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硕士学位论文

面向MEMS封装的纳米玻璃粉制备及其回流工艺研究

Study on Preparation and Reflow Process of Nano Glass Powder for MEMS Encapsulations

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摘 要

封装一直是MEMS器件的重难点，封装的好坏直接决定器件的成败。受成本、方便性、封装性能、工艺复杂程度、器件大小等诸多因素的影响，使用盖帽的圆片级封装成为一种明智、新颖和备受欢迎的方法，是MEMS器件封装的趋势。玻璃盖帽具有寄生电容小、和硅键合容易、绝热性能好等优点，是常用的封装盖帽。特别是高频RF传感器，玻璃盖帽因其良好的电学隔离作用，成为盖帽的最佳选择。然而玻璃盖帽的制作却非常困难。传统玻璃回流工艺是如今较好的一种玻璃盖帽制作方式，但仍然有很多不足，如抛光容易碎片、回流时间长、有最小线宽的限制、需要高真空阳极键合等。

本文以玻璃盖帽为出发点，研究了玻璃粉回流工艺的若干问题。为了获得纳米玻璃粉，通过离散元分析软件，研究了Borosilicate 33玻璃的高能球磨行为规律。基于前期球磨规律研究，确定填充率、球磨罐材料、磨球个数比等因素，探索了球磨速度、球料比对球磨性能的影响。分析了球磨罐的受力、颗粒碰撞次数随球磨速度、球料比的变化。确定该球磨机和Borosilicate 33玻璃的理论最佳球料比为40:1到80:1，临界转速在1000 r/min左右。结合离散元分析结果，设计正交试验，开展了纳米级玻璃粉最高出料率工艺研究。并通过XRD、扫描电子显微镜、激光粒度测试仪等对玻璃形貌、粒度、结晶度进行了表征。不仅探索出了Borosilicate 33玻璃的最佳球磨工艺，同时为研究超细球磨提供了系统的方法。

采用理论结合仿真的方式，利用有限元仿真技术结合材料力学、理论力学、电学等知识对玻璃盖帽进行了设计，并对该结构受热冲击的性能进行探究。最终求得了玻璃盖帽的总厚度、微腔厚度、垂直互联电极尺寸等。并基于传统MEMS加工技术，完成MEMS微腔体的加工。

对现有颗粒分离方法进行分析，得出离心法是最适合纳米玻璃粉的分离方法，利用该方法成功分离出纳米玻璃粉。并研究了干玻璃粉和带溶剂的玻璃粉的填充性能、填充率；研究了玻璃粉在空气气氛和真空气氛中的融化效果；探究玻璃在不同基底上的润湿性；不同试剂对液相玻璃的表面能改善性能；最后研究了玻璃粉烧结的烧结行为。

关键词：微机械系统；玻璃盖帽；玻璃粉回流；超细球磨

Abstract

Packaging which directly determines the success or failure of the device has always been the major difficulty in MEMS devices. Effected by many factors such as cost, convenience, package performance, process complexity, device size, wafer level packaging using a cap becomes a wise, novel and popular way, and it is the inevitable trend of MEMS package. Due to the advantages of small parasitic capacitance, easy bonding and good thermal insulation performance, glass cap a popular MEMS package cap. Especially for high frequency RF sensor, glass cap is the best choice because of its good electrical isolation. However, the production of glass cap is very difficult. The traditional glass reflow process is the best way to block the glass nowadays, but there are still many shortcomings, such as polishing debris easily, long sintering time, restrictions of minimum line width, requirement of high vacuum anode bonding, etc.

In this thesis, some problems of glass powder reflow process have been studied. In order to obtain nano glass powder, the behavior of high energy ball milling of Borosilicate 33 glass was studied by discrete element analysis software. Based on the study of the milling law, the factors such as the filling rate, the material of the milling ball and the number of milling balls were determined. The variation of the force and the number of particles collision with the ball milling speed and ball-glass ratio were analyzed. It is confirmed that the theoretical ball ratio of the ball mill and Borosilicate 33 glass is 40:1 to 80:1, the critical speed is about 1000 r/min. Based on the results of discrete element analysis. Orthogonal experiment was carried out to study the highest discharge rate of nanometer glass powder. The morphology, particle size and crystallinity of the samples were characterized by XRD, scanning electron microscopy and laser particle size analyzer. It not only explored the best ball milling technology of Borosilicate 33 glass, but also provided a systematic method for the study of ultrafine ball milling.

By using the method of combining theory and simulation, the finite element simulation is combined with the knowledge of mechanics of materials, mechanics, electricity and so on. Finally, the total thickness of the glass cap, the thickness of the micro cavity and the size of the vertical interconnect electrode are obtained. Through the traditional MEMS processing technology, the processing of MEMS micro cavity was completed.

Based on the analysis of the existing particle separation method, it is concluded that the centrifugal method is the most suitable for the separation n of nano glass powder. And to study the dry glass powder and glass powder filled with solvent properties, filling rate. The effect of glass powder in air and vacuum atmosphere melting; wettability of glass in the different substrate surface has also been studied. The surface energy of liquid glass was changed by adding different reagents. Finally the sintering behavior of glass powder has been studied.

Keywords: MEMS; glass cap; glass powder reflow; ultrafine ball milling

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