Presentation：玻璃基板有望成为载板未来发展趋势，关注玻璃基板国产进程

Glass Substrates Poised to Lead Future Trends in Carrier Development: Focus on Domestic Progress

张晓飞Xiaofei Zhang xf.zhang@htisec.com
崔冰睿Bingrui Cui br.cui@htisec.com
周扬Yang Zhou y.zhou@htisec.com
陈昊飞Haofei Chen haofei.chen@htisec.com

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投资结论:

- **IC载板是芯片封装环节的核心材料，玻璃基板有望成为载板未来发展趋势。**IC封装基板不仅为芯片提供支撑、散热和保护作用，同时在芯片与PCB之间提供电子连接，起着“承上启下”的作用。2023年全球传统ABF载板市场规模为507.12亿元。英特尔认为玻璃基板是载板未来发展趋势，在本世纪20年代末，将发生由有机基板向玻璃基板的转变。玻璃基板并不意味着用玻璃取代传统载板中的所有有机材料，而是载板的核心层采用玻璃材质。对于核心层上下两端的增层部分而言，依然可以使用ABF进行增层。
- **玻璃基板有望解决封装基板向大尺寸、高叠层持续迈进下出现的翘曲问题。**先进封装下高端算力芯片及相应载板面积持续增大。根据台积电技术路线，其正在开发制造超大尺寸中介层的方法，计划至2027年中介层可以达到光罩极限的8倍以上，载板面积将超过120mm × 120mm。大尺寸封装下，硅芯片、载板不同组成部分间CTE差异将极易发生翘曲现象，而相对于有机材料，玻璃CTE更接近于硅，能有效对抗封装过程中的翘曲。
- **TGV玻璃成孔及孔内金属填充是玻璃基板生产的关键工艺。**TGV（Through Glass Via，玻璃通孔）能够在玻璃基板上形成微小的导电通孔，从而实现芯片间的高效连接。TGV是生产用于先进封装玻璃基板的关键工艺。TGV主要流程可分为玻璃成孔、孔内金属填充两大环节。TGV玻璃成孔环节中激光诱导湿法刻蚀技术具备大规模应用前景。TGV孔径较大，多为通孔，而且由于玻璃表面平滑，与常用金属（如 Cu）的黏附性较差，容易造成玻璃衬底与金属层之间的分层现象，导致金属层卷曲甚至脱落等现象，提高金属层与玻璃表面的粘附性是产业目前的研究重点。
- **我们认为随着封装基板向大尺寸、高叠层方向发展，封装芯片存在的翘曲问题日渐突出。玻璃基板凭借其与硅芯片良好的CTE匹配度，能有效对抗封装过程中的翘曲问题，玻璃基板是封装基板未来的技术发展趋势。受益于先进封装下大尺寸AI算力芯片更新迭代，玻璃基板产业链有望迎来加速成长。建议关注：沃格光电、兴森科技。**
- 风险提示：全球宏观经济增长不及预期，云厂商资本开支不及预期，国产厂商玻璃基板研究进程不及预期。

