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T/UNP 733—2025

半导体热电致冷器件（TEC）测试方法

Test methods for thermoelectric cooling(TEC)semiconductor devices

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前　言

本文件按照GB/T 1.1—2020《标准化工作导则　第1部分：标准化文件的结构和起草规则》的规定起草。

请注意本文件的某些内容可能涉及专利。本文件的发布机构不承担识别专利的责任。

本文件由湖北赛格瑞新能源科技有限公司提出。

本文件由中国联合国采购促进会归口。

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引　言

为助力中国企业参与国际贸易，推动企业高质量发展，中国联合国采购促进会依托联合国采购体系，制定服务于国际贸易的系列标准，这些标准在国际贸易过程中发挥了越来越重要的作用，对促进贸易效率提升，减少交易成本和不确定性，确保产品质量与安全，增强消费者信心具有重要的意义。

联合国标准产品与服务分类代码（United Nations Standard Products and Services Code，UNSPSC）是联合国制定的标准，用于高效、准确地对产品和服务进行分类。在全球国际化采购中发挥着至关重要的作用，它为采购商和供应商提供了一个共同的语言和平台，促进了全球贸易的高效、有序发展。

围绕UNSPSC进行相关产品、技术和服务团体标准的制定，对助力企业融入国际采购，提升国际竞争力具有十分重要的作用和意义。

本文件采用UNSPSC分类代码由6位组成，对应原分类中的大类、中类和小类并用小数点分割。

本文件UNSPSC代码为“32.11.17”，由3段组成。其中：第1段为大类，“32”表示“电子元件及用品”，第2段为中类，“11”表示“分立半导体器件”，第3段为小类，“17”表示“半导体器件”。

半导体热电致冷器件（TEC）测试方法

1 范围

本文件描述了半导体热电致冷（TEC）器件的导线拉力，高温存储，恒定湿热，电热致冷、致热交变，耐压力，机械振动，抗剪切、使用寿命，防水和开关循环的测试方法。

本文件适用于半导体热电致冷（TEC）器件（以下简称“器件”）可靠性的测试。

2 规范性引用文件

下列文件中的内容通过文中的规范性引用而构成本文件必不可少的条款。其中，注日期的引用文件，仅该日期对应的版本适用于本文件；不注日期的引用文件，其最新版本（包括所有的修改单）适用于本文件。

GB/T 2423.2 电工电子产品环境试验 第2部分：试验方法 试验B：高温试验方法

GB/T 2423.3 环境试验 第2部分 试验方法 试验Cab 恒定湿热试验

GB/T 2423.6 电工电子产品环境试验 第2部分：试验方法 试验Eb和导则：碰撞

SJ 2855 温差电致冷名词术语、型号命名及其性能测试方法

T/UNP 734—2025 半导体温差发电（TEG）器件测试方法

3 术语和定义

SJ 2855界定的术语和定义适用于本文件。

4 导线拉力测试

4.1 测试设备和仪器

测试设备和仪器如下：

a) 固定底座；

b) 测试精度 0.1 N 及以上的拉力计。

4.2 测试环境

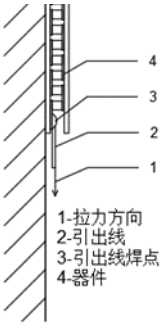
测试环境应整洁，无腐蚀性气体，无强磁场和电磁波干扰，环境温度为15 ℃～35 ℃，相对湿度为20%～80%，气压为86 kPa～106 kPa。

4.3 试样制备

试样尺寸和形状应符合产品设计要求，应选择常见的完整器件。常见的试样尺寸为边长1 cm、2 cm或4 cm左右的方形。试样数量为5只。

4.4 测试步骤

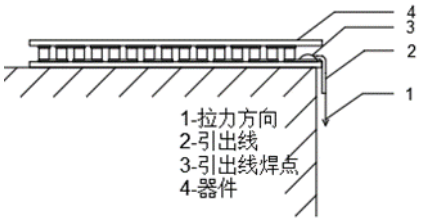
4.4.1 将器件垂直固定，在每根引出线上沿轴线方向施加静负荷 19.6 N（见图 1），时间为 9 s～11 s。



标引序号：
1——拉力方向；
2——引出线；
3——引出线焊点；
4——器件。

图1　轴向拉力测试示意图

4.4.2　将器件热面朝下水平固定，在引出线端部沿重力方向施加静负荷 4.9 N（见图 2），时间为 9 s～11 s。



标引序号：
1——拉力方向；
2——引出线；
3——引出线焊点；
4——器件。

图2　垂直拉力示意图

4.5　结果评估

试验结束后检查引出线外观，引出线没有断裂和机械损伤，认为导线拉力满足19.6 N水平拉力和4.9 N垂直拉力，判定为合格。

5　高温存储测试

5.1　测试设备和仪器

测试设备和仪器如下：

a)　恒温烘箱：温度均匀性在 3 ℃以内；

b)　LCR 数字电桥：测试频率＞1000 Hz，精度为 0.001 Ω 及以上。

5.2　测试环境

5.2.1　环境条件：温度 23 ℃～27 ℃、湿度 40%～60%、气压 86 kPa～106 kPa。

5.2.2　试验箱箱壁温度不应超过试验规定温度（按开尔文温度计）的 3%。

5.2.3　向试验箱中放置样品的任一区域温度应保持试验所规定空气温度（按开尔文温度计）的±1%。

5.2.4　试验箱内空气的绝对湿度不应超过 20 g/m³水汽。
5.2.5　试验箱的容积和空气速度应满足在放入试验样品后，箱内空气温度恢复到规定范围内的时间，不超过试验暴露时间的 10%。

