes by using chalk powder, which does not require a supporting structure to be deposited as a major advantage. NRD-guide and NRD 3-port junction have been designed, printed and validated through this procedure. Last, photo-polymerization of special plastic materials, allows to create extremely precise and controlled structures, and by means of silver conductive paints it is possible to realize waveguide components extremely light, cost effective and performant even at higher frequencies. To conclude, by merging the novel additive manufacturing techniques with the consolidate microwave technologies it was possible to create innovative, low cost, cheap components and systems for novel classes of devices operating at microwave and RF frequencies, for the new demanding Internet of Things (IoT) and the 5G era.**

***Index Terms*—3D Printing, additive manufacturing, Binder Jetting, chalk powder, Fused Deposition Modeling (FDM), IEEE MTT-S, IEEE MTT-S Graduate Fellowship, materials, microwave, NRD, photo-polymerization, RF, substrate integrated waveguide (SIW), substrate integrated slab waveguide (SISW).**

I. Introduction

THE MANUFACTURING of microwave components and systems by additive techniques and 3-D printing is becoming increasingly relevant for the implementation of the next generation of wireless sensors networks and the Internet of Things. Besides the rapid prototyping and low fabrication cost, 3-D printing offers unprecedented flexibility and a completely new design scenario. Those features motivated the research interest of the authors to investigate possible applications of various 3D printing techniques for the implementations of microwave and mm-wave devices and systems, as highlighted in the next paragraph.

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II. Project Outcomes

This paragraph briefly summarizes the main results achieved inside this project. First, the characterization of 3D-printed dielectric substrates with different infill for microwave applications has been investigated in [1], as shown in Fig. 1 and Fig. 2. Subsequently, the study of 3D-printed substrate integrated slab waveguide for single-mode bandwidth enhancement has been highlighted in [2], and a prototype is presented in Fig. 3. Afterwards, an ancillary work about an enhanced cavity sensor in SIW technology for material characterization has been presented in [3], to better retrieve the electrical properties of the materials to be adopted during the 3D manufacturing procedures, and a sketch is depicted in Fig. 4. In addition, to test novel metallization methodologies, a prototype of a 3D-printed high dielectric resonator waveguide microwave filter has been manufactured and validated [4], as shown in Fig. 5. Furthermore, as shown in Fig. 6, a novel study on chalk powder NRD 3-port junction 3D-printed via binder jetting technology has been presented in [5] and [6].

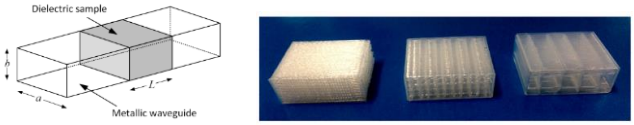

Fig. 1. Enhanced SIW cavity sensor for material characterization. [1]

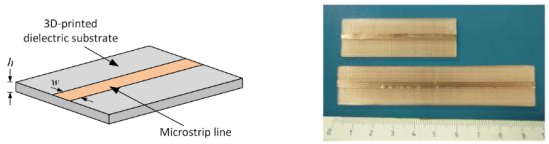

Fig. 2. Enhanced SIW cavity sensor for material characterization. [1]

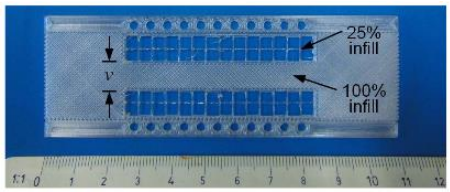

Fig. 3. 3D printed slab substrate integrated waveguide (SISW). [2]

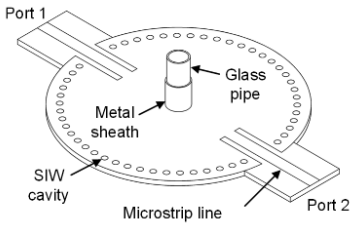

Fig. 4. Enhanced SIW cavity sensor for material characterization. [3]

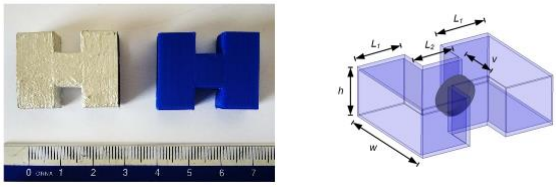

Fig. 5. 3D printed high dielectric resonator microwave filter. [4]

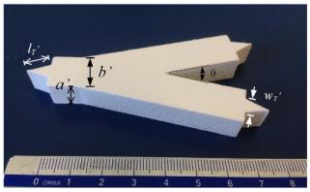

Fig. 6. 3D printed chalk powder NRD 3-port junction. [5]

III. Professional Career Plan

Receiving the 2018 IEEE MTT-S Graduate Fellowship Award gave me the chance to join the research center led by Professor Ke Wu at the École Polytechnique de Montréal. This experience gave me the chance to improve my skills on electromagnetic design and benefit of the incredible facilities of this fascinating set of laboratories. Indeed, this is a unique opportunity to get in touch with the research carried out abroad and it represented an important step for my growth as a young microwave engineer. After concluding this abroad research visiting period, I came back to conclude my Doctoral duties. When concluding the last educational step, I was offered the opportunity to join STMicroelectronics, a leading Italian-French company in the electronics/semiconductors market, as a R&D Design and Application Development Engineer, in charge of the RF Section in Milan, Italy. I grab this challenging opportunity during November 2018 and I started this novel adventure. My goal in the next future will be to maintain a good bridge between academia (University of Pavia) and industry (STMicroelectronics) to face with the novel challenges, in full accord with the spirit and mission of the IEEE MTT-Society.

IV. IMS 2018 in Philadelphia

IMS conference always represents the leading event for the RF/Microwave Community spread worldwide. It is the premier annual international meeting for technologists involved in all aspects of microwave theory and practice. It consists of a full week of events, including technical paper presentations, workshops, and tutorials, as well as numerous social events and networking opportunities. In addition, the symposium also hosts a large commercial exhibition, really worth going and benefiting from it! Then, this was my second participation in this event, and I was part of the big student volunteering team, a unique and formative experience. I was also a finalist of the "Three Minutes Thesis" Competition, and I received the "Honorable Mention" Award for my presentation entitled "Hear a Whisper in the Middle of a Concert: Be Selective!"

V. Conclusion

To summarize, this work was focused both on classical technologies like the SIW and the NRD, together with novel additive manufacturing procedures like the FDM, the Binder Jetting and the photo-polymerization to design, print/manufacture and experimentally validate innovative microwave and RF components and systems. This work is of extreme importance nowadays, because it paves the road to the future implementation of novel classes of components and systems operating at microwave and RF frequencies and inserted in the Internet of Things (IoT) paradigm for the new 5G era, and it is perfectly suited for the purposes of the IEEE MTT-Society. In fact, fascinating research aspects were treated during this period and certainly many others new development will follow in the future among this attractive topics for the RF/Microwave community at large.

Acknowledgment

The first author would like to thank the IEEE MTT-Society for selecting him as an awardee of this prestigious and meritorious recognition. Moreover, a special thank is addressed to Professor Ke Wu, that hosted the first author in his six months visiting research period abroad. During this experience, valuable support and precious advice have been provided by Professor Ke Wu, his lab team, including all the technicians of the Poly-Grames Research Center, Montréal, QC, Canada.

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