要点

一、传统IC载板与玻璃基板介绍

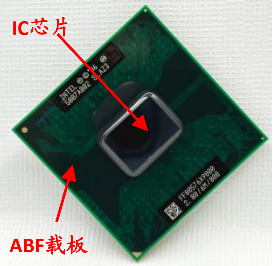
二、封装基板向大尺寸、高叠层持续迈进，玻璃基板有望解决封装芯片翘曲问题

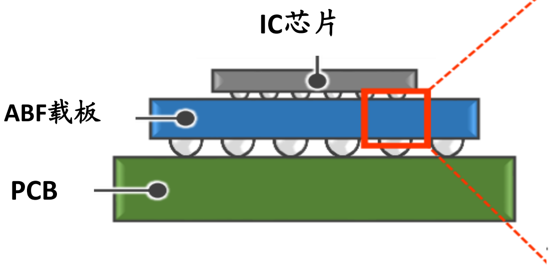
三、TGV玻璃成孔及孔内金属填充是玻璃基板生产的关键工艺

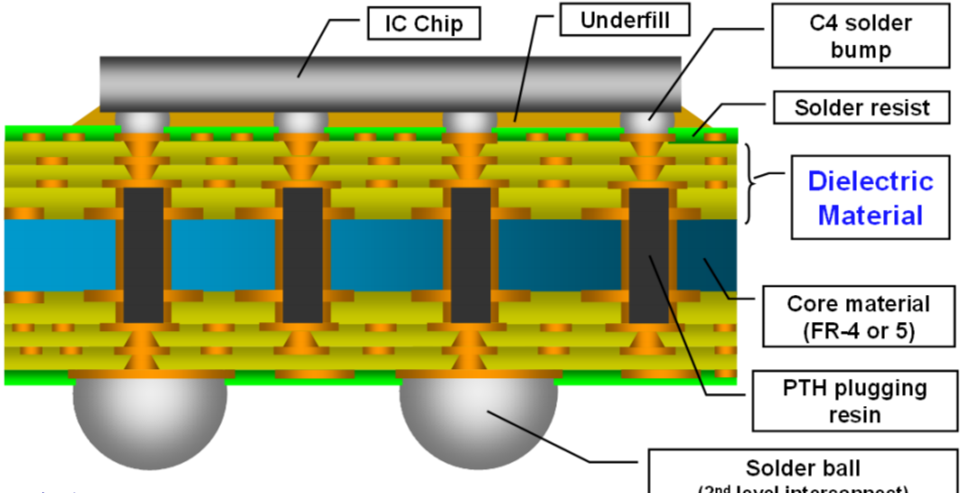
何为IC载板（封装基板）

- **IC载板是芯片封装环节的核心材料。**IC载板具有高密度、高精度、高性能、小型化及薄型化等特点，与裸片、引线等经过封装测试后共同组成芯片。IC载板不仅为芯片提供支撑、散热和保护作用，同时在芯片与PCB之间提供电子连接，起着“承上启下”的作用。

ABF载板内部结构示意图







资料来源：eBay，《和美精艺招股说明书（申报稿）》，味之素官网，HTI

IC载板分类：BT载板与ABF载板

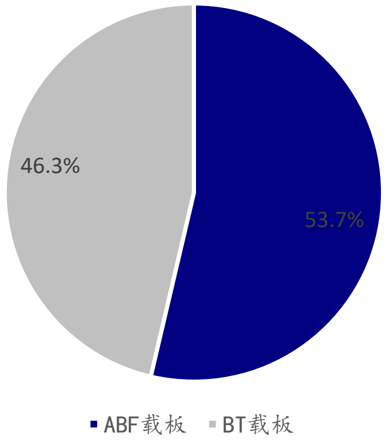
- **IC载板按基板材质主要分为BT载板与ABF载板。**BT树脂具备高Tg、高耐热性、抗湿性、低介电常数(Dk)和低散失因素(Df)等多种优势，多用于MEMS、射频和存储芯片等产品的封装。ABF载板相比于BT载板，其可做线路较细、适合高脚数高传输的IC，多用于CPU、GPU等大型高端芯片。
- **根据和美精艺问询回复援引中国台湾电路板协会数据，2023年全球IC封装基板的市场总规模为944.83亿元。**其中，BT类IC封装基板市场规模为437.71亿元，ABF类IC封装基板市场规模为507.12亿元。

IC载板分类及关键指标

IC载板类型（按封装工艺）	基板材质	终端芯片产品	生产工艺	关键性能指标（线宽/线距）
FC-BGA封装基板	ABF	高算力CPU、GPU等	SAP	8/8-15/15 μ m
	类ABF、ABF	桌面级CPU、桌面级GPU、MPU、AP等	mSAP/SAP	15/15-20/20 μ m
FC-CSP封装基板	BT	通信芯片（5G）、AP、精细线路易失性存储芯片等	mSAP	10/10-20/20 μ m

资料来源：品化科技官网，《和美精艺第一轮审核问询函的回复》，HTI

2023年ABF/BT载板市场规模占比

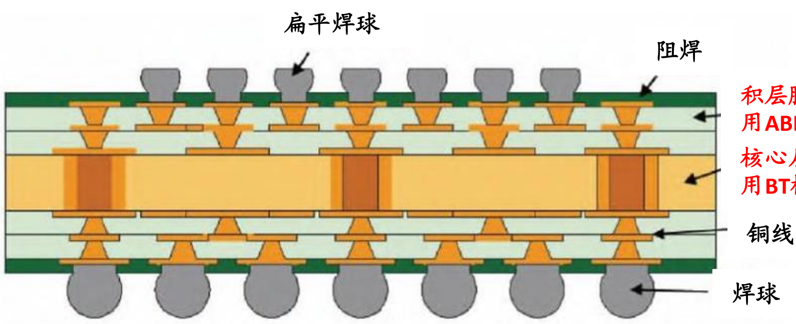


ABF载板结构与制造工艺

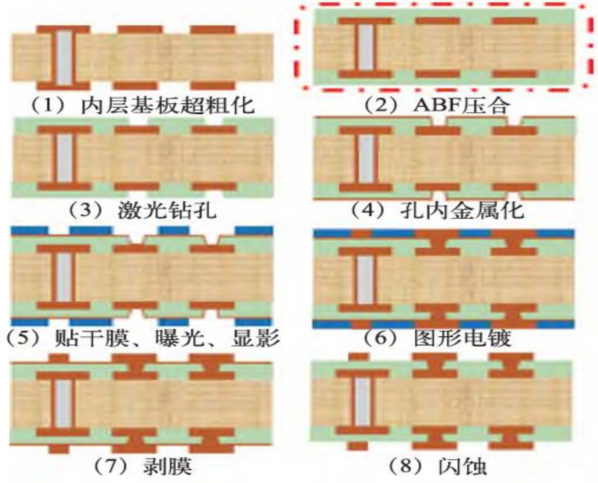
- **ABF载板通常由中心的Core层和两边的ABF积层组成：** 核心层通常选用BT树脂材料，积层膜为ABF，是日本味之素公司在生产味精时的一种副产物，是一种用合成树脂类材料做成的薄膜，具有很好的绝缘性。