5.3　试样制备

按4.3的规定进行。

5.4　测试步骤

5.4.1　按 GB/T 2423.2 的规定进行试验，将非工作状态的器件放置在 60 ℃～150 ℃环境下，持续 100 h～2000 h，试验时间和测试温度应根据详细规范的规定或采购方要求进行确认。
5.4.2　试验进行 500 h 后，每间隔 100 h，按 5.2.1 的要求对试样进行恢复。试样恢复完成后，进行室温内阻的测试，按 T/UNP 734—2025 中 8.1.1 的方法计算器件室温内阻变化率。室温内阻变化率不应大于 5%，否则判断器件发生失效，试验结束。
5.4.3　试验后应将试验样品置于 5.2.1 规定的环境中 4 h。

5.5　结果评估

试验后器件结构应完整、牢固可靠，最大致冷温差和内阻变化率的绝对值应不大于5%。

6　恒定湿热测试

6.1　测试设备和仪器

测试设备和仪器如下：
a)　恒温恒湿箱；
b)　温湿度采集仪；
c)　LCR 数字电桥：测试频率＞1000 Hz，精度 0.001 Ω及以上。

6.2　测试环境

6.2.1　温度为恒定 85 ℃（±3 ℃误差范围）。
6.2.2　湿度为恒定 85%相对湿度，误差在±3%内。
6.2.3　持续时间为 168 h 或采购方要求设定。

6.3　试样制备

6.3.1　样品应处于工作状态或非工作状态（视采购方要求进行确认）。
6.3.2　放置时应减少遮挡气流，确保温湿度均匀分布。
6.3.3　按 4.3 的规定进行。

6.4　测试步骤

6.4.1　按 GB/T 2423.3 的规定进行试验，将器件接通工作电压后放置在环境温度 82 ℃～88 ℃，环境湿度 82%～88%的条件下，持续 168 h～1500 h，试验时间应根据详细规范的规定或采购方要求进行确认。
6.4.2　试验进行 100 h 后，每间隔 100 h，按 6.2.1 和 6.2.2 的要求对试样进行恢复。试样恢复完成后，进行室温内阻的测试，并按 T/UNP 734—2025 中 8.1.1 的方法计算器件室温内阻变化率。要求室温内阻变化率不大于 5%，否则判断器件发生失效，试验结束。
6.4.3　试验后应将试验样品置于温度 23 ℃～27 ℃、湿度 40%～60%，气压 86 kPa～106 kPa 中 4 h。

6.5　结果评估

试验后器件结构应完整、牢固可靠，最大致冷温差和内阻变化率的绝对值应不大于5%。

7 电致冷、致热交变测试

7.1 测试设备和仪器

测试设备和仪器如下：

a) 试验台；
b) 测温热电偶；
c) 可编程直流电源。

7.2 测试环境

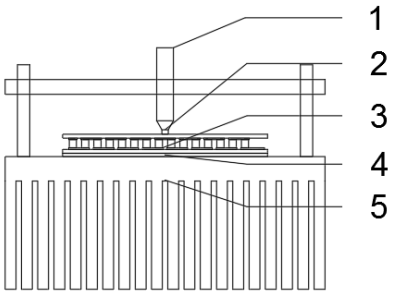
7.2.1 环境条件：温度 23 ℃～27 ℃、湿度 40%～60%、气压 86 kPa～106 kPa。
7.2.2 依据采购方要求，冷端温度在最低温和最高温之间循环，范围宜 10 ℃～90 ℃。
7.2.3 温度变化速率为 5 ℃/min～15 ℃/min。
7.2.4 循环次数：依据采购方要求。常见次数为 500 次、1000 次、5000 次，具体次数取决于应用场景。

7.3 试样制备

按4.3的规定进行。

7.4 测试步骤

将器件用夹具安装在专用试验台上（见图3），器件通电工作电压至冷端温度达到90 ℃，反向通电至冷端达到10 ℃为一循环周期，升降温速度大于4 ℃/s，循环30万次～100万次，循环次数应根据详细规范的规定或采购方要求进行确认。



标引序号：
1——弹簧压杆；
2——测温热电偶；
3——器件；
4——导热脂；
5——散热器。

图3 电致冷、致热交变试验试验平台

7.5 结果评估

试验后器件结构应完整、牢固可靠，最大致冷温差和内阻变化率的绝对值应不大于5%。

8 耐压力测试

8.1 测试设备和仪器

测试设备和仪器如下：

a) 静态压力测试机；
b) LCR 数字电桥：测试频率＞1000 Hz，精度 0.001 Ω 及以上。

8.2 测试环境

8.2.1 环境条件：温度 23 ℃～27 ℃、湿度 40%～60%、气压 86 kPa～106 kPa。
8.2.2 压力大小为 5 kgf/cm²，均匀垂直压力，减少局部加载。
8.2.3 夹具接触面的平面度应不大于 0.01 mm，上下夹具的平行度偏差应不大于 0.01 mm。
8.2.4 持续时间为 5 s～3600 s，分别模拟短时和实际安装后的受力情况。

