太陽ｴﾈﾙｷﾞｰ学会
QA Forum　国内TG4 活動報告

(QA Task Force 4 ; Diode, Shading & Reverse Bias)

■ ﾊﾞｲﾊﾟｽﾀﾞｲｵｰﾄﾞの熱暴走試験について ■
■ ﾀﾞｲｵｰﾄﾞのｼﾞｬﾝｸｼｮﾝ温度測定について ■

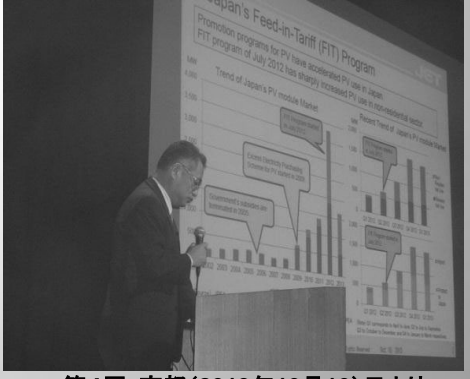
2014年6月4日　＠(株)東陽テクニカ本社 8F
一般財団法人 電気安全環境研究所
研究事業センター　内田泰徳

QAﾀｽｸﾌｫｰｽにおける取り組み

1）QAタスクフォースは、産総研、米国NREL,EU総局研究センターの研究機関，試験機関が呼び掛けあって発足、運営している。

2）QAタスクフォースの目的は、
(1)PVモジュールの信頼性に関する諸問題について、世界の専門家と国際的な議論を行い、その成果の国際標準化を推進する。
(2)20～25年以上の長期信頼性を評価する国際的に統一された試験方法の開発とそれに基づく国際基準認証システムを構築する。
(3)PVモジュールの設置環境・気象条件および設置方法を考慮した信頼性評価指標（レイティング）の開発を目指す。

3)国際QAフォーラムの開催
- 第1回：米国サンフランシスコ（2011年7月）
- 第2回：東京（2011年12月
- 第3回：東京（2012年11月）
- 第4回：京都（2013年10月）



第4回：京都（2013年10月10）日より

国際QAフォーラム – 国内で活動中の6つのタスクグループ

	活動内容	国内タスク グループ有無
TG1	PV QA Guideline for Manufacturing Consistency （設計・製造管理と品質保証）	○
TG2	Thermal and Mechanical Fatigue including Vibration （機械的ストレス）	○
TG3	Humidity ,Temperature and Bias（温湿度）	○
TG4	Diodes ,Shading and Reverse Bias （ダイオード、部分陰、逆バイアスの影響）	○
TG5	UV ,Temperature and Humidity（紫外線）	○
TG6	QA Rating Communication（レイティング情報の利用）	×
TG7	Wind & Snow Loading（風雪荷重）	×
TG8	Thin Film Testing（薄膜）	○
TG9	CPV Testing（集光型）	×
TG10	Connectors in junction boxes（接続箱中のコネクタ）	×

J-TG4 の活動報告

1. Dec.08, 2011 2nd. QA Forum Tokyo
2. Feb. 28, 2012 NREL PV Module Reliability Work-shop
3. May 07, 2012 WG2 STRESA meeting
4. Oct.01, 2012 WG2 Oslo meeting
5. Nov.27, 2012 3rd. QA Forum Tokyo
6. Feb.26,27, 2013 NREL PV Module Reliability Work-shop
7. May 13, 2013 WG2 Jamaica meeting
8. Oct. 10, 2013 4th. QA Forum Kyoto
9. Feb. 25,26, 2014 NREL PV Module Reliability Work-shop

TG4活動における規格化の成果の現状

1. **Bypass diode electrostatic discharge susceptibility testing (米国提案)**
   → IEC規格TS(Technical Specification) として、NWIP(New Work Item Proposal)で回覧中。

2. **Thermal runaway test for bypass diode (日本提案)**
   → NWIPとして提案済み。@ 2014.1.18

ﾊﾞｲﾊﾟｽﾀﾞｲｵｰﾄﾞにおける P/N diode からSBD への切替り背景

■ IEC 61215の Ed. 2 (2005-04) において、
“Bypass diode thermal test” が追加された。
① 75℃, Isc通電にて、ﾀﾞｲｵｰﾄﾞのMax. Tjを上回らないこと。
② 75℃, 1.25×Isc通電にて、ﾀﾞｲｵｰﾄﾞの機能を損なわないこと。

