Design and Fabrication of All-metal Micromachined Finline Structures for Millimeter and Sub-millimeter Applications

Citation for the original published paper (version of record):
López, C., Desmaris, V., Meledin, D. et al (2022). Design and Fabrication of All-metal Micromachined Finline Structures for Millimeter and Sub-millimeter Applications. 32nd International Symposium of Space Terahertz Technology, ISSTT 2022

Design and Fabrication of All-metal Micromachined Finline Structures for Millimeter and Sub-millimeter Applications

Cristian López*1, Vincent Desmaris[1], Denis Meledin[1], Alexey Pavolotsky[1], and Victor Belitsky[1]

Abstract— **We present the design and fabrication of All-metal micromachined finline structures. These novel structures have all the advantages of conventional finlines, i.e., large fractional bandwidth and ease in the mounting process. However, the absence of a dielectric substrate prevents the excitation of substrate modes and the associated resonances, hence the chip area is not limited by substrate size. All-metal finlines could be integrated with existing finline-to-microstrip transitions. This opens up new possibilities for the development of planar circuitry in the millimeter and sub-millimeter range, e.g., integrating this structure with an SIS mixer design.**

Keywords— micromachining, finlines, waveguide-to-substrate, microfabrication.

I. Introduction

Waveguides are widely adopted in modern THz systems for guiding electromagnetic waves and interconnecting different components and subsystems. However, certain key components are fabricated by employing thin-film technology, e.g., mixers and multipliers [1] [2]. Therefore, waveguide-to-substrate transitions play a crucial role in system performance. Among the variety of waveguide-to-substrate transitions reported in the literature, finlines stand out for their large fractional bandwidth and mounting tolerance when compared with other existing solutions [3], e.g., E-probes.

Typically, finline structures consist of a pair of conductive fins over a dielectric substrate. The substrate area and thickness are frequently minimized to reduce dielectric losses and avoid the excitation of substrate modes and resonances. Moreover, the substrate-waveguide interface introduces an impedance mismatch. In [3], the dielectric substrate between the fins was removed to reduce dielectric losses and improve matching over a larger bandwidth. Nonetheless, the dielectric underneath the fins was preserved to provide mechanical support to the structure. However, the substrate could be completely removed if the metallic fins are made sufficiently solid. All-metal finlines without any dielectric substrate constitute a promising solution where the chip area is not limited by the excitation of substrate modes and resonances. Moreover, the all-metal structure provides an excellent cooling capability, is not fragile, and tolerates stress during cooling better.

In this paper, we present the design and process development of all-metal micromachined finlines for millimeter and sub-millimeter applications. Such structures could be integrated with finline-to-microstrip transitions and employed as a new platform for prospective mixers SIS or Schottky mixers and multipliers.

*1E-mail: cristian.lopez@chalmers.se. The authors are with the Group for Advanced Receiver Development (GARD), Department of Space, Earth and Environment, Chalmers University of Technology, Gothenburg, Sweden.

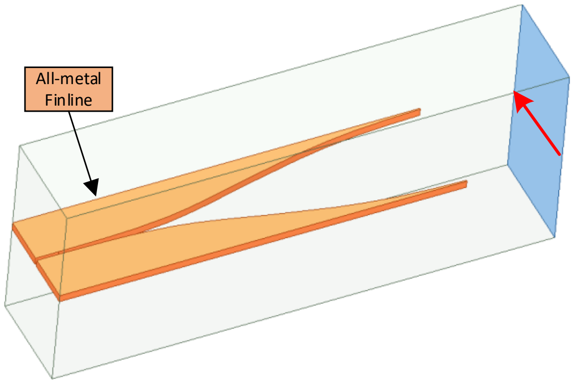

Fig. 1. HFSS 3D model of the proposed finline structure in a rectangular waveguide. The waveguide port is depicted in blue. The red arrow indicates the E-field excitation in the waveguide port. The design is intended for split-block technology.