8.3 试样制备

按4.3的规定进行。

8.4 测试步骤

8.4.1 将器件固定在静态压力测试机平台上，利用夹具对器件施加均匀垂直压力，压力值为 5 kgf/cm²。夹具接触面的平面度应不大于 0.01 mm，上下夹具的平行度偏差应不大于 0.01 mm。
8.4.2 施加压力时间 5 s～7 s 后关闭压力测试平台，取下产品目视检查，所有器件结构应完整、牢固可靠。如发生结构变形塌陷，判定为失效，试验结束。
8.4.3 按照 8.2 的要求将 8.4.2 取下的产品再次固定在静态压力测试平台上，再次施加 1 h 压力，取下产品目视检查。

8.5 结果评估

试验后器件结构应完整、牢固可靠，最大致冷温差和内阻变化率的绝对值应不大于5%。

9 机械振动测试

9.1 测试设备和仪器

测试设备和仪器如下：

a) 机械振动实验台：频率范围 5 Hz～2000 Hz，常用范围 10 Hz～500 Hz 或依据采购方要求，加速度 5 g～20 g 或依据采购方要求；
b) LCR 数字电桥：测试频率＞1000 Hz，精度 0.001 Ω及以上。

9.2 测试环境

9.2.1 环境条件：温度 23 ℃～27 ℃、湿度 40%～60%、气压 86 kPa～106 kPa。
9.2.2 振动参数：频率范围 5 Hz～2000 Hz，常用范围 10 Hz～500 Hz 或依据采购方要求，加速度 5 g～20 g 或依据采购方要求。
9.2.3 测试方向：轴向 X、Y、Z 正交方向依次测试。
9.2.4 测试时间：每轴向测试 5 个～10 个循环。

9.3 试样制备

试样尺寸和形状符合产品设计要求，选择具有代表性的完整器件。常见的试样尺寸为边长1 cm、2 cm或4 cm左右的方形，要求试样尺寸满足测试设备的制样要求。试样数量要求为5只～10只。

9.4 测试步骤

9.4.1 按 GB/T 2423.6 规定的方法进行试验。
9.4.2 试验前应测量器件的内阻和最大致冷温差，将器件用夹具固定在试验台上。
9.4.3 在非工作状态下，对器件三个相互垂直轴向的每个方向连续冲击 5 次～10 次，冲击加速度为 5 g～20 g，冲击次数和冲击加速度根据采购方要求确认。

9.5 结果评估

试验后器件结构应完整、牢固可靠，测试前后最大致冷温差和内阻变化率的绝对值应不大于5%。

10 抗剪切测试

10.1 实验仪器和设备

多功能推拉力测试机，能均匀施加0 N～20000 N以上水平推力。

10.2 测试环境

10.2.1 环境条件：温度 23 ℃～27 ℃、湿度 40%～60%、气压 86 kPa～106 kPa。
10.2.2 剪切速率：通常为 0.5 mm/min～5 mm/min。
10.2.3 加载方向：平行与 TEC 的陶瓷基板平面，施加剪切力直至失效。

10.3 试样制备

按4.3的规定进行。

10.4 测试步骤

10.4.1 将标准 TEC 样品固定在剪切试验机夹具中（见图 4），确保剪切力方向平行于陶瓷基板界面，设定试验温度（常温或根据采购方要求）及剪切速率。
10.4.2 逐步施加剪切载荷直至样品失效断裂，断开面为完全的晶粒材料处断裂。
10.4.3 记录剪切力、位移及温度数据。

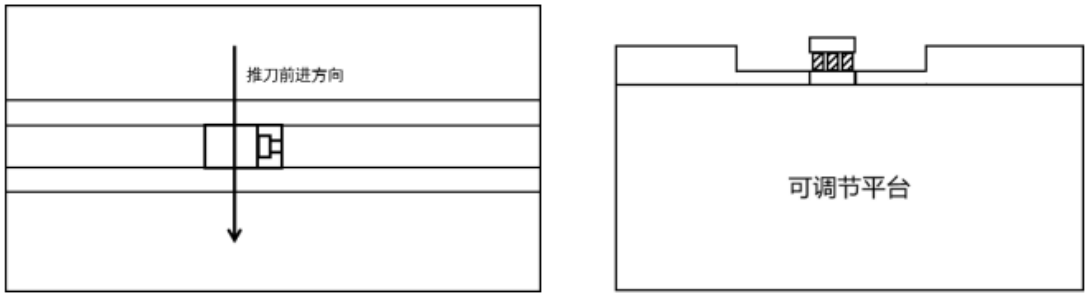


图4 抗剪切测试示意图

10.5 结果评估

10.5.1 样品数量：至少 20 个样品。
10.5.2 按公式（1）计算剪切强度。

$$T = \frac{F}{S} \quad \cdots\cdots (1)$$

式中：
T——剪切强度，单位为兆帕（MPa）；
F——切力，单位为牛顿（N）；
S——粒子总截面积，单位为平方米（mm^2）。

10.5.3 典型值如下：
a) 常规芯片：剪切强度≥5 MPa 或根据采购方要求；
b) 高可靠性场景（如汽车电子）：剪切强度≥10 MPa 或根据采购方要求。
10.5.4 失效剪切强度均大于典型值。

11 使用寿命测试

11.1 测试设备和仪器

测试设备和仪器如下：
a) 可调控温平台；
b) 直流电源。

11.2 测试环境

11.2.1 环境条件：温度 23 ℃～27 ℃、湿度 40%～60%、气压 86 kPa～106 kPa。
11.2.2 测试电流：调节工作电压使 TEC 以最大温差电流工作。

