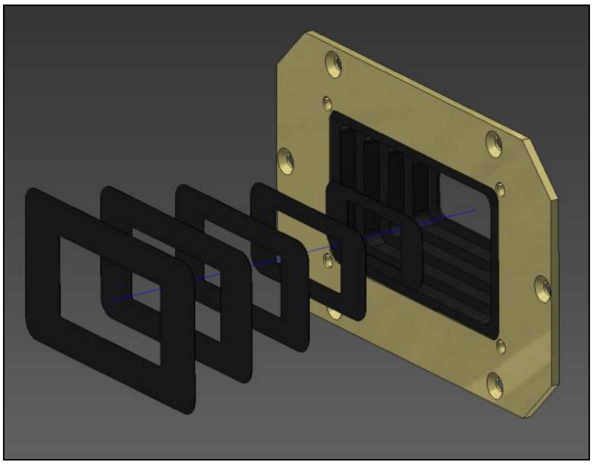
2	Originator: L.Seimetz Originator reference: CAU	**3**	Subsystem: STEP collimator, EH1/ EH2 and STEP MLI-standoffs, purgin tube filter-insert. Equipment: EH1, EH2, STEP
4	Item description: Part I: STEP's collimator/ baffle subassembly glued using EPO-TEK H20E and being part of the PQM and FM test-campaign. Adressing Kiel actions #4 and #11(ESA-TECQ-MIN-003027) Part II: MLI-standoffs glued using Scotch-Weld 2216 B/A grey and being part of the PQM and FM test-campaign. Adressing Kiel action #10 (ESA-TECQ-MIN-003027) Part III: Swagelok tube stiffener and pall filter (DMPL 56.1.1 and DMPL 56.1.2) being part of the FM test campaign. Adressing Kiel action #14 (ESA-TECQ-MIN-003027)	**5**	PMP list item number: EPO-TEK H20E, DML 10.1.19 Structural Glueing of STEP collimator, DPL 1.1.6 Scotch-Weld 2216 B/A, DML 10.1.3 Swagelok tube stiffener, DMPL 56.1.1 Pall particle filter, DMPL 56.1.2 list references: DML: SO-EPD-KIE-LI-0061_iss5_rev5 DMPL: SO-EPD-KIE-LI-0062_iss5_rev5 DPL : SO-EPD-KIE-LI-0063_iss5_rev6
6	Item status: Scotch Weld 2216 B/A from 3M : expiration date: Sept. 11, 2017; handling acc. to attached procedure EPO-TEK H20E from Epo-Tek: expiration date: May 1, 2016 ; handling acc. to attached procedure		
Manufacturer: Process executed by CAU under ISO-8 conditions		Manufacturer qualification reference: Several space projects for NASA/ESA	
Supplier:		Qualification status: n/a	
Product/material specification: Datasheets attached		Procurement specification: n/a	
Process/handling specification: SO-EPD-KIE-PR-0032 - STEP collimator glueing SO-EPD-KIE-PR-0027 - Application proc. SW2216BA		Related specification: Data sheet EPO-TEK H20E Data sheet Scotch-Weld 2216 B/A	
Verification/qualification specification: n/a		Report: n/a	
7	Reason for RFA		
	EPO-TEK H20E as the adhesive to join the STEP baffles with its dedicated collimator housing (Part I) and Scotch-Weld 2216 B/A for glueing the MLI-standoffs to the chassis (Part II) both have to withstand all dynamic and thermal loads induced during testing and operation of the SO mission. The same applies to the combination of the tube stiffener and the particle filter, where H20E has been used to glue the filter disk in the tube stiffener. This RfA has been issued as an outcome of the MPCB4, 30sep2016, according to ESA-TECQ-MIN-003027.		

8	Application/location details: STEP telescopes' collimators, EHs' and STEP's MLI-standoffs and purging tubes' filter-inserts.	CIL Reference: n/a		
9	Evaluation/validation programme (title, reference)			
	Since for both applications the expected mechanical loads are small compared to the glues' dedicated shear loads no qualification programme has been carried out. As being parts of EHs' and STEP's PQM- and FM-models, the STEP-collimator, both units' MLI-standoffs and the units' purgin tube filter-inserts underwent the units' qualification and acceptance test campaigns and concluded them with no evidence of failures.			
10		**Materials and process es responsible**	**PA responsible**	**Project responsible**
	Supplier approval on RFA first issue	L.Seimetz	W.Boogaerts	C.Martin
11	Decision on RFA first issue: - Request refused: - Submit deviation: - Proceed with validation programme:		Comments:	
12	**Decision**	**Materials and process es responsible**	**PA responsible**	**Project responsible**
	Customer agree/disagree			
	Final customer (if applicable) agree/disagree			
13	**Justification results**			

Part I: STEP's collimator/ baffle subassembly glued using EPO-TEK H20E and being part of the PQM and FM test-campaign.

Analysis:

The STEP collimator consists of a cnc-milled base and five sheet-metal parts, called baffles, made of CuBe2 with a thickness of 0,1mm. The stair-shaped inner walls of the collimator as well as the baffles are coated with a black optical coating called Vacuum Black which is processed by ACKTAR LTD (DML 9.1.3).



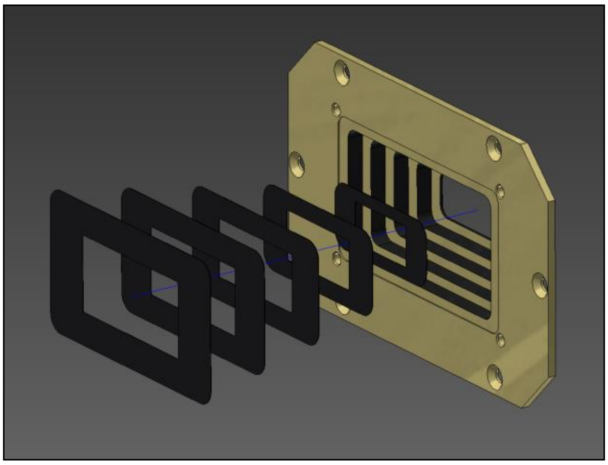


Fig.1: Exploded view of collimator assembly showing all black coated areas.

Fig.2: Parts of the collimator walls' black coating faded-out to visualize collimator base' shape.

The mass of the baffles ranges from 0,2 grams for the smallest to 0,7grams for the largest outermost one. The baffles are glued to the base structure using multiple small drops of EPO-TEK H20E (H20E). The drops are applied manually under a microscope, so slight variations regarding the glueing dot position and applied amount is expected. The glueing dot diameter is about 1,5mm.

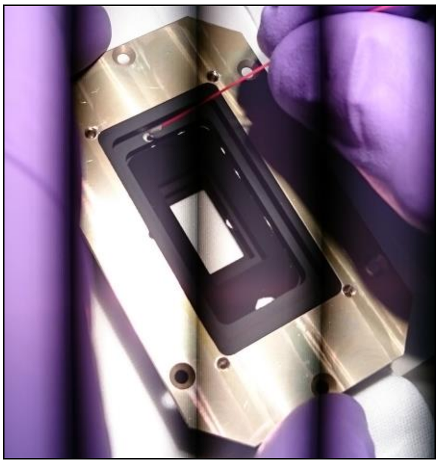


Fig.3: Application of glueing dots.
(Black stripes are optical artefact caused by lab-lamp/ camera asynchronity.)