SBD ; Schottky Barrier Diode

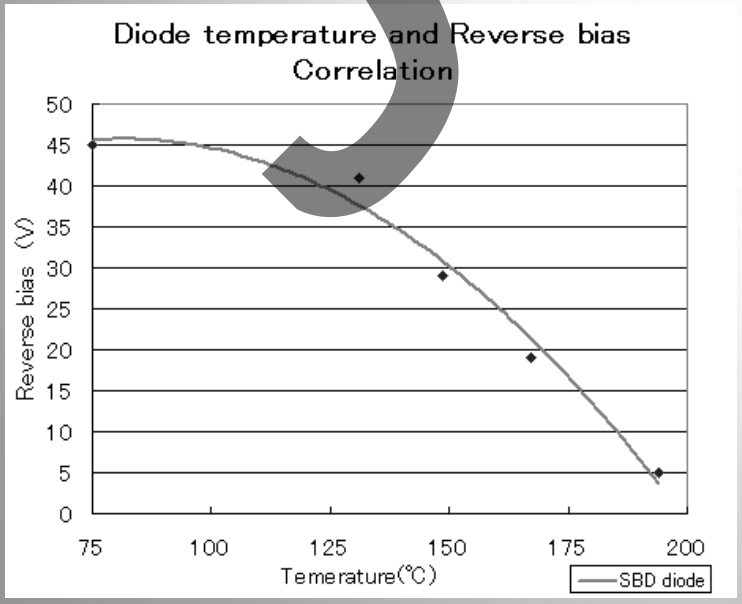
そこで、SBDはVf値が低く発熱が抑えられ、Switching speedも早く、価格も安価になってきたという背景から、P/N diode からSBDに切り替わってきた。

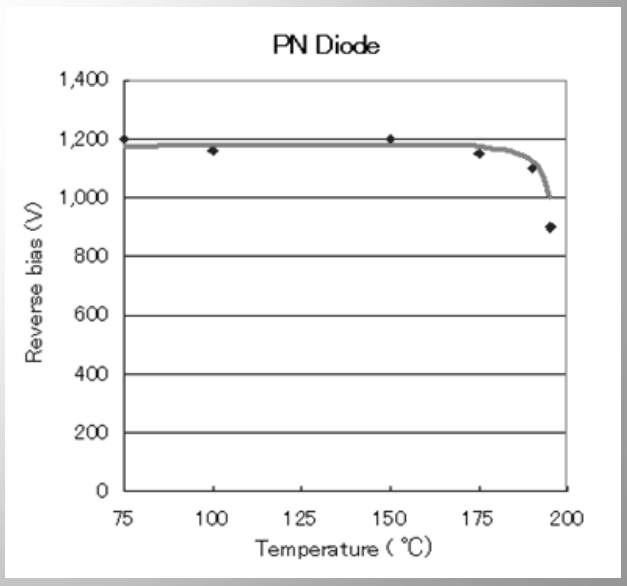
つづく →

	P/N Diode	Schottky Barrier Diode
Merit	① High reverse voltage (1000V) → Low possibility of break down ② Low leak current → Low Possibility of thermal runaway	① Low forward voltage (Vf ; 0.2-0.5V) → Low power dissipation in diode chip ② Fast switching speed → for fast switching ③ Price lower than P/N diode
Demerit	① High forward voltage (Vf ; 0.6-1.2V) → High power dissipation in diode chip ② Price higher than SBD	① High leak current (10-100 times more than P/N diode) → High possibility of thermal runaway. ② Low reverse Voltage (30-200V) →High possibility of break down

International PV Module Quality Assurance Forum

しかしながら、SBDは高温逆バイアス時の耐圧が従来のSi P/N diodeと比較して、低いという問題がある。





そこで、我々はBDを組み込んだJ-boxを評価試料として、熱暴走試験を実施してきました。

評価結果は、使用されるBDあるいはJ-boxの熱設計の仕方により、いろいろ違った結果を確認しました。

よって、この熱暴走試験はBD及びJ-boxの熱設計評価をする上で有効であると判断し、2013年5月のTC82/WG2 Jamaica meeting において、

■ Thermal runaway test for bypass diode
（ﾊﾞｲﾊﾟｽﾀﾞｲｵｰﾄﾞの熱暴走試験）

を提案いたしました。

1. The proposal of thermal runaway test for bypass diode

Current situation ;