11.2.3 测试温度：调节控温平台使 TEC 热面恒定温度（85 ℃～150 ℃）。

11.3 试样制备

按4.3的规定进行。

11.4 测试步骤

11.4.1 将 TEC 热面安装于可调控温平台，设置平台温度恒定，冷面空载，接入直流电源并调节电压使 TEC 以最大温差电流工作，在此条件下连续工作 1000 h 以上，平台温度与工作时间根据相关行业规定或采购方要求进行确认。

11.4.2 试验进行 500 h 后，每间隔 100 h，将试样置于 11.2.1 规定的环境中进行试样恢复。

11.4.3 试样恢复完成后，进行室温内阻的测试，按 T/UNP 734—2025 中 8.1.1 的方法计算器件室温内阻变化率。

注：室温内阻变化率不大于5%，否则判断器件发生失效，试验结束。

11.4.4 测试后应将试验样品置于 11.2.1 规定的环境中 4 h。

11.5 结果评估

试验后器件结构应完整、牢固可靠，最大致冷温差和内阻变化率的绝对值应不大于5%。

12 防水测试

12.1 测试设备和仪器

测试设备和仪器如下：

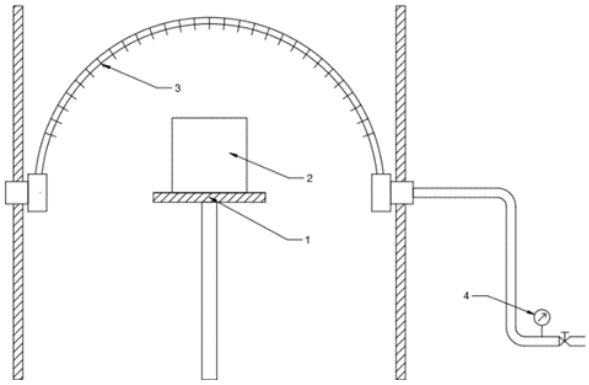
a) 旋转平台；
b) 流量表；
c) 喷淋装置。

12.2 试验条件

12.2.1 环境条件：23 ℃～27 ℃、湿度 40%～60%、气压 86 kPa～106 kPa。

12.2.2 水流量按摆管的喷水孔数计算每孔为 0.07 L/min，总流量根据不同防水等级或采购方要求确认。

12.2.3 喷水时间:如图 5 所示位置喷淋持续 5 min 或根据采购方确认的时间后将产品绕 Z 轴旋转 90°，再次喷淋 5 min 或根据采购方确认的时间。



标引序号：
1——旋转平台；
2——待测器件；
3——喷水孔；
4——流量表。

图5 防水测试示意图

12.3 试样制备

按4.3的规定进行。

12.4 测试步骤

12.4.1 选择半径 200㎜～150㎜ 摆管使样品台面的高度处于摆管直径位置上。
12.4.2 将试样放在台上，使其顶部到样品喷水口的距离不大于 200 ㎜，样品台不旋转。
12.4.3 开启喷水阀喷淋器件表面若干分钟后，再将器件旋转 90°，再次喷淋。

12.5 结果评估

取下产品擦干表面水分，观察密封胶无脱落，剥开密封胶，内部电路板无渗水痕迹，测试前后最大致冷温差和内阻变化率的绝对值应不大于5%。

13 开关循环测试

13.1 测试仪器和设备

测试设备和仪器如下：

a) 试验台；
b) 可编程直流电源。

13.2 测试环境

13.2.1 环境条件：温度 23 ℃～27 ℃、湿度 40%～60%、气压 86 kPa～106 kPa。
13.2.2 通电电流应设定为设备最大额定电流的 80%。
13.2.3 循环次数为 500 次、1000 次、5000 次或依据采购方要求，根据应用场景确认。

13.3 试样制备

按4.3的规定进行。

13.4 测试步骤

13.4.1 将器件用夹具安装在专用试验台上（如图 3），向器件施加最大电流额定值的 80%大小的电流后，器件持续工作 1.5 min，随后断电 4.5 min 为一个循环，共持续 500 次～5000 次循环或根据采购方要求确认。
13.4.2 试验后将试验样品置于 13.2.1 规定的环境中 4 h。

13.5 结果评估

试验后器件结构应完整、牢固可靠，最大致冷温差和内阻变化率的绝对值应不大于5%。

ICS 31.080.01
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Group Standard of CAPUNP

T/UNP 733—2025

Test methods for thermoelectric cooling(TEC)semiconductor devices

半导体热电致冷器件(TEC)测试方法

（English Translation）

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Contents

Foreword

This document is drafted in accordance with the rules specified in GB/T 1.1—2020 Guidelines for Standardization—Part 1: Structure and Drafting Rules for Standardized Documents.

Attention is drawn to the possibility that some elements of this document may involve patents. The issuing organization of this document does not assume the responsibility for identifying these patents.

This document is proposed by Hubei Saigerui New Energy Technology Co., Ltd.

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Introduction

To assist Chinese enterprises in participating in international trade and promote their high—quality development, the China United Nations Procurement Promotion Association, relying on the United Nations procurement system, formulates a series of standards serving international trade. These standards play an increasingly important role in the process of international trade, which is of great significance for improving trade efficiency, reducing transaction costs and uncertainties, ensuring product quality and safety, and enhancing consumer confidence.

The United Nations Standard Products and Services Code (UNSPSC) is a standard formulated by the United Nations for efficiently and accurately classifying products and services. It plays a vital role in global international procurement, providing a common language and platform for purchasers and suppliers, and promoting the efficient and orderly development of global trade.

Formulating group standards for related products, technologies, and services around UNSPSC is of great importance for helping enterprises integrate into international procurement and enhancing their international competitiveness.