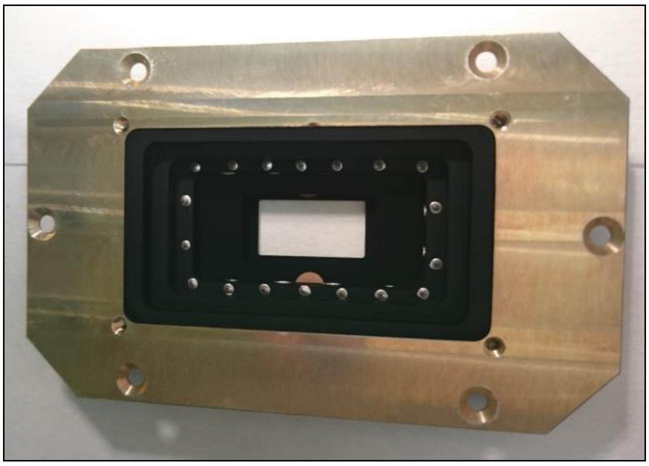


Fig.4: Glueing dot pattern for baffle #3

The number of glueing dots ranges from n = 8 (smallest baffle) to n = 30 (largest baffle).

Using the weight of a baffle (m_baffle), the glueing dot area (A_gdot =1,8 mm^2) and the quasi-static load (RfD STEP notching / SO-EPD-KIE-RD-0017, Iss.1, Rev.2) it can be calculated that the shear stress on every glueing joint is

σ_shear_gdot = F_shear / A_gdot * n = m_baffle * QSL_STEP_Z / (A_gdot * n)

where QSL_STEP_Z = 57.63 * g is the worst case in-plane quasi-static load. This calculation leads to shear stresses ranging from σ_shear_gdot (baffle1) = 0,008 N/mm^2 to σ_shear_gdot (baffle5) = 0,007 N/mm^2.

(The difference coming from rounding a calculative number of joints per baffle to always the next even number. This is necessary in order to support the equal manual distribution of the dots along the available baffle seat area. (Fig.4))

These stresses have to be compared against H20E's ultimate shear stress. The datasheet (attached to this RfA) defines a lap shear strength of σ_lap_H20E = 1475 psi = 10.17 N/mm^2.

Following the general approach of determining a safety margin

MoS = (Allowable Load / (Limit Load *sf)) -1 (ECSS-E-HB-32-23A, 16 April 2010)

a safety margin against bondline failure can be calculated using the lap shear strength, the calculated glueing dot shear stress and a safety factor sf. (sf has been set to 2 accounting for an analysis only case) assuming the given lap shear strength is an ultimate (maximum, not-to-exceed) material's value.

MoS_shear- failure= (σ_lap_H20E / (σ_shear_gdot* sf)) – 1 ➔ MoS_shear- failure = app. 635

Since the MoS is a significant positive number it shows that the expected stress acting on the glueing joints compared to the ultimate lap shear strength of the glueing material is very small. Therefore the glueing interface can be considered non-structural.

Destructive lab test:

A destructive lab test has been performed to test the adhesion/ cohesion of the joint. For this test an adapter has been put at the backside of the innermost baffle and mechanical pressure has been applied via a force gauge in order to quantify the max. load until the glueing dots fail. The applied force has been recorded at the time the first glueing joint failed.

Note: Only a single collimator setup consisting of 5 baffles was available for this test, so the results lack a high number of repetitions in order to provide a statistically proven result. Nevertheless the results fit well into the overall characteristics and behaviour of this material and are provided as additional informations.

Five of these press-out tests, one for each baffle, have been performed following the above described setup. The applied force necessary to achieve the first glueing dot to break ranged from F_tensile_test = 4,0 N to 12,9 N. For the following calculation the smallest value of this test F_tensile_test = 4,0 N is used to follow a worst case scenario approach.

Using the quasi-static load QSL_STEP_X = 63,45 * g (RfD STEP notching / SO-EPD-KIE-RD-0017, Iss.1, Rev.2) the max. expected force on a single glueing dot can be calculated using

F_tensile_calc = m_baffle * QSL_STEP_X / n

With a mass of 0,2g and a number of n=8 glueing dots for baffle1 the expected max. tensile force on a single glueing dot will be F_tensile _calc = 0,016 N.

Deriving a margin of safety from these two values using

MoS_tensile-failure= (F_tensile_test / (F_tensile_calc * sf)) – 1 leads to

MoS_tensile- failure = app. 128

As for the margin of safety against a shear joint failure also this MoS is a significantly high positive number which shows that the joints can compensate significantly higher loads than the ones which are expected to act on the joints during the mission.

Tests:

The following tests were conducted with the collimator installed:

Vibration

Unit	*Model*	*Ref Test Report*	*Level*	*Axes*
STEP	PQM	SO-EPD-KIE-TR-0020	Qual	X, Y, Z
STEP	PFM	SO-EPD-KIE-TR-0033	Qual	X, Y, Z

Tests' results: Passed, no anomalies detected

Thermal

Unit/ Test	*Model*	*Ref Test Report*	*Level*	*Number of cycles*
STEP/ TBT	PQM	SO-EPD-KIE-TR-0021	Qual	1
STEP/ TCT	PQM	SO-EPD-KIE-TR-0022	Qual	8
STEP/ TCT	PFM	SO-EPD-KIE-TR-0028	Acc	5

Tests' results: Passed, no anomalies detected

Conclusion part I (EPT-TEK H20E):

The analysis, lab test and the unit's acceptance and qualification tests show that the glueing material fulfills the requirements. Regarding the outcome of this section this glueing interface is considered non-structural. DPL 1.1.6 is named "Structural glueing of STEP collimator" and will be corrected to "Non-structural" in an upcoming update in order to reflect the non-structural characteristics.

Part II: MLI-standoffs glued using Scotch-Weld 2216 B/A grey and being part of the PQM and FM test-campaign.

Note

Revision 1 of this RfA has been issued as a response to action item #8 of NRB#3 of SOL.SC.ASTR.NCR.700:

"New action#8: EPD team to update the RFA to explicitly state the full coverage including metal to metal bonding and coupon level test planning, K Palmer, 02/06/17.",

Email " Summary of the NRB#3 of SOL.SC.ASTR.NCR.700 held on 30/05/17"/ A. Ewbank, 2017-05-30

Updates in the scope of revision 1 are written in purple colored text.

Revision 2 of the RFA has been issued to report the successful qualification process performed according to procedure SO-EPD-KIE-TP-0061 and reported in test report SO-EPD-KIE-TR-0050

The two Kiel units' MLI standoff interfaces comprise two different material combinations.

Type A: vespel standoffs directly glued to the aluminium chassis surface.

Type B: vespel standoffs glued on an aluminium bracket (EN-AW 6061) which again is glued to the chassis. That means that type B effectively comprises two interfaces, of which the first one (standoff to bracket) is comparable to type A and the second one is an aluminium/ aluminium bonding interface.