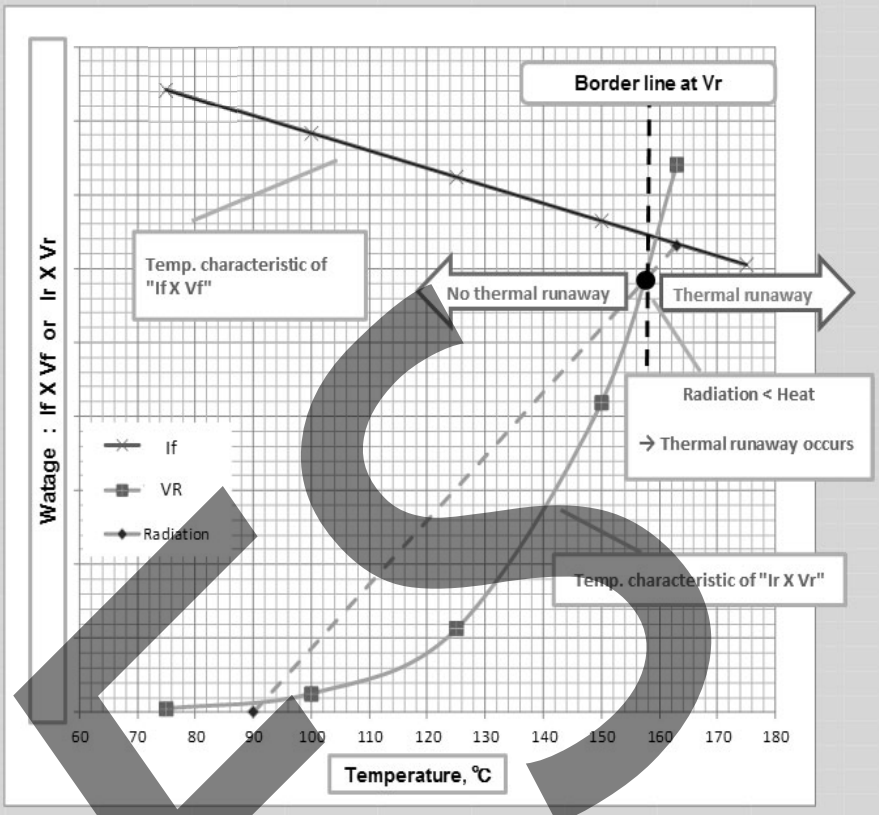
NWIP draft for “Thermal runaway test for bypass diode” was submitted to TC82/WG2 on Jan. 18, 2014 and is expected to be discussed in the next WG2 meeting in June.

Scope and Purpose

This international standard provides a method for evaluating whether a bypass diode as mounted in the module is susceptible to thermal runaway or if there is sufficient cooling for it to survive the transition from forward bias operation to reverse bias operation without overheating.

The concept of thermal runaway occurrence

When the amount of heat generated in the diode is greater than the capability of radiation to extract the heat, thermal runaway occurs.