The UNSPSC code adopted in this document is composed of 6 digits, corresponding to the original classification of major categories, middle categories, and subcategories, divided by decimal points.

The UNSPSC code of this document is "32.11.17", composed of 3 segments. Among them: the first segment is the major category, "32" represents "Electronic Components and Supplies"; the second segment is the middle category, "11" represents "Discrete Semiconductor Devices"; the third segment is the minor category, "17" represents "Semiconductor Devices".

Test Methods for Thermoelectric Cooling (TEC) Semiconductor Devices

1 Scope

This document describes the test methods for wire tension, high-temperature storage, constant temperature and humidity, electrothermal cooling and heating alternation, pressure resistance, mechanical vibration, shear resistance, service life, waterproofing, and switch cycle of thermoelectric cooling (TEC) semiconductor devices.

This document is applicable to the reliability testing of thermoelectric cooling (TEC) semiconductor devices (hereinafter referred to as "devices").

2 Normative references

The contents of the following documents constitute the indispensable clauses of this document through the normative reference in the text. For the dated references, only the versions corresponding to the dates apply to this document; for the undated references, their latest versions (including all amendments) apply to this document.

GB/T 2423.2 Environmental Testing for Electrical and Electronic Products—Part 2: Test Methods—Test B: High-Temperature Test Method

GB/T 2423.3 Environmental Testing—Part 2: Test Methods—Test Cab: Constant Temperature and Humidity Test

GB/T 2423.6 Environmental Testing for Electrical and Electronic Products—Part 2: Test Methods—Test Eb and Guidelines: Impact

SJ 2855 Nomenclature, Model Naming, and Performance Testing Methods for Thermoelectric Cooling

T/UNP 734—2025 Test Methods for Thermoelectric Generation (TEG) Semiconductor Devices

3 Terms and definitions

The terms and definitions defined in SJ 2855 apply to this document.

4 Wire Tension Test

4.1 Test Equipment and Instruments

The test equipment and instruments are as follows:

a) Fixed base;
b) Tensile tester with a test accuracy of 0.1 N or above.

4.2 Test Environment

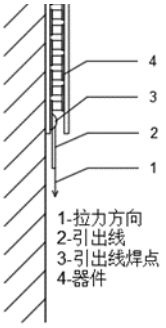
The test environment shall be clean, free of corrosive gases, strong magnetic fields, and electromagnetic wave interference. The ambient temperature is 15 ℃～35 ℃, the relative humidity is 20%～80%, and the air pressure is 86 kPa～106 kPa.

4.3 Sample Preparation

The sample size and shape shall meet the product design requirements, and common complete devices shall be selected. Common sample sizes are squares with side lengths of about 1 cm, 2 cm, or 4 cm. The number of samples is 5.

4.4 Test Procedures

4.4.1 Fix the device vertically, apply a static load of 19.6 N along the axial direction on each lead (see Figure 1) for 9 s～11 s.



Legend:

1—Tension direction;

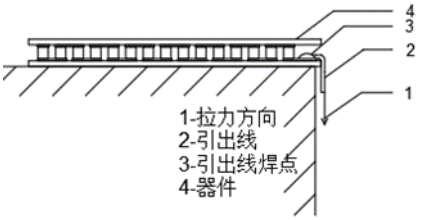
2—Lead wire;

3—Lead wire solder joint;

4—Device.

Figure1 Axial Tension Test Schematic Diagram

4.4.2 Fix the device horizontally with the hot surface facing down, apply a static load of 4.9 N along the gravity direction at the end of the lead (see Figure 2) for 9 s～11 s.



Legend:

1—Tension direction;

2—Lead wire;

3—Lead wire solder joint;

4—Device.

Figure2 Vertical Tension Schematic Diagram

4.5 Result Evaluation

After the test, check the appearance of the leads. If the leads are not broken or mechanically damaged, it is considered that the wire tension meets the 19.6 N horizontal tension and 4.9 N vertical tension, and the judgment is qualified.

5 High-Temperature Storage Test

5.1 Test Equipment and Instruments

The test equipment and instruments are as follows:

a) Constant temperature oven: temperature uniformity within 3 ℃;
b) LCR digital bridge: test frequency >1000 Hz, accuracy 0.001 Ω or above.

5.2 Test Environment

5.2.1 Environmental conditions: temperature 23 ℃ ~ 27 ℃, humidity 40% ~ 60%, air pressure 86 kPa ~ 106 kPa.

5.2.2 The temperature of the oven wall shall not exceed 3% of the specified test temperature (measured by a Kelvin thermometer).

5.2.3 The temperature in any area where the sample is placed in the oven shall be maintained at ±1% of the specified air temperature (measured by a Kelvin thermometer).

5.2.4 The absolute humidity of the air in the oven shall not exceed 20 g/m³ water vapor.

5.2.5 The volume and air velocity of the oven shall meet that after placing the test sample, the time for the air temperature in the oven to return to the specified range shall not exceed 10% of the test exposure time.

5.3 Sample Preparation

Prepare according to 4.3.

5.4 Test Procedures

5.4.1 Carry out the test in accordance with GB/T 2423.2. Place the non-operating device in an environment of 60 °C ~ 150 °C for 100 h ~ 2000 h. The test time and test temperature shall be confirmed according to the detailed specification or the purchaser's requirements.

5.4.2 After 500 h of the test, every 100 h, restore the sample according to the requirements of 5.2.1. After the sample is restored, test the room temperature internal resistance, and calculate the room temperature internal resistance change rate of the device according to the method in 8.1.1 of T/UNP 734—2025. The room temperature internal resistance change rate shall not be greater than 5%, otherwise the device is judged to have failed, and the test ends.