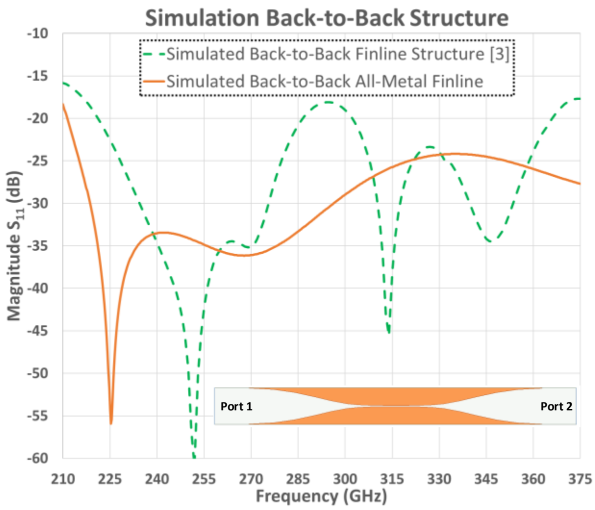

Fig. 2. Simulation of S11 Magnitude for 2 structures: finline structures with a thin dielectric substrate as presented in [3], and the proposed All-metal finlines in a Back-to-Back arrangement. It is clearly observed that the proposed All-Metal Finlines could achieve as broadband performance as their counterpart with thin dielectric substrate [3].

II. Design

The all-metal finline depicted in Fig. 1 was designed for the frequency range 210-375 GHz. In order to define the finline profile, the impedance vs width was analyzed following the procedure described in [3]. Afterward, the profile was optimized with the aid of Ansys HFSS. Fig. 2 depicts the performance comparison between the structure based on silicon substrate fins, presented in [3] and the proposed all-metal finlines. Both structures are arranged in a

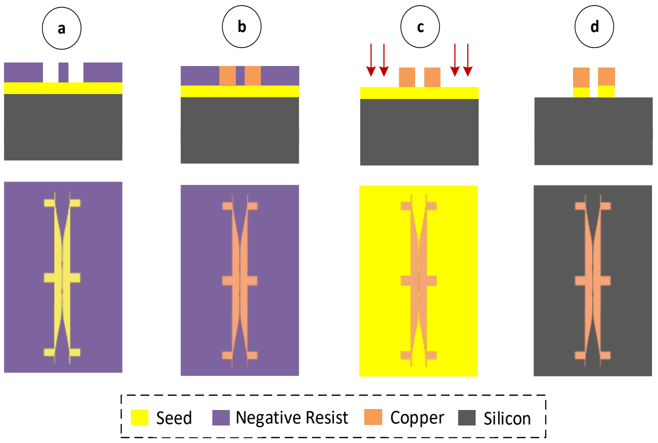

Fig. 3. Simplified fabrication process: (a) Sputtering of metallic seed and patterning of thick negative resist layer. (b) Copper electroplating. (c) Stripping of the resists and the remaining seed layer. (d) All-metal finlines over silicon. The silicon carrier is further etched away to release the structures.

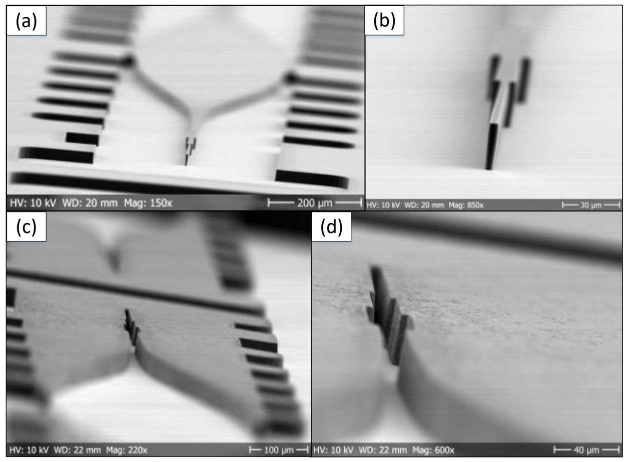

Fig. 4. SEM (Scanning Electron Microscope) pictures of the Fabricated samples (a) Patterned resist. (b) Detail of the central transformer in the patterned resist. (c) Fabricated structure fabricated on electroplated copper. The resist has been removed. (d) Detail of the central slotline transformer of the fabricated structure.