In the scope of this RfA only the aluminium-aluminium will be discussed for the type B, since it is considered that the vespel-aluminium interface is comparable to type A and thus separately covered.

While EPT-HET 1/2 use both types of interfaces, STEP just contains glueing joints of type A.

	EPT-HET 1/2	STEP
Type A	11x	23x
Type B	16x	n/a

Interface type (A): Vespel to aluminium

The MLI of the Kiel instruments is attached to the units via Vespel-standoffs which are glued to various locations on the surface of the units.

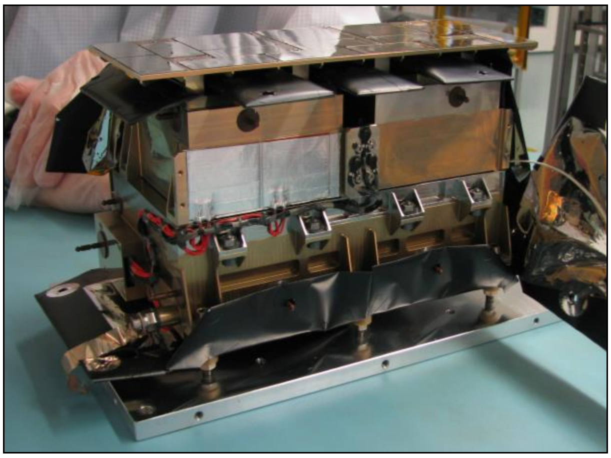


Fig.5: MLI-standoffs on STEP instrument (brownish pins with circular base)

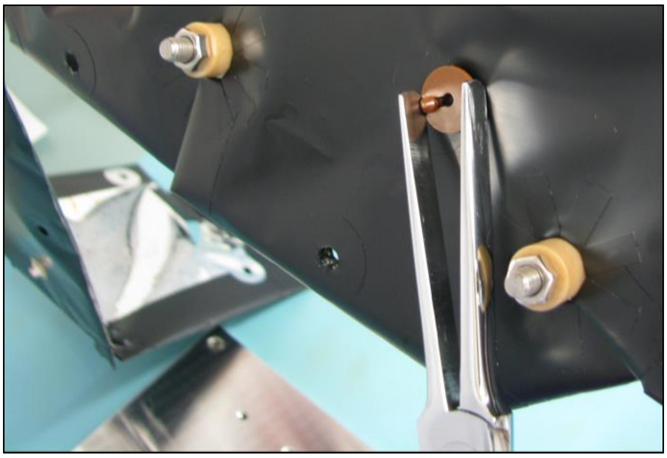


Fig.6: Fixing MLI using clip-washers.

The MLI itself is attached via dedicated punched-out holes and held in position by fixing clipwashers which are connected to the stand-offs using a snap-in mechanism. The standoffs are glued to the units using Scotch-Weld 2216 B/A (handling procedure and datasheet attached). It is widely used at CAU for different space missions, e.g. MSL/RAD. The Kiel personnel has extensive experience in using it for screw-locking and strain-reliefing, etc.. It's also one of the standard materials of Iberespacio, Kiel's MLI-supplier for EH1, EH2 and STEP, and is used there in various projects.

Analysis:

The same logic as for EPO-TEK H20E has been applied to Scotchweld 2216 B/A in the scope of the MLI-standoff glueing, although the situation in this interface is different from the collimator. The MLI adds additional mass which has to be compensated by the glueing joint.

The following calculation uses a worst-case assumption in order to cover both instruments, STEP and EH 1/2. The MLI mass for STEP is 54 grams. Looking at the instrument's MLI design it can be assumed that 5 of six faces are covered with MLI. Additionally every side includes standoffs which will take the loads induced by the faces' MLI.

Following this logic it is assumed that 1/5 of the MLI mass acts on every surfaces' standoffs. The lowest number of standoffs per side is n=4, so 1/5 of the load coming from the MLI mass of 54 grams, plus the standoffs' and clipwashers' mass of 0,53 grams , has to be compensated by these 4 standoffs. The standoff' contact area (glueing area) is A_standoff = 177mm^2. Using the worst case QSL-load in X direction (QSL-STEP-X = 63,45 * g) the expected shear load in on glueing joint can be calculated:

Equation II/1:

σ_shear_standoff =

((m_MLI / 5) + 4*(m_standoff+m_clipwasher)) * QSL_STEP_X / (A_standoff * n) = app. 0,01 N/mm^2

Comparing this shear load with the ultimate shear load of the glue σ_shear_SW2216 = 17 N/mm^2 (datasheet attached to this document) leads to MoS against shear failure of

Equation II/2:

MoS_shear- failure= (σ_shear_SW2216 / (σ_shear_standoff * sf)) – 1

➔ MoS_shear-joint-failure = app. 748

Interface type (B): aluminium to aluminium

In the scope of answering initial questions regarding the issue 0 of this RfA to Francesca Muratore/ ESA (please refer to Annex F) it has been described, that the general approach of putting an allowable load in relation to a limit load in order to derive a margin of safety (Part I of this document) for a given interface (also a glueing joint) is not limited to a certain material combination or surface property. Thus the relation is also applied to derive a MoS for the type B aluminium-aluminium interface.

The type B interface comes in different variants:

- 3 types of standoff heights (“double”, “simple”, “simple-short”)
- 3 different types of bracket sizes (“normal_A”, “normal_B”, “small”)

which finally build 5 different combinations. Please refer to annex E for details.

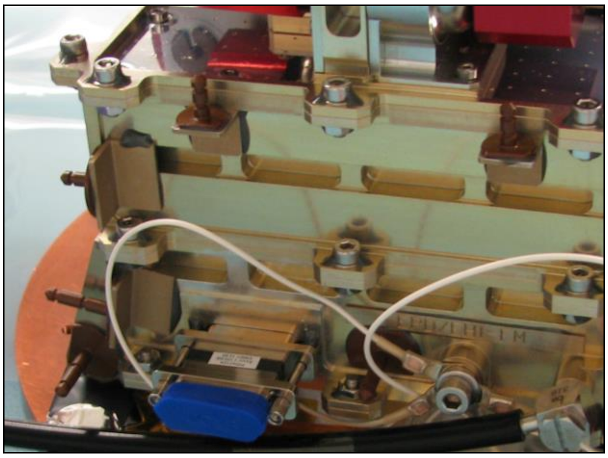


Fig.7: MLI-standoffs type A and type B on EPT-HET instrument. Different lengths and bracket widths can be seen.

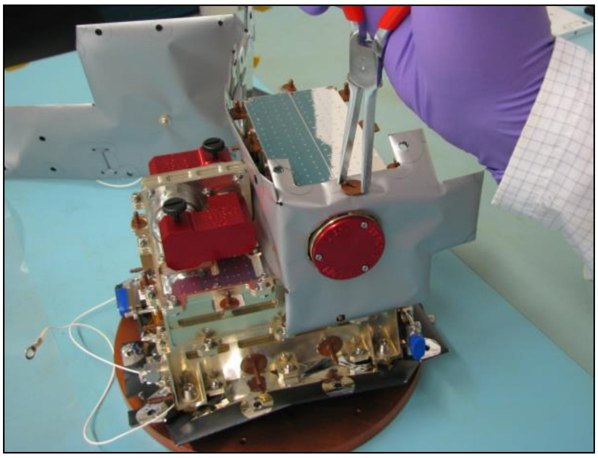


Fig.8: Fixing MLI using clip-washers.