- **ABF载板的制造通常选用SAP工艺。** SAP工艺是将内层基板做超粗化处理以增强介质和下层金属线路间的结合力，在基板2面贴增层介质，通过真空压膜和镜面钢板整平获得均匀覆盖在基板表面的介质层，激光钻孔后对介质表面做除胶工艺处理，清除钻孔产生的残渣并形成均匀的、纳米尺度的粗糙表面，在孔内及介质表面沉积疏松的化铜层，再经过图形发生（包括贴膜、曝光、显影工艺）和图形转移（包括图形电镀、剥膜和闪蚀）等一系列工艺形成增层线路。

ABF载板结构



SAP工艺流程

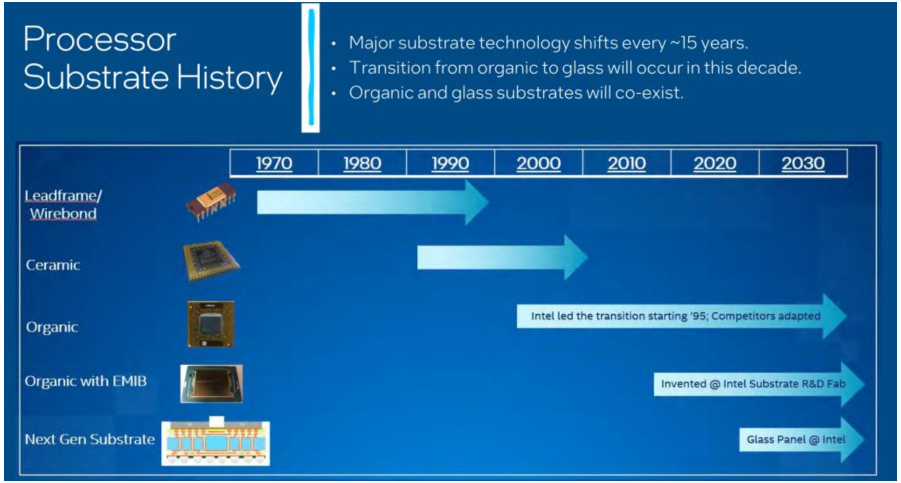


资料来源：《10层FCBGA载板的制作关键技术研究》（王立刚等），《FCBGA基板关键技术综述及展望》（方志丹等），HTI

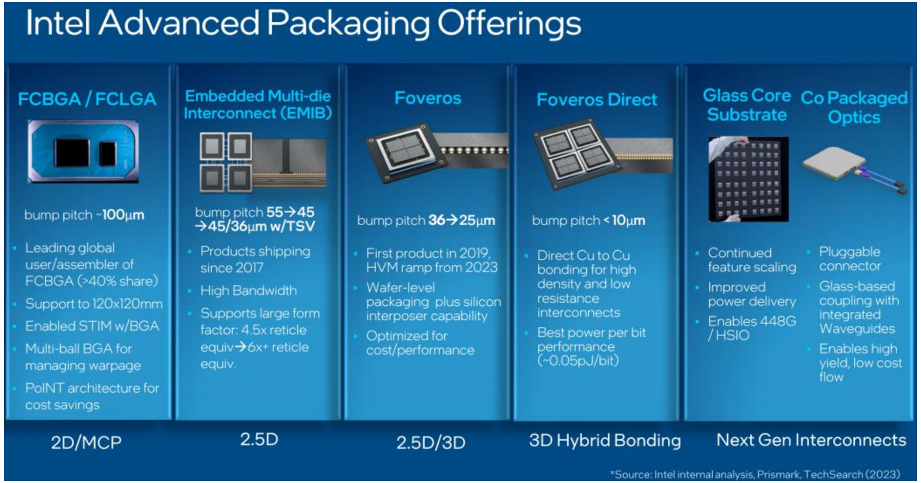
英特尔认为玻璃基板是载板未来发展趋势

- **英特尔认为玻璃基板是载板未来发展趋势。**根据英特尔官网披露，到这个十年末，有机材料封装上扩展晶体管的能力上可能会达到极限。这些有机材料消耗更多电力，并存在诸如收缩和翘曲等局限性，而玻璃基板是半导体发展的可行且关键的下一步解决方案。英特尔认为主流的载板封装技术每15年会改变一次，在这个十年末，将发生由有机基板向玻璃基板的转变，但有机基板和玻璃基板将会共存。