Test procedure

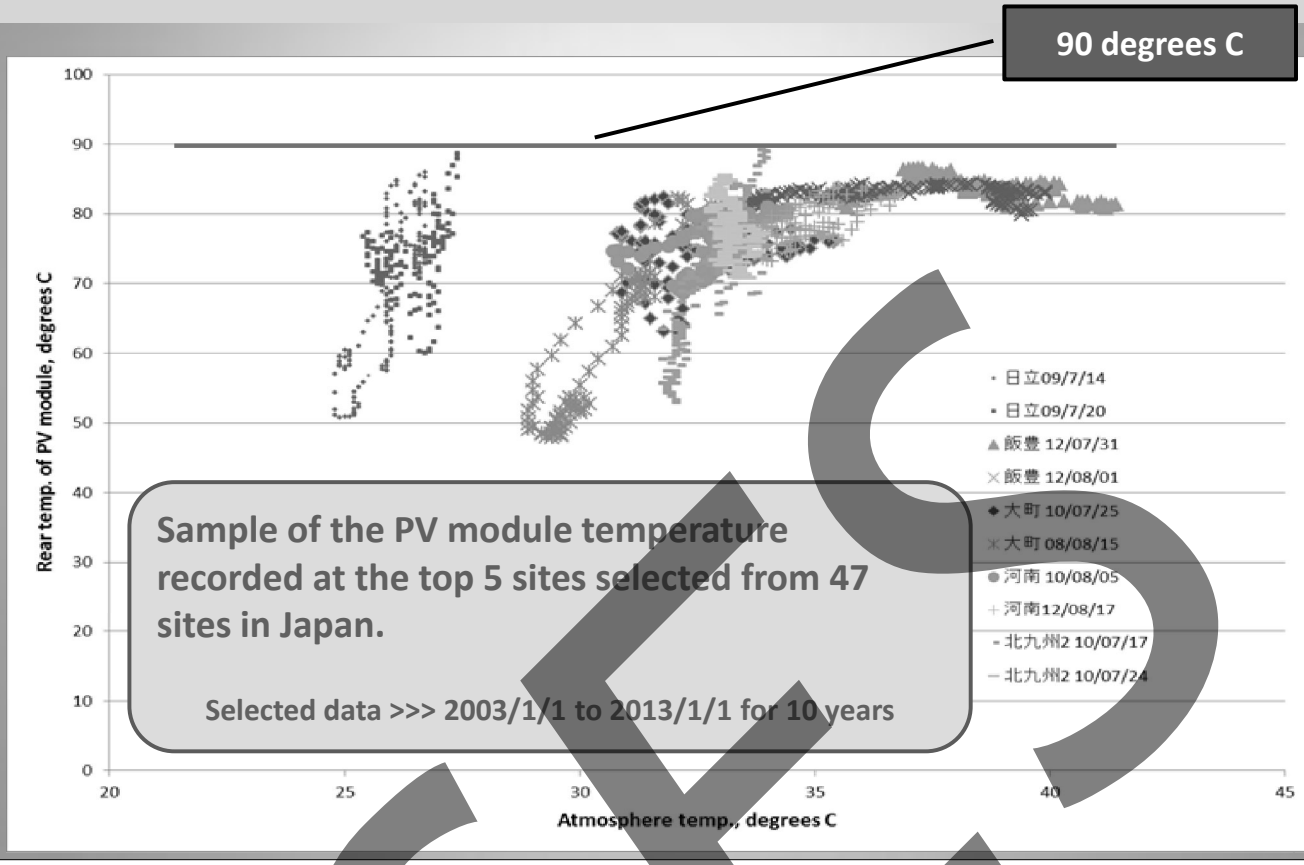
(1) In the preheated climate chamber at 90℃, apply the forward current equal to “the 1.25 X STD short circuit current of the module” until the diode temperature stabilizes

(2) Within 10ms after shutting off the forward current supply, apply the reverse bias voltage (Vr*) to the diode and keep it for one minute unless the temperature of the diode extraordinarily increases.

* Vr = Sum of Voc of the cells protected by one bypass diode

(3) If the temperature stabilizes or begins to decrease during one minute, remove the J-box from the chamber and verify that the diode is still operational.

The test condition “90℃” is proposed assuming the worst case according to the following results.



The foundation data for the environment temperature

As for the consistency of the test standard, first of all, we would like to propose 90 degrees C as the environmental temperature for Thermal runaway test.

	Environment temp.
■Bypass diode thermal test (IEC61215 / 10.18)	75℃
■Thermal runaway test for bypass diode	90℃

We confirmed that the module temperature in Japanese summer season achieves 90 degrees C at the highest temperature based on NEDO field data during the 10 year period from 1/2003 to 1/2013.

- NEDO 47 siteのフィールドﾃﾞｰﾀから、Roof-mount において Worst caseで90℃に達することが確認できています。
- まず、熱暴走試験では周囲温度90℃で提案していく。

2. Tj measurement method for Bypass diode

At NREL workshop last year, we discussed "Vf-Tj method" and "Tcase / lead method" of Tj measurement of BD.
This time, I will indicate the issues of Tcase/lead method by the specific examples.

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Case 1 ;

#1 ; The temperature of the center diode in the J-box becomes always the highest.
#2 ; Tj by Vf-Tj method is higher than Tj by Tlead method.