As for the other sections in this RfA again a worst case assumption is being made in order to limit the available 5 cases to 2. Case B1 is the glueing interface with the smallest adhesion area, B2 the one with the biggest mass. If both margins of safety are positive as a result it is assumed that all 5 combinations satisfy the mechanical loads requirement.

The following identifiers again refer to Annex E

B1 (smallest area): Bracket of type “small” + standoff of type “simple-short”

B2 (highest mass): Bracket of type “normal_A” + standoff of type “double”

As described for the type A interfaces the same assumptions are being made for the type B interfaces regarding the MLI mass, clipwasher mass, deviation to the standoffs and the QS loads.

Equation II/1 is adapted accordingly:

σ_shear_bracket = ((m_MLI / 5) + 4*(m_bracket+m_standoff+m_clipw)) * QSL_STEP_X / (A_bracket * n)

Using m_bracket_B1=0.52g, m_clipwasher=0,12g, m_standoff_B1=0,38g and A_bracket_B1=40mm^2 leads to σ_shear_bracket_B1 = app. 0,23 N/mm^2.

Using II/2 the MoS against shear failure can be calculated:

MoS_shear-failure_bracket_B1= (σ_shear_SW2216 / (σ_shear_bracket_B1 * sf)) – 1

= (17 N/mm^2 / (0,23 N/mm^2 * 2))-1 = app. 36

Repeating the same calculation for the B2 interface using m_bracket_B2=0.75g, m_clipwasher=0,12g, m_standoff_B2=0,43g and A_bracket_B2=127.5mm^2 it leads to σ_shear_bracket_B2 = app. 0,08 N/mm^2

MoS_shear-failure_bracket_B2= (σ_shear_SW2216 / (σ_shear_bracket_B2 * sf)) – 1

= (17 N/mm^2 / (0,08 N/mm^2 * 2))-1 = app. 105

Tests:

The following tests were conducted with MLI-standoffs mounted:

Vibration

Unit	*Model*	*Ref Test Report*	*Level*	*Axes*
EPTHET	PQM	SO-EPD-KIE-TR-0015	Qual	X, Y, Z
STEP	PQM	SO-EPD-KIE-TR-0020	Qual	X, Y, Z

Tests’ results: Passed, no anomalies detected

Thermal

Unit	*Model*	*Ref Test Report*	*Level*	*Number of cycles*
EPTHET, TBT	PQM	SO-EPD-KIE-TR-0013	Qual	1
STEP, TBT	PQM	SO-EPD-KIE-TR-0021	Qual	1
STEP, TCT	PQM	SO-EPD-KIE-TR-0022	Qual	8

Tests’ results: Passed, no anomalies detected

The vibration runs where conducted without MLI. This means that the loads on the MLI-standoffs during the tests where effectively lower compared to the final environment.

However, running the above calculation again and assuming the full MLI load on a single standoff, which is by far overly pessimistic, still results in a positive MoS.

Due to the above conclusion this glueing joint is considered non-structural.

Conclusion part II (Scotch Weld 2216 B/A):

The analysis and the unit's acceptance and qualification tests show that the glueing material fulfils the requirements.

The following section addresses the required coupon test plan in the scope of AI#8 of NRB#3:

During the preparation and gluing of the MLI standoffs on the EPT-HET and STEP units, several test coupons were also prepared. These test coupons are representative in shape and material and use the same glue mixture as the original FM standoffs. The coupons are to be tested for particular services or applications and/or to be kept in a dedicated environment for a particular period and being studied afterwards. The test coupons were labelled and packed in order to prevent any degradation due to corrosion, deterioration or physical damage. The supplier shall retain the associated test coupon for at least launch + 90 days or commissioning.

In addition to the FM MLI standoffs and test coupons, spare samples are also produced to cover the Flight Spare unit assembly, Flight Spare kit and supplementary testing.

Part III: Swagelok tube stiffener and pall filter (DMPL 56.1.1 and DMPL 56.1.2) being part of the FM test campaign.

The purging line of the Kiel instruments include a tube stiffener with an included reinforced stainless steel filer in order to prevent the PTFE tube from collapsing during connection with the S/C purge inlet. The filter acts as an additional security measure against particular contamination of the unit.

The filter disc is glued into a seat in the tube stiffener using H20E (Part I).

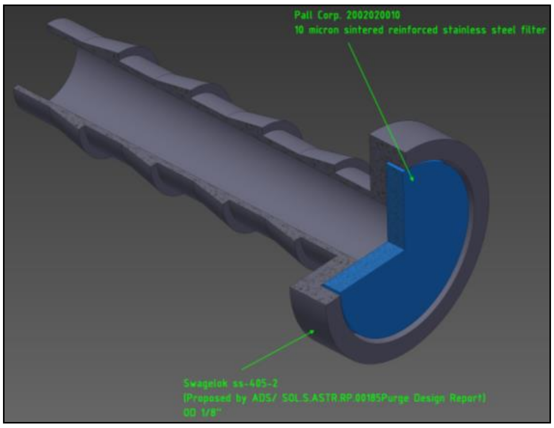


Fig.9: CAD-view of the filter-insert setup

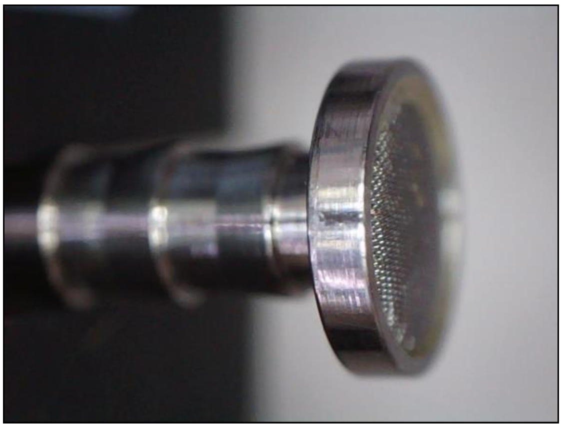


Fig.10: Detail photo of the final setup.

Analysis:

The mass of the stiffener/ filter subassembly is m_filter = 0,37 grams. This mass is comparable to the subassemblies/ setups in part 1 and 2 of this document. The dynamic loads are expected to be similar as well. Since the mass of the filter is of the same order of magnitude as the parts from part 1 and 2 the MoS will also be large for this case. Thus the detailed calculation is not repeated at his point.

This joint is also considered to be non-structural.