英特尔封装基板材质路线图



英特尔封装技术路线图



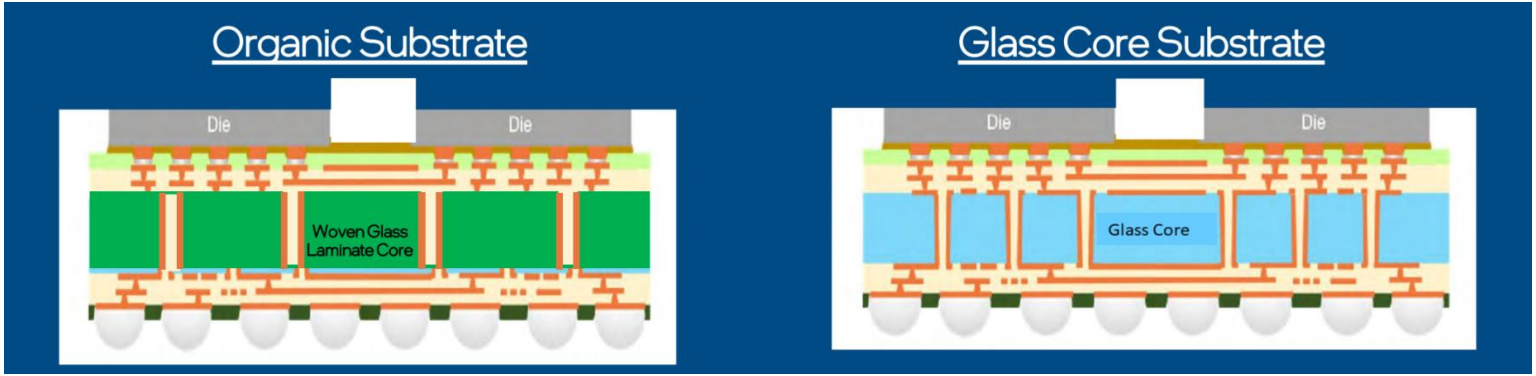
资料来源：Intel官网，HTI

玻璃基板：核心层由玻璃代替，增层部分仍可使用ABF

- **玻璃基板并不意味着用玻璃取代整个基板，而是载板的核心层采用玻璃材质。**对于核心层上下两端的增层部分而言，依然可以使用ABF材料进行增层。

- **相比有机载板，玻璃基板具备诸多优势。**玻璃基板具有可调弹性模量与与硅更接近的热膨胀系数（CTE），使得玻璃基板可支持更大尺寸的封装。玻璃基板通孔密度相对较高，有利于改善基板布线和信号传输。同时，其介电损耗低，可实现高速信号传输。

英特尔有机基板与玻璃基板结构对比



资料来源：Intel官网，HTI

要点

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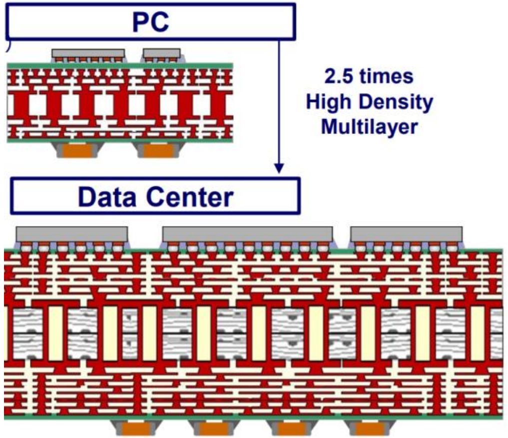
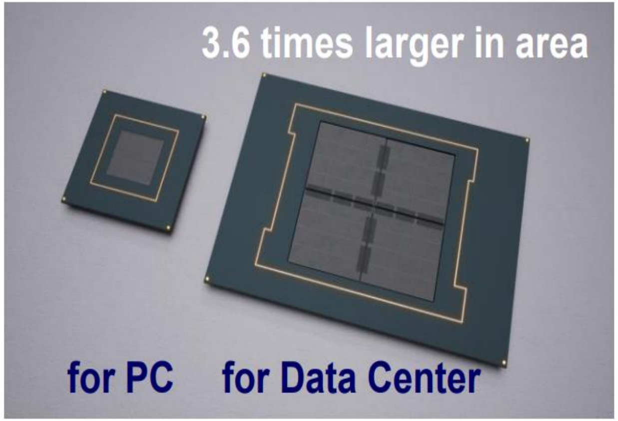
载板朝着更高层数，更大面积方向发展

- 高性能计算需求下，ABF载板朝着更高层数，更大面积方向发展。根据IBIDEN展示材料，平均单个数据中心芯片ABF载板面积是单个PC芯片ABF载板层数的2.5倍，面积的3.6倍。