5.4.3 After the test, place the test sample in the environment specified in 5.2.1 for 4 h.

5.5 Result Evaluation

After the test, the device structure shall be complete and firm, and the absolute value of the maximum cooling temperature difference and the internal resistance change rate shall not be greater than 5%.

6 Constant Temperature and Humidity Test

6.1 Test Equipment and Instruments

The test equipment and instruments are as follows:

a) Constant temperature and humidity chamber;
b) Temperature and humidity collector;
c) LCR digital bridge: test frequency >1000 Hz, accuracy 0.001 Ω or above.

6.2 Test Environment

6.2.1 Temperature is constant 85 °C (±3 °C error range).

6.2.2 Humidity is constant 85% relative humidity, with an error of ±3%.

6.2.3 The duration is 168 h or set as required by the purchaser.

6.3 Sample Preparation

6.3.1 The sample shall be in an operating state or a non-operating state (confirmed according to the purchaser's requirements).

6.3.2 When placing, the blocking of the air flow shall be reduced to ensure uniform distribution of temperature and humidity.

6.3.3 Prepare according to 4.3.

6.4 Test Procedures

6.4.1 Carry out the test in accordance with GB/T 2423.3. Place the device with the working voltage connected in an environment with a temperature of 82 °C ~ 88 °C and a humidity of 82% ~ 88% for 168 h ~ 1500 h. The test time shall be confirmed according to the detailed specification or the purchaser's requirements.

6.4.2 After 100 h of the test, every 100 h, restore the sample according to the requirements of 6.2.1 and 6.2.2. After the sample is restored, test the room temperature internal resistance, and calculate the room temperature internal resistance change rate of the device according to the method in 8.1.1 of T/UNP 734—2025. It is required that the room temperature internal resistance change rate is not greater than 5%, otherwise the device is judged to have failed, and the test ends.

6.4.3 After the test, place the test sample in an environment with a temperature of 23 °C ~ 27 °C, humidity of 40% ~ 60%, and air pressure of 86 kPa ~ 106 kPa for 4 h.

6.5 Result Evaluation

After the test, the device structure shall be complete and firm, and the absolute value of the maximum cooling temperature difference and the internal resistance change rate shall not be greater than 5%.

7 Electrothermal Cooling and Heating Alternation Test

7.1 Test Equipment and Instruments

The test equipment and instruments are as follows:

a) Test bench;
b) Temperature measuring thermocouple;
c) Programmable DC power supply.

7.2 Test Environment

7.2.1 Environmental conditions: temperature 23 °C ~ 27 °C, humidity 40% ~ 60%, air pressure 86 kPa ~ 106 kPa.

7.2.2 According to the purchaser's requirements, the cold end temperature cycles between the minimum and maximum temperatures, and the range is preferably 10 °C ~ 90 °C.

7.2.3 The temperature change rate is 5 °C/min ~ 15 °C/min.

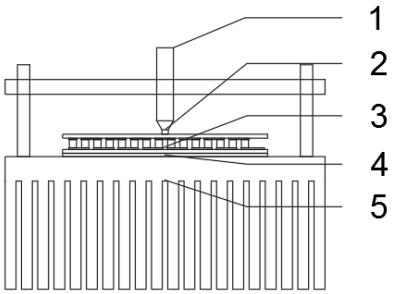
7.2.4 Number of cycles: according to the purchaser's requirements. Common numbers of cycles are 500 times, 1000 times, and 5000 times, and the specific number of cycles depends on the application scenario.

7.3 Sample Preparation

Prepare according to 4.3.

7.4 Test Procedures

Install the device on a special test bench with a fixture (see Figure 3). Power on the device to make the cold end temperature reach 90 °C, and reverse power on to make the cold end reach 10 °C as a cycle period. The temperature rise and fall rate is greater than 4 °C/s, and the number of cycles is 300,000 ~ 1,000,000 times. The number of cycles shall be confirmed according to the detailed specification or the purchaser's requirements.



Legend:

1—Spring pressure rod;

2—Temperature measuring thermocouple;

3—Device;

4—Thermal grease;

5—Radiator.

Figure3 Electrothermal Cooling and Heating Alternation Test Platform

7.5 Result Evaluation

After the test, the device structure shall be complete and firm, and the absolute value of the maximum cooling temperature difference and the internal resistance change rate shall not be greater than 5%.

8 Pressure Resistance Test

8.1 Test Equipment and Instruments

The test equipment and instruments are as follows:

a) Static pressure testing machine;
b) LCR digital bridge: test frequency >1000 Hz, accuracy 0.001 Ω or above.

8.2 Test Environment

8.2.1 Environmental conditions: temperature 23 °C ~ 27 °C, humidity 40% ~ 60%, air pressure 86 kPa ~ 106 kPa.

8.2.2 The pressure is 5 kgf/cm², uniform vertical pressure, and local loading shall be reduced.

8.2.3 The flatness of the fixture contact surface shall not be greater than 0.01 mm, and the parallelism deviation of the upper and lower fixtures shall not be greater than 0.01 mm.

8.2.4 The duration is 5 s ~ 3600 s, simulating the short-term and actual installed stress conditions respectively.

8.3 Sample Preparation

Prepare according to 4.3.