【 Chamber temp. ; 75℃】

		Left diode		Center diode		Right diode	
		Tlead, ℃	Vf-Tj, ℃	Tlead, ℃	Vf-Tj, ℃	Tlead, ℃	Vf-Tj, ℃
If	9A	158.1	160.1	165.0	173.3	143.1	156.7
	11A	175.2	178.7	183.4	192.7	156.9	176.8
	12A	183.5	187.5	192.4	201.5	164.0	184.5
	13A	192.0	195.5	201.2	212.1	170.7	193.7

【 Chamber temp. ; 90℃】

		Left diode		Center diode		Right diode	
		Tlead, ℃	Vf-Tj, ℃	Tlead, ℃	Vf-Tj, ℃	Tlead, ℃	Vf-Tj, ℃
If	9A	168.8	171.0	175.2	182.6	154.2	169.8
	11A	185.4	189.2	192.8	201.4	168.1	186.4
	12A	193.7	197.2	201.9	211.3	174.7	194.3
	13A	201.7	205.3	210.4	220.1	181.3	203.7

Note 1　Tlead : Tj by "Tlead method"
Tj = Tlead + (Vf X If X Rth)　　Rth ⇒ 2.5℃/W　provided by diode manufacturer
Note 2　Vf-Tj : Tj by "Vf-Tj method" in accordance with "IEC61646 Ed.2 10.18 Bypass diode thermal test / Procedure 2"

Case 2 ;

Measured Rth (Thermal resistance) varies widely, even if the sampled diodes are taken from the same type lot.

For example ;

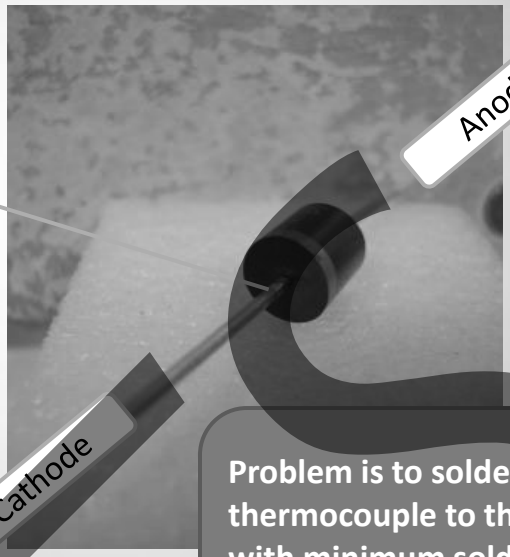
Sample	Rth (℃/W) at 9A
Diode – A	3.0
Diode – B	5.0
Diode - C	4.8

Note 1 ; Rth presented by diode manufacturer is 2.5 ℃/W.
Note 2 ; These Rth were measured by JET.

Case 3 ; Problem of Tlead measurement

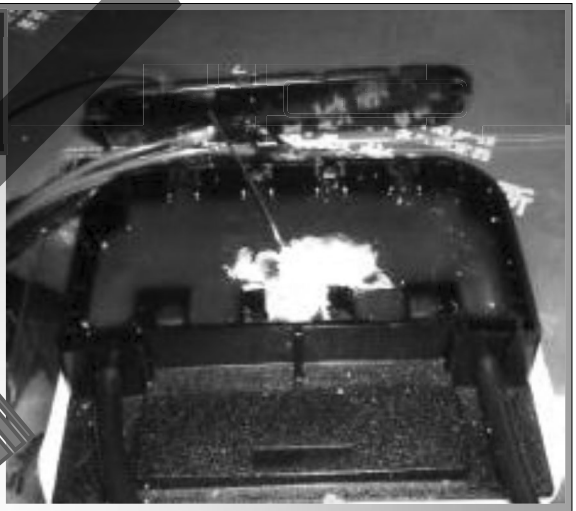
■ Axial diode

Theory ;
should be soldered as close as possible to the cathode terminal of diode.