PC与数据中心ABF载板用量区别





SAP Load per Application

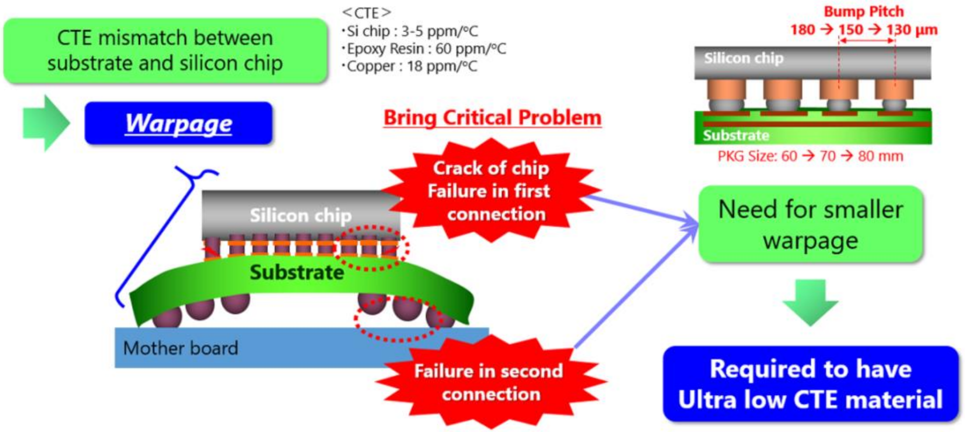
		2021	2025
PC	Size	1.0	1.0
	Numbers of Buildups	1.0	1.3
	SAP Load	1.0	1.3
Server	Size	2.6	3.6
	Numbers of Buildups	2.5	2.5
	SAP Load	6.5	9.0

资料来源：IBIDEN官网2021财年及2022财年半年度展示材料，HTI

硅芯片、载板不同组成部分间CTE差异造成翘曲

- **翘曲是由芯片/载板的片状结构中不同组成部分间的CTE差异造成的。**根据《FCBGA基板关键技术综述及展望》内容，在制造过程中，芯片/载板各个部分随温度变化涨缩不同，产生的机械应力不同，造成片状结构表面起伏。严重的基板翘曲会导致2个重要的问题：1. 翘曲导致封装失效的表现通常为倒装焊的焊球局部无法与PCB连接，或相邻焊球间发生桥接；2. 过大的基板翘曲导致封装后的基板与芯片间存在较大应力，过大的应力导致焊球开裂、芯片开裂等可靠性问题。

硅芯片、载板不同组成部分间的CTE差异造成翘曲



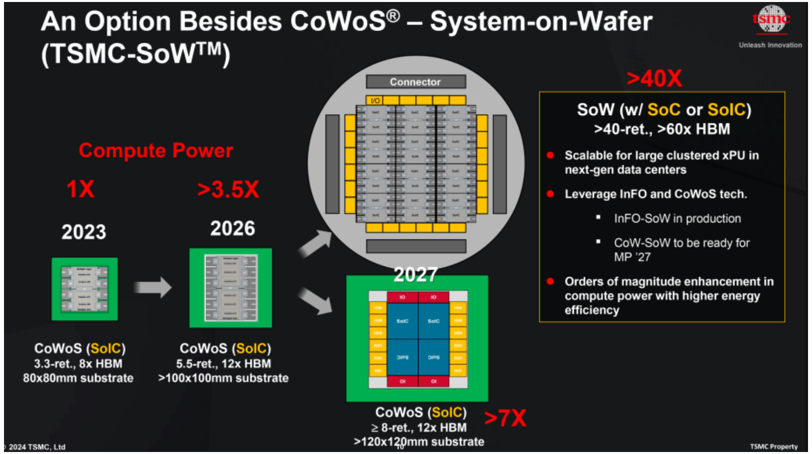
资料来源：《FCBGA基板关键技术综述及展望》（方志丹等），Resonac官网，HTI

高端芯片面积逐步增大，翘曲问题日渐突出

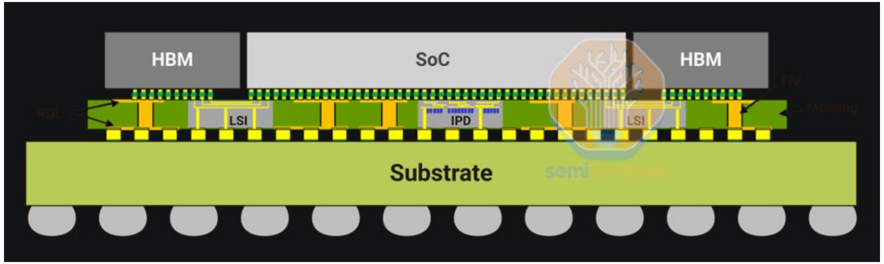
- **台积电披露的先进封装路线显示其未来高端芯片中介层面积将不断增大。** 台积电通过使用CoWoS技术将多个芯片安装到中介层上来生产更大的芯片。当前一代CoWoS允许中介层达到台积电光罩极限的3.3倍，台积电仍计划制造更大的芯片，以满足HPC和AI行业的预计需求。台积电宣布他们正在开发制造超大尺寸中介层的方法，计划至2027年中介层可以达到光罩极限的8倍以上，载板面积将超过120mm × 120mm。