8.4 Test Procedures

8.4.1 Fix the device on the static pressure testing machine platform, and use the fixture to apply uniform vertical pressure to the device, with a pressure value of 5 kgf/cm². The flatness of the fixture contact surface shall not be greater than 0.01 mm, and the parallelism deviation of the upper and lower fixtures shall not be greater than 0.01 mm.

8.4.2 After applying the pressure for 5 s ~ 7 s, turn off the pressure testing platform, remove the product, and visually inspect it. All device structures shall be complete and firm. If structural deformation and collapse occur, it is judged as failure, and the test ends.

8.4.3 Fix the product removed in 8.4.2 on the static pressure testing platform again according to the requirements of 8.2, apply pressure again for 1 h, remove the product, and visually inspect it.

8.5 Result Evaluation

After the test, the device structure shall be complete and firm, and the absolute value of the maximum cooling temperature difference and the internal resistance change rate shall not be greater than 5%.

9 Mechanical Vibration Test

9.1 Test Equipment and Instruments

The test equipment and instruments are as follows:

a) Mechanical vibration test bench: frequency range 5 Hz ~ 2000 Hz, common range 10 Hz ~ 500 Hz or according to the purchaser's requirements, acceleration 5 g ~ 20 g or according to the purchaser's requirements;
b) LCR digital bridge: test frequency >1000 Hz, accuracy 0.001 Ω or above.

9.2 Test Environment

9.2.1 Environmental conditions: temperature 23 °C ~ 27 °C, humidity 40% ~ 60%, air pressure 86 kPa ~ 106 kPa.

9.2.2 Vibration parameters: frequency range 5 Hz ~ 2000 Hz, common range 10 Hz ~ 500 Hz or according to the purchaser's requirements, acceleration 5 g ~ 20 g or according to the purchaser's requirements.

9.2.3 Test direction: axial X, Y, Z orthogonal directions are tested in sequence.

9.2.4 Test time: 5 ~ 10 cycles for each axis.

9.3 Sample Preparation

The sample size and shape meet the product design requirements, and representative complete devices are selected. Common sample sizes are squares with side lengths of about 1 cm, 2 cm, or 4 cm, and the sample size is required to meet the sample preparation requirements of the test equipment. The number of samples is 5 ~ 10.

9.4 Test Procedures

9.4.1 Carry out the test in accordance with the method specified in GB/T 2423.6.

9.4.2 Before the test, measure the internal resistance and maximum cooling temperature difference of the device, and fix the device on the test bench with a fixture.

9.4.3 In the non-operating state, each of the three mutually perpendicular axial directions of the device is continuously impacted 5 ~ 10 times, with an impact acceleration of 5 g ~ 20 g. The number of impacts and the impact acceleration are confirmed according to the purchaser's requirements.

9.5 Result Evaluation

After the test, the device structure shall be complete and firm, and the absolute value of the maximum cooling temperature difference and the internal resistance change rate before and after the test shall not be greater than 5%.

10 Shear Resistance Test

10.1 Test Instruments and Equipment

Multi-function push-pull tester, which can apply a uniform horizontal thrust of 0 N ~ 20000 N or above.

10.2 Test Environment

10.2.1 Environmental conditions: temperature 23 °C ~ 27 °C, humidity 40% ~ 60%, air pressure 86 kPa ~ 106 kPa.

10.2.2 Shear rate: usually 0.5 mm/min ~ 5 mm/min.

10.2.3 Loading direction: parallel to the plane of the TEC ceramic substrate, apply shear force until failure.

10.3 Sample Preparation

Prepare according to 4.3.

10.4 Test Procedures

10.4.1 Fix the standard TEC sample in the shear testing machine fixture (see Figure 4), ensure that the shear force direction is parallel to the ceramic substrate interface, and set the test temperature (normal temperature or according to the purchaser's requirements) and shear rate.

10.4.2 Gradually apply the shear load until the sample fails and breaks, and the fracture surface is at the completely grained material.

10.4.3 Record the shear force, displacement, and temperature data.

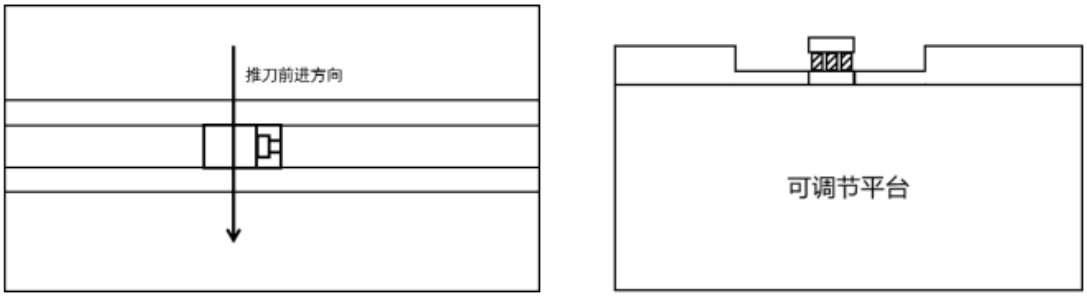


Figure4 Shear Resistance Test Schematic Diagram

10.5 Result Evaluation

10.5.1 Number of samples: at least 20 samples.

10.5.2 Calculate the shear strength according to formula (1).

$$T = \frac{F}{S} \quad (1)$$

Where:

T——Shear strength, unit is megapascal (MPa);

F——Shear force, unit is newton (N);

S——Total cross-sectional area of particles, unit is square millimeter (mm^2).

10.5.3 Typical values are as follows:

a) Conventional chips: shear strength ≥5 MPa or according to the purchaser's requirements;
b) High-reliability scenarios (such as automotive electronics): shear strength ≥10 MPa or according to the purchaser's requirements.