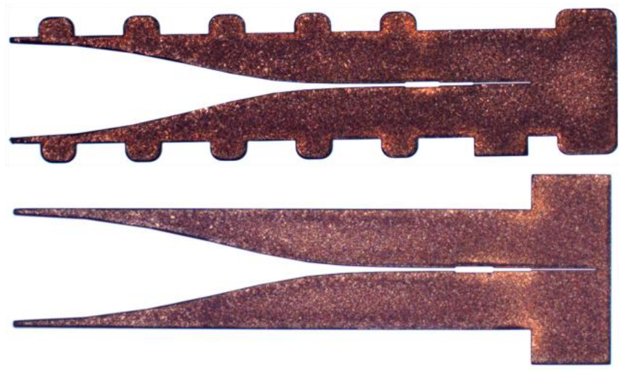

Fig. 5. Microscope picture of the fabricated test structures. The smallest fingap was 4 um.

Back-to-Back configuration. It is seen that the proposed finlines could achieve broadband performance as their counterpart with a thin dielectric substrate.

A transition from finline to thin-film microstrip could be implemented with, e.g., a Marchand Balun which presents a large fractional bandwidth with minimum insertion loss [4].

III. Fabrication

The all-metal micromachining technique for waveguide components were demonstrated in [5] and [6]. A simplified process flow is depicted in Fig. 3. The process started with cleaning a 4” wafer followed by the deposition by magnetron sputtering of a metal seed bilayer of Ti/Au. Afterward, a negative thick photoresist was spin-coated, baked, and patterned by photolithography. This step was followed by the electroplating in copper plating solution. Structures with different copper thicknesses ranging from 30 μm to 50 μm were produced. Afterward, the resist layer was stripped by a wet remover. The remaining seed was dry etch using the copper structures as a hard mask. Finally, the silicon carrier was etched away to release the test structures. Fig. 4 depicts Scanning Electron Microscopes pictures of the resist layer and the fabricated test structures. Moreover, Fig. 5 shows the released structures where the smallest fingap is 4 μm.

IV. Conclusion

In this study, we have detailed the design, simulation, and fabrication of all-metal micromachined finlines, with the potential for integration with existing microstrip-to-slotline transitions. Moreover, all-metal finlines without a dielectric substrate are a promising solution to avoid limitations of,e.g., silicon substrate structures that usually present substrate modes, dielectric losses, and resonances. The high fractional bandwidth exhibited by the proposed structure enables its use in broadband SIS mixer design for future applications.

References

[1] V. Belitsky *et al.*, "ALMA Band 5 receiver cartridge - Design, performance, and commissioning, " *Astron. & Astrophys.*, vol. 611, pp.1-10, Mar. 2018, Art. no. A98, doi: 10.1051/0004-6361/201731883.

[2] H. Rashid, S. Krause, D. Meledin, V. Desmaris, A. Pavolotsky and V. Belitsky, "Frequency Multiplier Based on Distributed Superconducting Tunnel Junctions: Theory, Design, and Characterization," in *IEEE Transactions on Terahertz Science and Technology*, vol. 6, no. 5, pp. 724-736, Sept. 2016, doi: 10.1109/TTHZ.2016.2583201.

[3] C. López, V. Desmaris, D. Meledin, A. Pavolotsky, and V. Belitsky, "Waveguide-to-Substrate Transition Based on Unilateral Substrateless Finline Structure: Design, Fabrication, and Characterization," *IEEE Trans. THz Sci. Technol.*, vol. 10, no. 6, pp. 668-676, Nov. 2020, doi: 10.1109/TTHZ.2020.3020683.

[4] C. López, M. A. Mebarki, V. Desmaris, D. Meledin, A. Pavolotsky, and V. Belitsky, "Wideband Slotline-to-Microstrip Transition for 210-375 GHz based on Marchand Baluns," *IEEE Trans. THz Sci. Technol.*, 2022, doi: 10.1109/TTHZ.2022.3149413.

[5] V. Desmaris, D. Meledin, A. Pavolotsky, R. Monje and V. Belitsky, "All-metal micromachining for the fabrication of sub-millimetre and THz waveguide components and circuits," *Journal of Micromechanics and Microengineering*, 2008, doi: 10.1088/0960-1317/18/9/095004

[6] V. Desmaris et. al., "Terahertz components packaging using integrated waveguide technology," *2011 IEEE MTT-S International Microwave Workshop Series on Millimeter Wave Integration Technologies*, 2011, pp. 81-84, doi: 10.1109/IMWS3.2011.6061893.