- **翘曲成为台积电CoWoS-L封装所需面对的重要问题。** 根据Semianalysis的报告，CoWoS-L使用RDL有机中介层，其中嵌入了局部硅互连（LSI）和桥接芯片，以桥接封装上各种计算和内存之间的通信。CoWoS-L封装下硅芯片、桥接器、有机中介层和基板之间的CTE不匹配，容易引起翘曲问题。

台积电先进封装路线下中介层面积不断增大



CoWoS-L封装结构



资料来源：Anandtech，Semianalysis，HTI

玻璃基板成为解决翘曲问题的破局之道

- **相较于有机材料，玻璃和硅的CTE更为接近，可有效降低硅芯片/基板间的应力。**翘曲是由芯片/载板的片状结构中不同组成部分间的CTE差异造成的。材料CTE差距较大，不同材料随温度变化涨缩不同，造成翘曲。硅的CTE为2.7ppm/℃，有机材料FR-4 CTE为16ppm/ ℃，低CTE玻璃的CTE为3.8ppm/ ℃，由此可见硅和玻璃的CTE更加匹配，可有效降低严重翘曲的发生。

不同材料关键参数对比

Material	E (GPa)	CTE (ppm/°C)	Poisson's ratio	Material model
Glass (High CTE)	74	9.8	0.23	Elastic
Glass (Low CTE)	77	3.8	0.22	Elastic
Silicon	130	2.7	0.28	Elastic
FR-4	24	16	0.3	Elastic
Solder	Temp. dep.	22	0.34	Visco-plastic
Copper	121	17.3	0.3	Elastic-plastic

资料来源：《Large low-CTE glass package-to-PCB interconnections with solder strain-relief using polymer collars》（Gary Menezes等），HTI

海通國際 HAITONG

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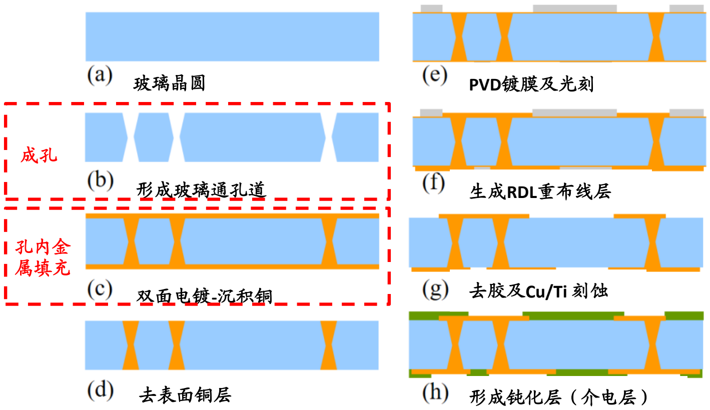
玻璃基板生产关键工艺：TGV玻璃成孔

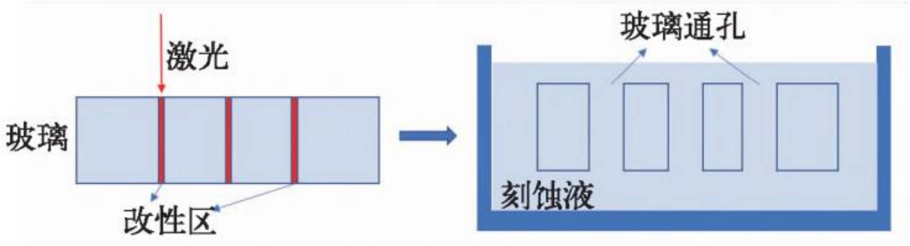
- **TGV（Through Glass Via，玻璃通孔）能够在玻璃基板上形成微小的导电通孔，从而实现芯片间的高效连接。**TGV是生产用于先进封装玻璃基板的关键工艺。TGV主要流程可分为玻璃成孔、孔内金属填充两大环节。

- **TGV玻璃成孔环节中激光诱导湿法刻蚀技术具备大规模应用前景。**TGV主流成孔方法包括喷砂法、光敏玻璃法、等离子刻蚀法、激光烧蚀和激光诱导湿法刻蚀法等。其中，激光诱导湿法刻蚀法利用脉冲激光诱导玻璃产生连续的变性区，相比未变性区域的玻璃，变性玻在氢氟酸刻蚀速率较快，基于这一特性可以在玻璃制作通孔/盲孔。激光诱导湿法刻蚀技术具有快速高效成孔、工艺简单、侧壁光滑、高精度成孔等显著优点，被广泛应用于各种玻璃材料的三维微流道加工，其成本相对较低，有大规模应用的前景。