Tests:

The following test were conducted with MLI-standoffs mounted

Vibration

Unit	*Model*	*Ref Test Report*	*Level*	*Axes*
STEP	PFM	SO-EPD-KIE-TR-0033	Qual(*)	X, Y, Z

(*) Qualification level, acceptance level duration

Test results: Passed, no anomalies detected

Conclusion part III (tube stiffener and filter):

Although the filter-insert setup has just been tested once to the full qualification level it is considered to be uncritical, mainly because of the expected high MoS against bondline failure. It is concluded that the glueing material fulfils the requirements.

14	Supplier approval on RFA final issue	**Materials and processes responsible**	**PA responsible**	**Project responsible**
15	Decision on RFA final issue	**Materials and processes responsible**	**PA responsible**	**Project responsible**
	Customer agree/disagree			
	Higher level customers (as necessary) agree/disagree			

Attachments : Plans, Procedures, schedule, etc.

Gluing Procedures Number:

ANNEX A: STEP collimator glueing **SO-EPD-KIE-PR-0032_iss1_rev3**

ANNEX B: EPO-TEK H20E

ANNEX C: Application procedure 3MScotchWeld 2216BA **SO-EPD-KIE-PR-0027_iss1_rev0**

ANNEX D: Scotch Weld 2216 B/A

ANNEX E: 20150330_EPT-HET_PQM_MLI_standoffs_reference.pdf

ANNEX F: 2017-05-18_RFA0002_answer_v1-with-Annexes-A-B.pdf

<u>Scope and Contents</u> (acc. to ECSS-Q-ST-70C Annex D)

1.	The header	identifying the document as a request for approval together with the project logo and project name, RFA reference, issue revision and date.
2.	Originator	Originator's name and reference.
3.	Location	Subsystem and equipment codes.
4.	Item description	Brief description of the item.
5.	PMP information	The DML, DMPL or DPL item number and list reference.
6.	Item status	including the following information: (a) manufacturers' name and qualification reference; (b) suppliers' name and qualification status; (c) product or material specification; (d) procurement specification; (e) process or handling specification; (f) other related process or handling specifications; (g) verification or qualification specification; (h) report on verification or qualification.
7.	Reason for RFA	Enter the reason for the RFA.
8.	Application and location details	Enter here the details of the application and exact location of the item. Give the reference in the CIL.
9.	Evaluation and validation programme	Reference and details of main tests.
10.	Subcontractor supplier approval	for the first issue of the RFA.
11.	Customer initial decision	to be entered on first issue of the RFA providing: (a) the decision concerning the proposed material, (b) the requirement to perform tests (deviation request as necessary) (c) the decision concerning the proposed test programme.
12.	Customer's and final customer's	signature (if applicable)

13.	Justification results	obtained with reference to the supplier's validation report and conclusion.
14.	Subcontractor supplier	approval on RFA final issue.
15.	Final approval	status of the RFA by the customer.

SOLAR ORBITER ENERGETIC PARTICLE DETECTOR

Document ID:	SO-EPD-KIE-PR-0032
Issue:	1
Revision:	3
Date:	November 16, 2016

SO/ EPD - STEP
Assembly (Glueing) of Collimator

Signature not needed if electronically approved by route					
Author/ Engineering	**Checked**	**Approved Configuration Control**	**Approved QA**	**Approved Experiment Manager**	**Approved Principal Investigator**
Lars Seimetz **Date and Signature**	**Lauri Panitzsch** **Date and Signature**	**César Martín** **Date and Signature**	**Date and Signature**	**Date and Signature**	**Date and Signature**

File: V:\MECHANICAL\baffles\assembly-procedure\SO-EPD-KIE-PR-0032_nnnn_STEP_Glueing_Acktar_parts\SO-EPD-KIE-PR-0032_iss1_rev3_STEP-collimator-glueing.doc

Pages: 25

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CHANGES RECORD

Issue	Revision	Date	Modified by	Section / Paragraph modified	Change implemented
1	0	11 June 2015	L. Seimetz	All	Initial release
1	1	11 Feb 2016	L. Seimetz		Adjusting heat cure temperatures
1	2	02 Nov 2016	L. Seimetz		Added H20E as masking option, chapter 4.3 removed
1	3	15 Nov 2016	L. Seimetz		Equipment lists updated

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1. INTRODUCTION

1.1 Purpose

Some parts of the Solar Orbiter EPTHET and STEP Instruments receive an anti-reflective optical coating on special surfaces/ structures of their collimator subsystems. The purpose is to absorb potential straylight which enters the collimator. The collimator of the STEP instrument is designed to build a structure which acts as a light trap. Here the stray-light which enters the collimator is reflected multiple times at the surfaces of so called baffles in order not to enter the aperture. In order to decrease the amount of light during every reflection an absorbing anti-reflective coating called "Vacuum Black" has been processed on all parts in the optical path, baffles as well as parts of the chassis. The anti-reflective coating is processed by the company Acktar Limited/ IL.

Vacuum Black (VB) is a black porous material layer which is applied to the parts via a vacuum deposition process under elevated temperature. The material forms an electrically conductive open structured layer on the surface of the parts.

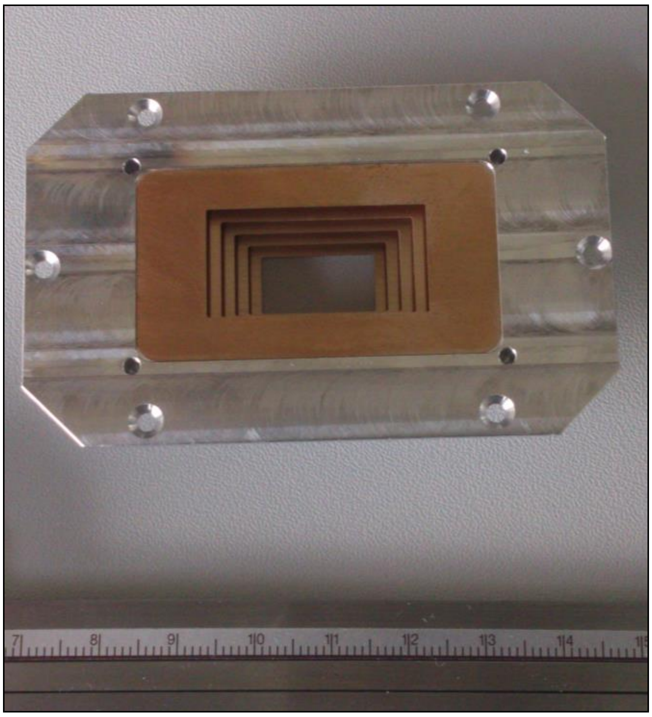


Figure 1.1-1 Fitcheck with STEP collimator chassis and baffles using uncoated parts.

