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微纳技术与精密机械

60 GHz贴片天线用低温共烧陶瓷基板的微机械加工

缪旻[1],张小青[1],姚雅婷[1],沐方清[2],胡独巍[3]

1. 北京信息科技大学 信息微系统研究所
2. 中国电子科技集团公司 第四十三研究所
3. 北京大学 微米纳米加工技术国家级重点实验室

摘要： 为有效提升60 GHz贴片天线及阵列的辐射带宽，提出利用微机械手段加工天线的低温共烧陶瓷（LTCC）基板。通过微切削方法在特定生瓷层上制作贯通结构，充填可挥发牺牲材料，完成基板叠压、烧结，待牺牲层升华排净后最终构成三维微结构。设计、制备了悬臂梁、围框结构和微管道等工艺样品。对天线设计电性能进行全波分析，并测试了微流道散热特性。实验结果表明：提出的方法成功解决了不同轴系各方向收缩率不一致、空腔塌陷等工艺问题，制作出的悬臂梁与围框尺寸高宽比达4∶1，总长为12 mm，总层厚为1.4 mm；内嵌微流道横截面为200 μm×200 μm，长度达25 cm以上；内部光滑，基板表面贴装发热功率密度达2 W/cm^{2}的功率器件时提供40 K以上的冷却能力；基板经过微机械加工后，天线的辐射带宽可从2.7 GHz增加到5.3 GHz，而增益的损失甚微。这些结果显示，用简单、低成本的微机械加工方法可在不显著增加制造成本的情况下有效扩增毫米波贴片天线的辐射带宽，为贴片天线阵中有源发射功率器件的设计和贴片天线的三维高密度集成提供了有效的技术支持。

关键词： 陶瓷微机械加工 低温共烧陶瓷基板 毫米波 贴片天线

Micromachining of LTCC Substrate for 60 GHz Patch Antenna

MIAO Min[1],ZHANG Xiao-qing[1],YAO Ya-ting[1],MU Fang-qing[2],HU Du-wei[3]

1. Information Microsystem Institute, Beijing Information Science and Technology University
2. The 43th Research Institute of China Electronic Technology Group Corporation
3. National Key Laboratory of Science and Technology on Micro/Nano Fabrication, Peking University

Abstract: To effectively enhance the radiation bandwidth of 60 GHz patch antennas, a micromachining process for the Low Temperature Co-fired Ceramic (LTCC) substrate was proposed. Specific green tape layers of substrate were micromilled to form perforated structures which were then filled with sacrificial materials. Thereafter, the individual layers were stacked up and sintered to form a three-dimensional (3D) microstructure. The cantilevers, enclosing frame structures and embedded microchannels were fabricated to verify the effectiveness of the process. The electrical properties of the antenna designs were validated by a full-wave analysis, and the effectiveness of the cooling channel was experimentally tested. The experiments show that the proposed process solves problems like the variation of contraction rate in various axes and the collapsing of the embedded cavities. The 3D frame, cantilever and the embedded microfluidic structure are fabricated with a maximum aspect ratio as high as 4∶1, and a total thickness of 1.4 mm (14 layers). The cross section size of the microchannel is as large as 200 μm×200 μm and its maximum length is beyond 2.5 cm. With smooth inner walls, the smooth microfluidic flow may provide a cooling effect over 40 K for the integrated power devices with a heating power density of 2 W/cm^2. The simulated radiation pattern shows a doubled increase of radiation bandwidth from 2.7 GHz to 5.3 GHz and has a little gain loss. These results demonstrate that simple and low-cost micromachining may effectively enhance the radiation bandwidth of patch antennas without additional costs, which is beneficial to the design and implementation of large scale and highly integrated transmitting/receiving arrays with active power devices.

Keywords: Ceramic micromachining Low Temperature Co-fired Ceramic(LTCC) substrate Milimeter wave Patch antenna

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嵌入低温共烧陶瓷多层封装基板的微机械太赫兹波导、波导元件及其工艺研究;LTCC微加速度计;系统级封装多层基板中冷却用微管道网络的微制造技术;高密度三维系统级封装的关键技术研究;三维系统级封装（3D SIP）设计技术基础研究

通讯作者: 缪旻

作者简介: 缪旻（1973-），男，博士,副教授，2005年于北京大学获博士学位。主要从事信息与通信工程、微米/纳米加工、微电子学与固体电子学、高等教育学等方面的研究。

作者Email: miaomin@bistu.edu.cn

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