TGV主要流程



激光诱导湿法刻蚀成孔



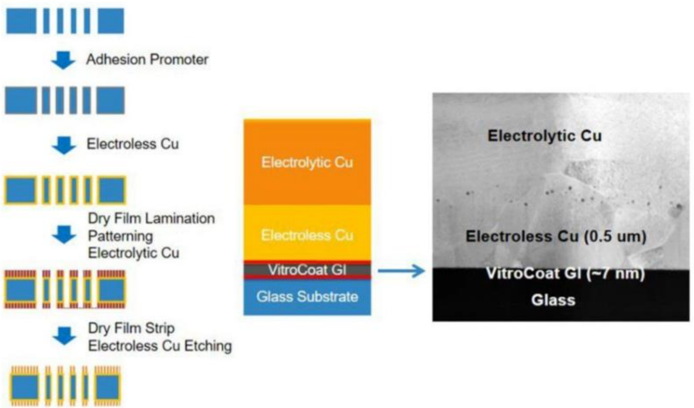
资料来源：艾邦半导体官方公众号，《玻璃通孔技术研究进展》（陈力等），HTI

玻璃基板生产关键工艺：TGV孔内金属填充

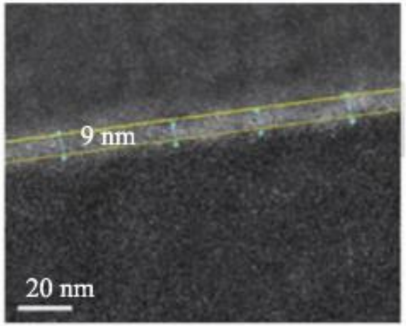
- **对通孔进行高质量的金属填充技术难度大。**与 TSV（硅通孔）不同，TGV孔径较大，且多为通孔，电镀时间长、成本高；另一方面，与硅材料不同，由于玻璃表面平滑，与常用金属（如 Cu）的黏附性较差，容易造成玻璃衬底与金属层之间的分层现象，导致金属层卷曲甚至脱落等现象。

- 在对TGV通孔进行电镀填充时，通常需要先沉积金属粘附层如钛(Ti)、铬(Cr)等，种子层Cu，后进行电镀。目前在开发采用化镀Cu 种子层的低成本TGV填充方案，然后再通过半加成法（SAP）在 胶图形上电镀出Cu线路。由于玻璃与金属Cu之间热膨胀系数不同，化学结构存在明显差异，并且玻璃具有非常光滑的表面，导致玻璃与化镀Cu之间的黏附力差，需要特殊的处理来提高结合力。例如美国安美特公司报道了金属氧化物粘附增强方法，通过把玻璃基板浸入化学药液，覆盖纳米厚度的金属氧化物粘附促进剂形成黏附层提高化镀Cu层的黏附力。

利用超薄金属氧化物粘附促进剂进行镀膜



金属氧化物粘附层透射电镜(TEM)图片



资料来源：未来半导体官方公众号援引安美特，《玻璃通孔技术研究进展》（陈力等），HTI

投资建议

我们认为随着封装基板向大尺寸、高叠层方向发展，封装芯片存在的翘曲问题日渐突出。玻璃基板凭借其与硅芯片良好的CTE匹配度，能有效对抗封装过程中的翘曲问题，玻璃基板是封装基板未来的技术发展趋势。受益于大尺寸AI算力芯片更新迭代，玻璃基板产业链有望迎来加速成长。

根据沃格光电2024年半年度报告，沃格光电是全球少数同时掌握TGV技术的厂家之一，具备行业领先的玻璃薄化、TGV（玻璃基巨量互通技术）、溅射铜以及微电路图形化技术（RDL布线能力）以及SAP多层线路堆叠，采用自主开发绝缘膜材。沃格光电拥有的TGV技术可在玻璃基板上进行不同的线路和通孔设计，以满足终端产品不同的应用场景。根据兴森科技官方公众号，兴森科技在工艺技术整合与研发创新实现突破，于玻璃材料上完成线路制作与ABF压合等工艺，成功研制出玻璃基板工程样品，并于第25届CIOE中国光博会中展示。建议关注：沃格光电、兴森科技。

风险提示

全球宏观经济增长不及预期;

云厂商资本开支不及预期;

国产厂商玻璃基板研究进程不及预期。

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优于大市，未来12-18个月内预期相对基准指数涨幅在10%以上，基准定义如下
中性，未来12-18个月内预期相对基准指数变化不大，基准定义如下。根据FINRA/NYSE的评级分布规则，我们会将中性评级划入持有这一类别。
弱于大市，未来12-18个月内预期相对基准指数跌幅在10%以上，基准定义如下
各地股票基准指数：日本 – TOPIX, 韩国 – KOSPI, 台湾 – TAIEX, 印度 – Nifty100, 美国 – SP500; 其他所有中国概念股 – MSCI China.