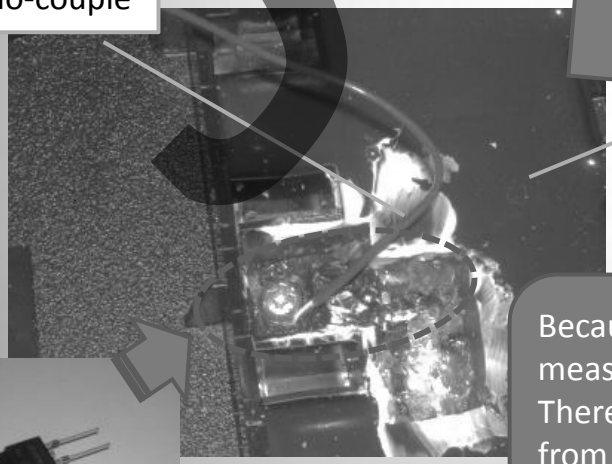
Problem is to solder the thermocouple to the diode lead with minimum solder and as close as possible to the diode body.

Case 4 ; Problem of Tcase measurement



■ TO220 type diode in J-box

Thermo-couple

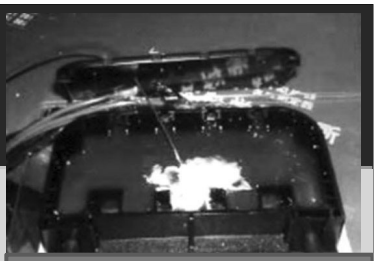


Molded resin

TO220 type diode

Because it is covered by the molded resin, the measurement of Tcase is difficult.
There is no choice but to get the measurement from the part of the screw.

Comparison results
between "Tcase method" and "Vf-Tj method"



Test sample

■ Tcase method

Tj = Tcase + Vf ×If× Rth

Tcase : 95.6℃ (Temp. of diode's case)

Vf : 0.3391V

(Saturated voltage after 1h operating)

If : 9A (Forward current)

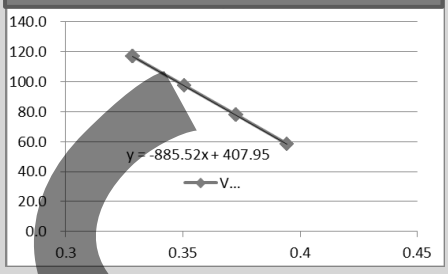
Rth : 1.5℃/W presented by manufacturer

Tj = 95.6(℃) + 0.3391(V) ×9(A)×1.5(℃/W)