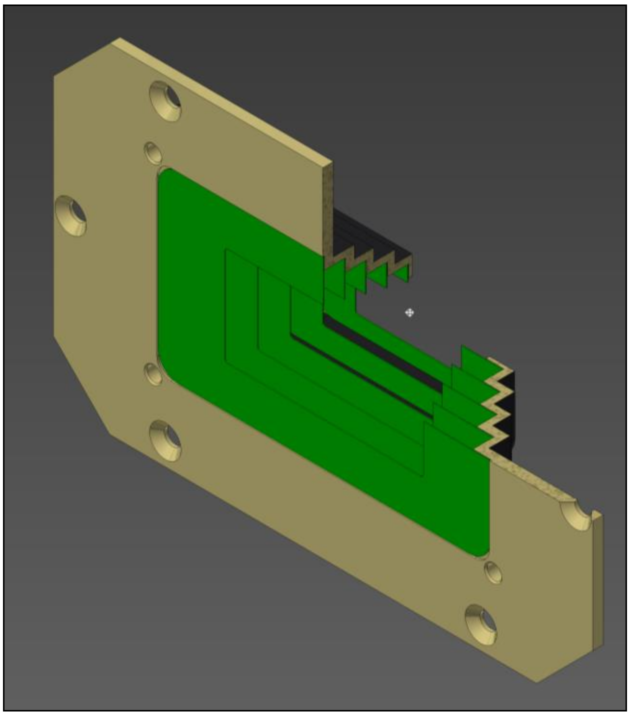


Figure 1.1-2 CAD-model with chassis (golden) and installed baffles (green)

The STEP instrument's collimator consists of an arrangement of 5 rectangular sheet metal parts, called baffles, which consist of copper-beryllium with a thickness of 0,1mm. They are mounted in a surrounding aluminium part, called chassis, which has been designed in a way that it provides a stair shaped structure which defines the desired location of the baffles. By that the necessary parameters of the ion-optical telescope are set (Figure 1.1-1 & 2).

VB adheres well to the object's surface so it can be used to directly use it as the base layer for glueing on it. This characteristic is used in the assembly of the collimator to glue the baffles to the chassis using a silver filled epoxy called "EPO-TEK H20E".

In order to prevent too high thermal stress (due to differential CTE) between the adhesive and the collimator parts the adhesion area of the joint is not homogeneous but uses a dot-pattern of drops which are applied manually to the specific mounting interface. Second purpose of this dot-pattern is to minimize the amount of excess adhesive material to squeeze out of the glueing joint between the baffle and the chassis.

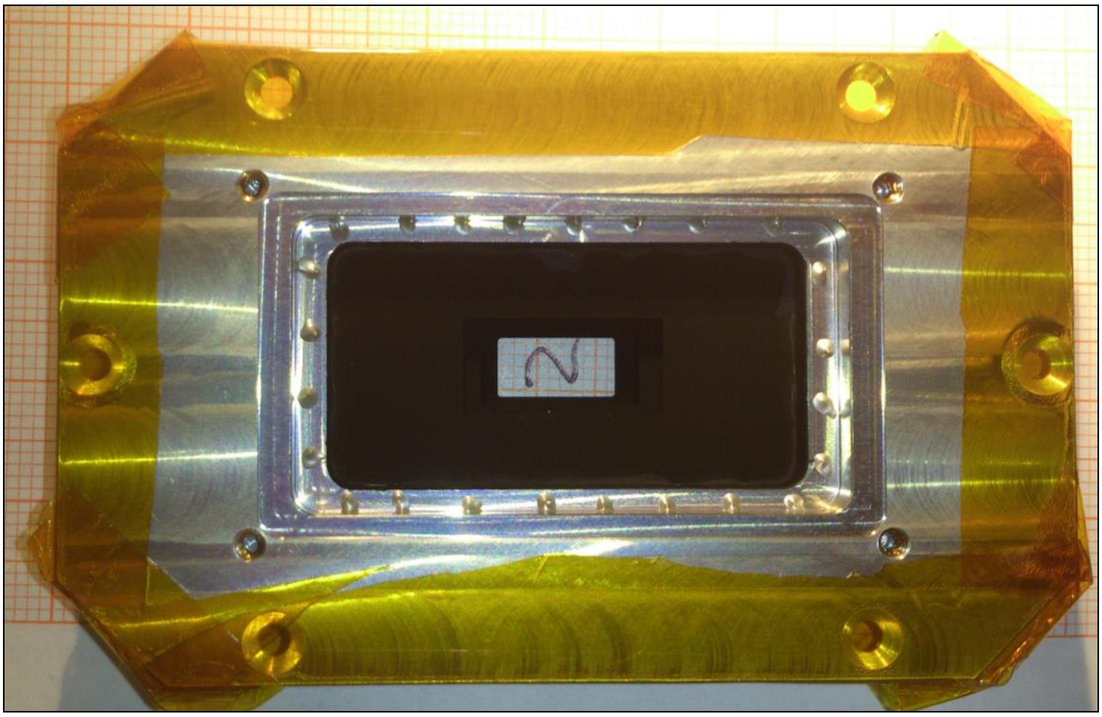


Figure 1.1-3: Test-part showing the glueing dot pattern (24 pc.) on the seat of baffle4.

Acktar's coating process requires a certain positioning of the to-be-coated parts during the process. That's why parts need to be supported by certain jigs/ clamps during the application which can leave an uncoated area behind.

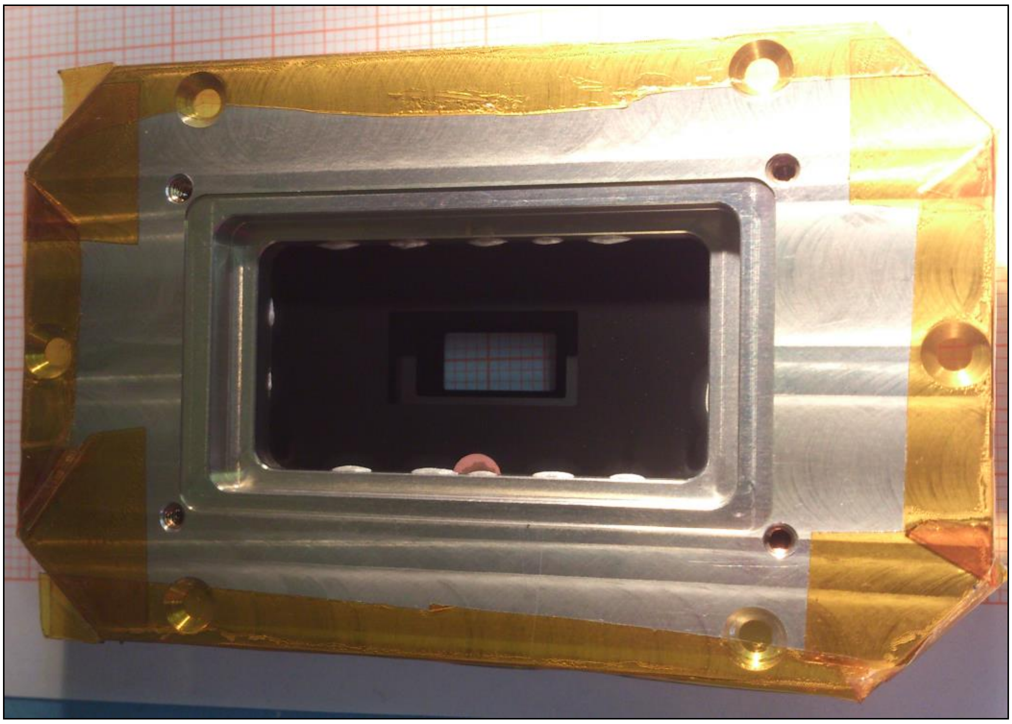


Figure 1.1-4 Test part showing half-circle shaped uncoated area (brownish feature at bottom edge of baffle) from processing VB.