10.5.4 The failure shear strength is greater than the typical value.

11 Service Life Test

11.1 Test Equipment and Instruments

The test equipment and instruments are as follows:

a) Adjustable temperature platform;
b) DC power supply.

11.2 Test Environment

11.2.1 Environmental conditions: temperature 23 °C ~ 27 °C, humidity 40% ~ 60%, air pressure 86 kPa ~ 106 kPa.

11.2.2 Test current: adjust the working voltage to make the TEC work with the maximum temperature

difference current.

11.2.3 Test temperature: adjust the temperature control platform to make the TEC hot surface at a constant temperature (85 °C ~ 150 °C).

11.3 Sample Preparation

Prepare according to 4.3.

11.4 Test Procedures

11.4.1 Install the TEC hot surface on the adjustable temperature platform, set the platform temperature to be constant, leave the cold surface unloaded, connect to the DC power supply, and adjust the voltage to make the TEC work with the maximum temperature difference current. Under this condition, work continuously for more than 1000 h. The platform temperature and working time are confirmed according to relevant industry regulations or the purchaser's requirements.

11.4.2 After 500 h of the test, every 100 h, place the sample in the environment specified in 11.2.1 for sample restoration.

11.4.3 After the sample is restored, test the room temperature internal resistance, and calculate the room temperature internal resistance change rate of the device according to the method in 8.1.1 of T/UNP 734—2025.

Note: The room temperature internal resistance change rate is not greater than 5%, otherwise the device is judged to have failed, and the test ends.

11.4.4 After the test, place the test sample in the environment specified in 11.2.1 for 4 h.

11.5 Result Evaluation

After the test, the device structure shall be complete and firm, and the absolute value of the maximum cooling temperature difference and the internal resistance change rate shall not be greater than 5%.

12 Waterproof Test

12.1 Test Equipment and Instruments

The test equipment and instruments are as follows:

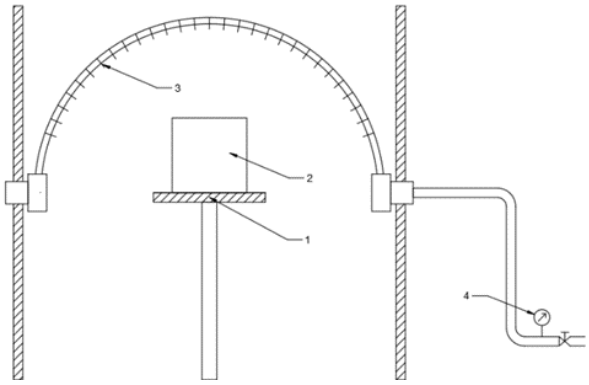
a) Rotating platform;
b) Flow meter;
c) Spraying device.

12.2 Test Conditions

12.2.1 Environmental conditions: 23 °C ~ 27 °C, humidity 40% ~ 60%, air pressure 86 kPa ~ 106 kPa.

12.2.2 The water flow is calculated as 0.07 L/min per hole according to the number of spray holes of the pendulum tube, and the total flow is confirmed according to different waterproof grades or the purchaser's requirements.

12.2.3 Spraying time: spray at the position shown in Figure 5 for 5 min or according to the time confirmed by the purchaser, then rotate the product 90° around the Z axis, and spray again for 5 min or according to the time confirmed by the purchaser.



Legend:

1—Rotating platform;

2—Device under test;

3—Spray hole;

4—Flow meter.

Figure5 Waterproof Test Schematic Diagram

12.3 Sample Preparation

Prepare according to 4.3.

12.4 Test Procedures

12.4.1 Select a pendulum tube with a radius of 200 mm ~ 150 mm so that the height of the sample table is at the diameter position of the pendulum tube.

12.4.2 Place the sample on the table so that the distance from its top to the sample spray port is not more than 200 mm, and the sample table does not rotate.

12.4.3 Open the spray valve to spray the device surface for several minutes, then rotate the device 90°, and spray again.

12.5 Result Evaluation

Remove the product, dry the surface moisture, observe that the sealant does not fall off, peel off the sealant, there is no water seepage trace on the internal circuit board, and the absolute value of the maximum cooling temperature difference and the internal resistance change rate before and after the test shall not be greater than 5%.

13 Switch Cycle Test

13.1 Test Instruments and Equipment

The test equipment and instruments are as follows:

a) Test bench;
b) Programmable DC power supply.

13.2 Test Environment

13.2.1 Environmental conditions: temperature 23 °C ~ 27 °C, humidity 40% ~ 60%, air pressure 86 kPa ~ 106 kPa.

13.2.2 The energized current shall be set to 80% of the maximum rated current of the device.

13.2.3 The number of cycles is 500 times, 1000 times, 5000 times, or according to the purchaser's requirements, confirmed according to the application scenario.

13.3 Sample Preparation

Prepare according to 4.3.

13.4 Test Procedures

13.4.1 Install the device on a special test bench with a fixture (as shown in Figure 3), apply a current of 80% of the maximum rated current to the device, make the device work continuously for 1.5 min, then power off for 4.5 min as a cycle, for a total of 500 ~ 5000 cycles or confirm according to the purchaser's requirements.

13.4.2 After the test, place the test sample in the environment specified in 13.2.1 for 4 h.

13.5 Result Evaluation

After the test, the device structure shall be complete and firm, and the absolute value of the maximum cooling temperature difference and the internal resistance change rate shall not be greater than 5%.