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Analyst Stock Ratings
Outperform: The stock’s total return over the next 12-18 months is expected to exceed the return of its relevant broad market benchmark, as indicated below.
Neutral: The stock’s total return over the next 12-18 months is expected to be in line with the return of its relevant broad market benchmark, as indicated below. For purposes only of FINRA/NYSE ratings distribution rules, our Neutral rating falls into a hold rating category.
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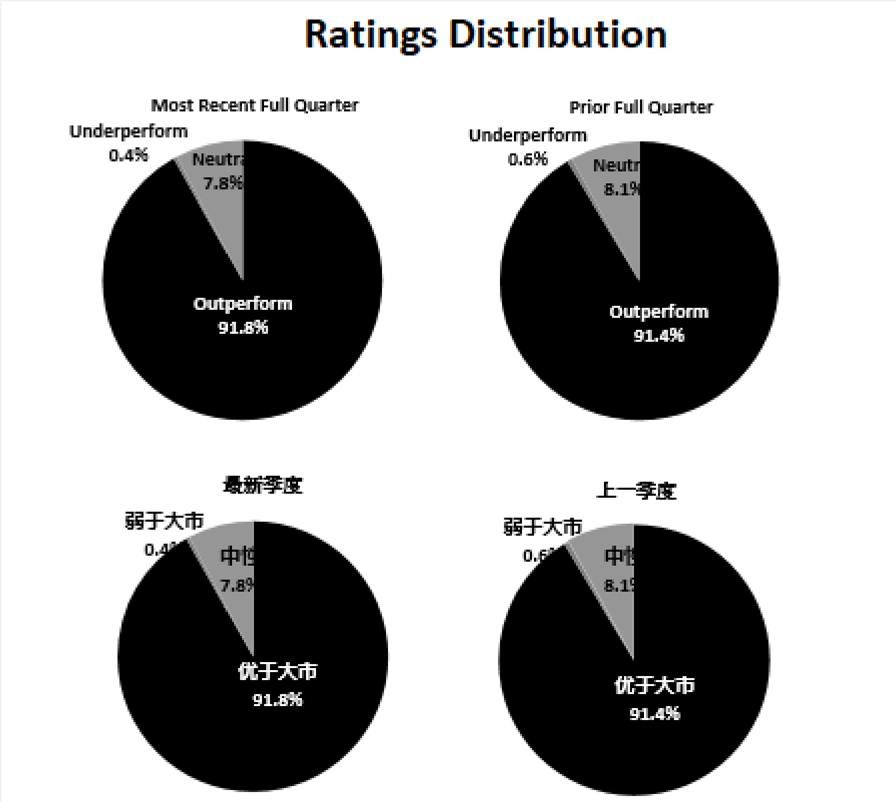
评级分布Rating Distribution



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截至2024年9月30日海通国际股票研究评级分布

	优于大市	**中性 (持有)**	**弱于大市**
海通国际股票研究覆盖率	91.8%	7.8%	0.4%
投资银行客户*	3.5%	4.4%	0.0%

*在每个评级类别里投资银行客户所占的百分比。
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买入，未来12-18个月内预期相对基准指数涨幅在10%以上，基准定义如下
中性，未来12-18个月内预期相对基准指数变化不大，基准定义如下。根据FINRA/NYSE的评级分布规则，我们会将中性评级划入持有这一类别。
卖出，未来12-18个月内预期相对基准指数跌幅在10%以上，基准定义如下
各地股票基准指数：日本 – TOPIX, 韩国 – KOSPI, 台湾 – TAIEX, 印度 – Nifty100; 其他所有中国概念股 – MSCI China.

Haitong International Equity Research Ratings Distribution, as of September 30, 2024

	Outperform	**Neutral (hold)**	**Underperform**
HTI Equity Research Coverage	91.8%	7.8%	0.4%
IB clients*	3.5%	4.4%	0.0%

*Percentage of investment banking clients in each rating category.
BUY, Neutral, and SELL in the above distribution correspond to our current ratings of Outperform, Neutral, and Underperform.
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地址: 1203A, Floor 12A, Tower 2A, One World Center
841 Senapati Bapat Marg, Elphinstone Road, Mumbai 400 013, India
CIN U74140MH2011FTC224070
电话: +91 22 43156800 传真:+91 22 24216327
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Name of the entity: Haitong Securities India Private Limited

SEBI Research Analyst Registration Number: INH000002590

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Address : 1203A, Floor 12A, Tower 2A, One World Center
841 Senapati Bapat Marg, Elphinstone Road, Mumbai 400 013, India
CIN U74140MH2011FTC224070
Ph: +91 22 43156800 Fax:+91 22 24216327
Details of the Compliance Officer and Grievance Officer : Prasanna Chandwaskar : Ph: +91 22 43156803; Email id: prasanna.chandwaskar@htisec.com

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