In case of the thin baffles the jig causes a certain shaped uncoated artefact on the final coat which needs to be surface treated during the assembly process. The shape varies from a half-circle shape (Figure 1.1-4) to an uncoated edge of app. 1-2mm width.

Since these artefacts are not coated the bare copper-beryllium is accessible at this locations. Due to the toxicity of beryllium and its oxide these bare CuBe-spots are covered with H20E during the assembly process.

Figure 1.1-5 Covering production artefacts w/ H20E.

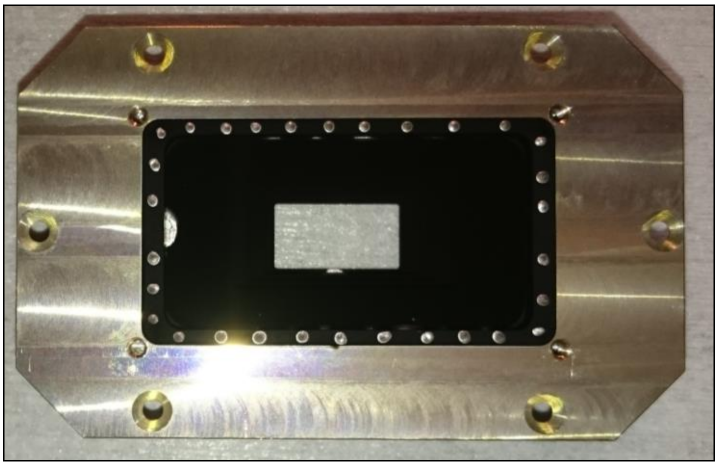


Figure 1.1-6 Collimator w/ covered VB production artefacts

The following chapters detail all necessary steps in order to assemble the STEP collimator.

1.2 Scope

This document applies to the assembly process of the STEP collimator subassembly and all personnel involved into it.

2. GLOSARY AND DEFINITIONS

2.1 Acronyms and Abbreviations

85SBC	AZ Technologies MLS-85SB-C
CAU	Christian-Albrechts-Universität zu Kiel
EPD	Energetic Particles Detector
EPT	Electron, Proton Telescope
H20E	EPO-TEK H20E
HET	High Energy Telescope
PR	Procedure
SO	Solar Orbiter
VB	Acktar Vacuum Black

3. APPLICABLE AND REFERENCE DOCUMENTS

3.1 Applicable Documents

Reference

ID.	Title	Reference	Iss./Rev.
AD-01	Coating Specifications Acktar	so-step-c2_2341_col-chassis_acktar-coated-area-definitions	Rev0
AD-02	Coating Specifications Acktar	so-step-c2_2342_baffle-1_rev01_acktar-coated-area-definition	Rev1
AD-03	Coating Specifications Acktar	so-step-c2_2343_baffle-2_rev01_acktar-coated-area-definition	Rev1
AD-04	Coating Specifications Acktar	so-step-c2_2344_baffle-3_rev01_acktar-coated-area-definition	Rev1
AD-05	Coating Specifications Acktar	so-step-c2_2345_baffle-4_rev01_acktar-coated-area-definition	Rev1
AD-06	Coating Specifications Acktar	so-step-c2_2346_baffle-5_rev01_acktar-coated-area-definition	Rev1

3.2 Reference Documents

ID.	Title	Reference	Iss./Rev.	Date
RD-01	Technical Informations Acktar	Acktar Black		2.2011
RD-02	Technical data sheet EPO-TEK H20E → Annex B	EPO-TEK H20E	Rev. XI	Feb 2010
RD-03	How to Work Properly with Epoxies Step By Step Instructions	EPO-107-01		
RD-04	Calculation of glueing dot numbers/ L.	Ref	n/a	data
RD-05	Product data sheet AZ Technologies MLS-85SB-C	n/a	n/a	n/a
RD-06	Process Specification AZ PRSPEC MLS-85SB	CPS-C-011	n/a	n/a
RD-07	Workmanship procedure for black thermal paint application	SO-EPD-KI-PR-0003_iss2-rev0_Procedure_black_paint	Iss.2/ Rev.0	09/07/2015
RD-08	Epoxy Technology Inc. – Tech Tip 1: Proper Mixing & Handling of Epoxies	EPO-102-01		2009

4. PREPARATION

This section lists all steps necessary to prepare the components in order to build one STEP collimator subassembly.

4.1 Mechanical Parts

One STEP collimator subassembly consists of the following mechanical parts.

Table 4.1-1: Mechancial Parts

Pc.	*Part*	*Part Name*	*Part Number*	*Condition*
1	Collimator Chassis	Col-chassis	so-step-c2_2341_col-chassis	Coated acc. AD-01
1	Baffle	baffle-1	so-step-c2_2342_baffle-1_rev01	Coated acc. AD-02
1	Baffle	baffle-2	so-step-c2_2343_baffle-2_rev01	Coated acc. AD-03
1	Baffle	baffle-3	so-step-c2_2344_baffle-3_rev01	Coated acc. AD-04
1	Baffle	baffle-4	so-step-c2_2345_baffle-4_rev01	Coated acc. AD-05
1	Baffle	baffle-5	so-step-c2_2346_baffle-5_rev01	Coated acc. AD-06

4.2 Dose and mixing of EPO-TEK H20E

All parts involved in this document are glued using EPO-TEK H20E (H20E). It’s a two component epoxy adhesive including a silver filler. It provides a low electrical resistance and a high thermal conductivity. It has a long pot life of 2.5 days. The appearance is a silverish thixotropic paste. H20E is a heat curing adhesive. For details on the curing schedule refer the datasheet in ANNEX B.

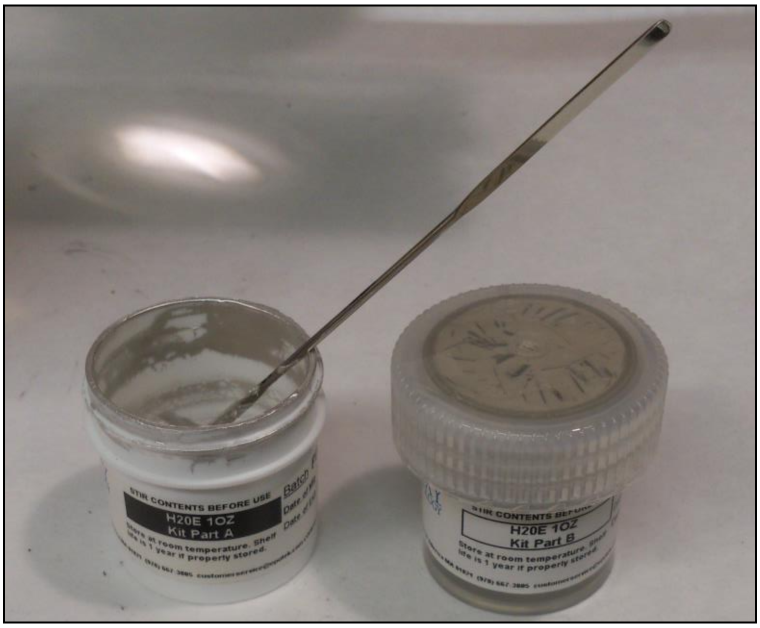


Figure 4.1-1 Part A & B of H20E. Micro spatula used for taking material out of container.