= 100.2℃

■ Vf-Tj method

Vf-Tj characteristic



Tj = -885.52 Vf + 407.95

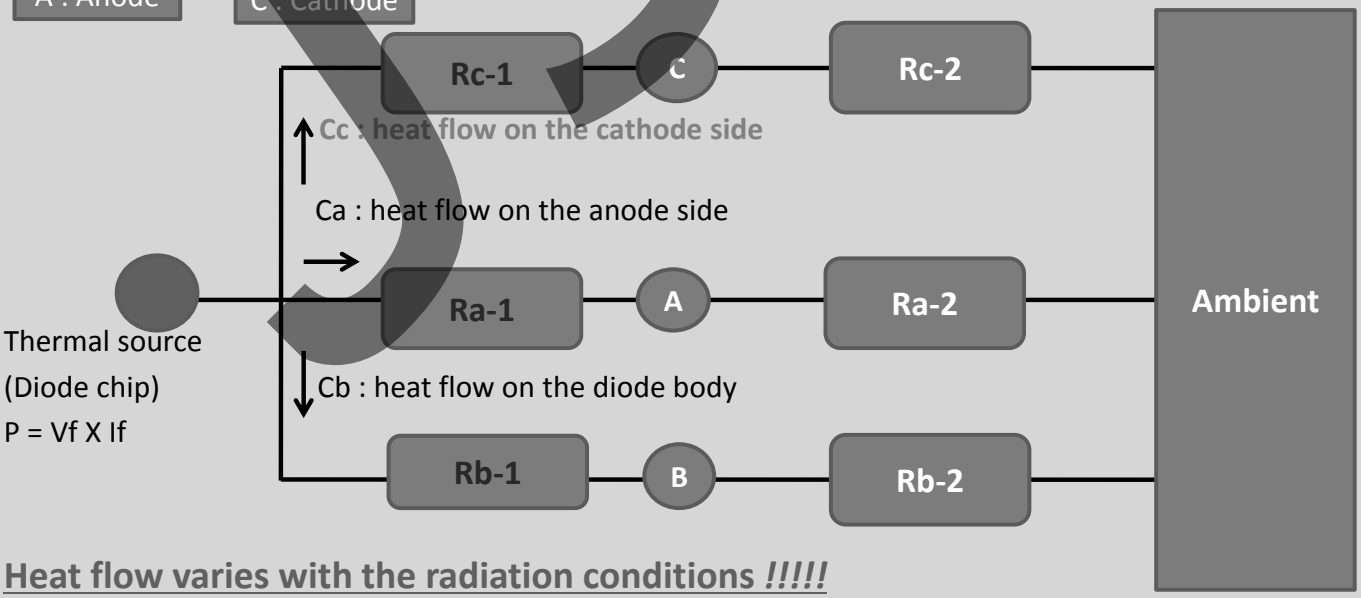
= -885.52×0.3391 + 407.95

= 107.7 ℃

The Rth changes depending on where the diode is placed in the J-box.

Heat flow from Diode chip

Rc-1 ≒ Ra-1 << Rb-1



Heat flow varies with the radiation conditions *!!!!!*

Tj = Tlead + Vf×If × Cc × Rth (→ real Rth) → **apparent Rth**

Heat flow from diode chip.

In the case of a Rth measurement for single diode,

- First of all, diode chip will be heat up by the applying current into J-box.
- Then, this heat will flow to C, A and then B divergently.
- In this case, the constant Cc would vary depending on the heat radiation conditions.
- When the diode is mounted in the J-box, this constant changes.
- Therefore, the apparent Rth changes.

Tj that is calculated,

$$Tj = \underline{Tcase/lead} + (Vf \times If \times \underline{Rth})$$

The temperature of Tcase/lead is very difficult to measure correctly, because there are the issues of the soldering technique including the soldering place and the amount of solder.

By being incorporated in the J-box, Rth presented by the diode manufacturer changes.

As a result, the error of the calculated value may become large.

Conclusion of Tcase/lead method

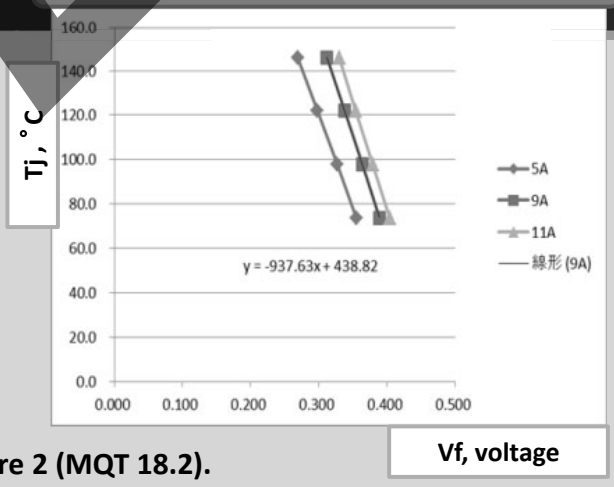
Due to the Rth change and the Tcase/lead measurement error, the calculated value of the Tj has some error compared to the real Tj.

Therefore, the judgment by using Tj value which is calculated by Tcase/lead method is misleading !!!!!

Vf – Tj method

- **Once Vf-Tj relation is obtained, Tj is easily and accurately decided from the value of Vf. Vf-Tj relation can be acquired by measuring the temperature of the lead and the voltage across the diode in thermal equilibrium condition.**
- **It is specified in IEC61215-2 Ed.1 draft / 4.18.2 Procedure 2 (MQT 18.2).**

Case of Vf-Tj characteristics

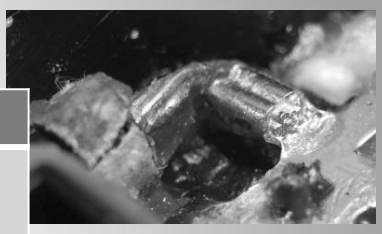


- **To achieve this, the preparation of some special measuring equipment is required.**

Therefore, I will continue to explore the practical measuring method.

Bypass Diode (BD) の接続方法について

J-box 中BDの接続方法による有意差について



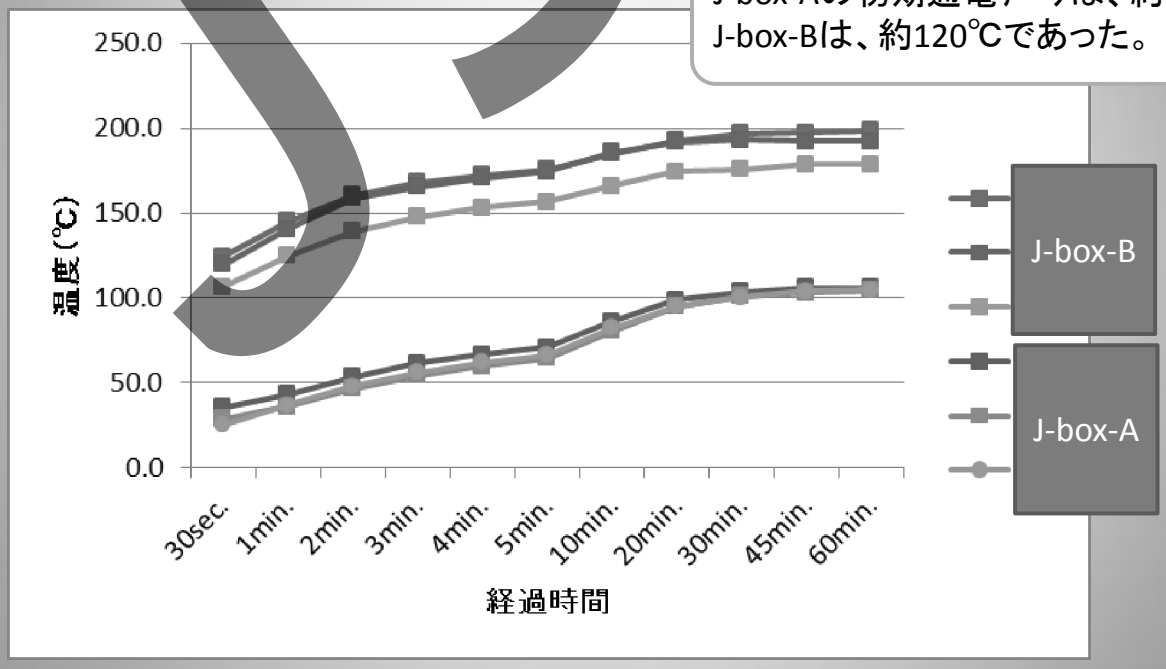
	N数	BDの接続	ﾎﾟｯﾃｨﾝｸﾞ材の有無
J-box-A	3	はんだ+かしめ	有
J-box-B	3	挿入	無

上記2種類のJ-boxについて、TC200 試験(温度サイクル/ -40℃～85℃/ 200cycles/25℃以上時にBDに通電)を実施。

試験後、BDに順方向に電流を1時間流し、J-box内温度の推移を確認した。

TC200後のBD通電による温度の推移

J-box-Aの初期通電ﾃﾞｰﾀは、約100℃
J-box-Bは、約120℃であった。



TC200 後のサーモ観察結果

■ J-box-A
(はんだ+かしめ/ﾎﾟｯﾃｨﾝｸﾞ有)

BD 1時間通電後の表面温度

■ J-box-B
(挿入/ﾎﾟｯﾃｨﾝｸﾞ無)

BD 1時間通電後の表面温度

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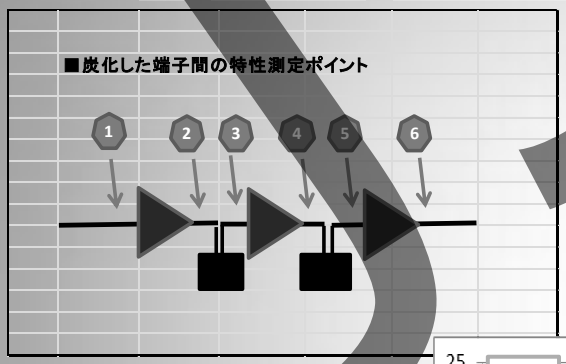
J-box-B のBDの特性回復について



②-③と④-⑤の炭化した端子を削り、銅箔をはんだ付けすると、ﾀﾞｲｵｰﾄﾞの順特性が回復した。

なお、逆方向特性は試験により変化なし。