The following summarizes the mixing procedure of H20E (RD-02, RD-08):

Precautions: Pollution of one part with residue of the other has to be strictly avoided, since it can reduce the shelf life of the material significantly. ➔ Always use clean tools and/ or bowls which get into contact with material. Clean thoroughly with IPA, wipe and let dry before reuse. Change/ clean gloves if contaminated.

(Refer to ANNEX C for details)

- Mix every part thoroughly for 2 mins separately with clean spatula. (Clean spatula in between!)
- Mixing ratio: 1:1 (Part A: Part B) with a minimum of 2 grams per part. (Gives a total of 4 grams of every batch).
- Weigh 2 grams +/- 5% of part A in aluminium bowl on precision scale (Annex A-A1).
- Weigh 2 grams +/- 5% of part B as with part A and place _beside_ part A. (By this –keeping the parts separated until final mixing- you allow yourself to readjust amount if necessary and don't cross-contaminate the material.

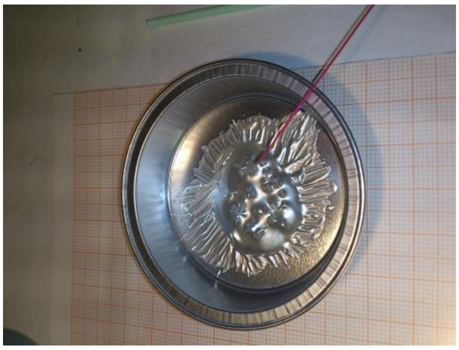


Figure 3.1-2 Aluminium bowl with mixed H20E, AWG24 PTFE-coated single-wire used as dosing tool.

5. ASSEMBLY

Due to the fact that every larger/ next assembled baffle encloses the inner/ smaller/ previously assembled one, it is required to follow a certain workflow in order to assemble the collimator. Untrained operators shall practise the application on test samples. Make yourself familiar with the assembly sequence before beginning.

Assembly steps' overview:

1. Manual application of H20E/dot-pattern to baffle1-seat in chassis.
2. Covering potential production artifacts on both sides on baffle1 with H20E.
3. Insertion of the baffle into chassis.
4. Applying compression force to baffle1 for spreading glueing layer.
5. Repeat process for baffles 2 to 5.
6. Heat curing of adhesive.
7. Cooling to ambient temperature.

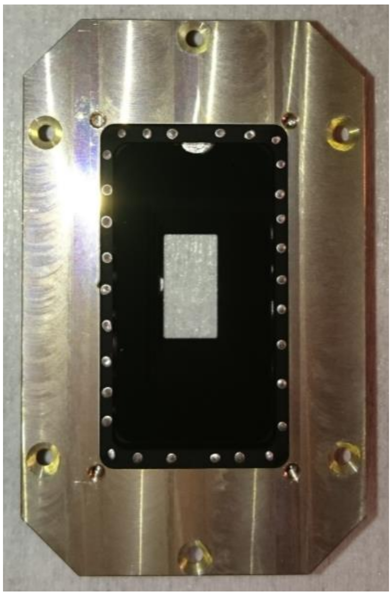
5.1 Detailed Collimator Assembly Sequence

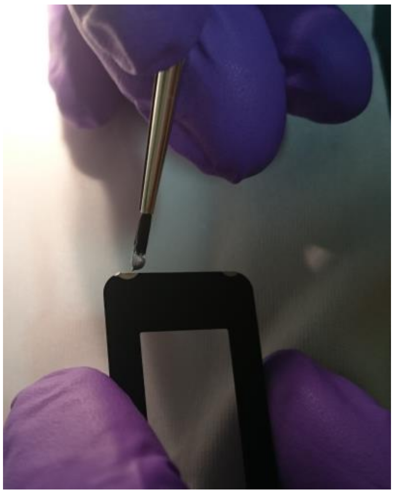
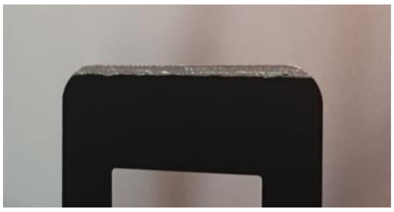
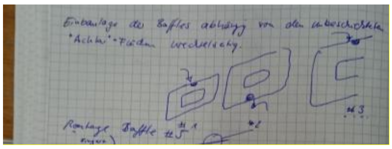
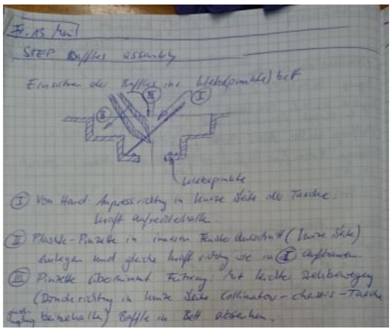
The following detailed step by step procedure assumes that all preparatory steps (see above) have been finished beforehand and that all involved parts are available in their final configuration (e.g. baffles painted, glue mixed, tools prepared).

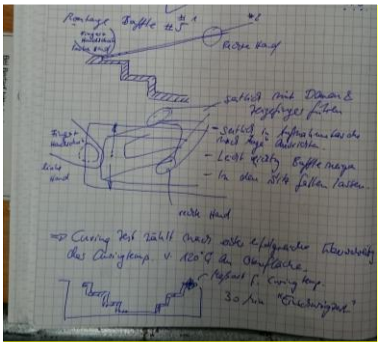
- Summary: 30mins balance time to reach 120°C, 15mins@120°C nominal curing time.

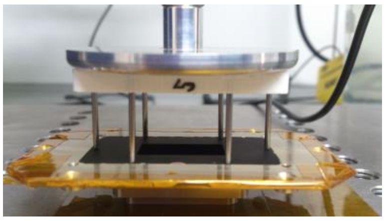
Table 5-1 Detailed collimator assembly sequence

Step	***Description***	***Details***	***Pictures***	***Comments***
1	**Application of Glueing Dots**			
1.1	Apply [8, 12, 18, 24, 30] * (RD-04) dots of H20E evenly to the outer rim of the next seat. * Numbers apply to assembly turn of baffles 1 to 5 [Refer to explanatory section below for workmanship details]	PTFE-coated single-wire of dA = AWG24 = 0,5mm to apply dots.		
				

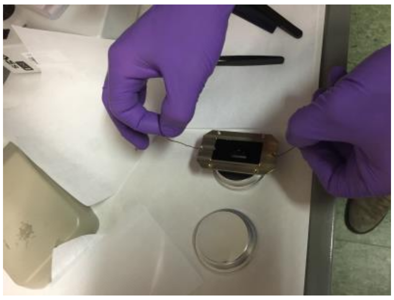
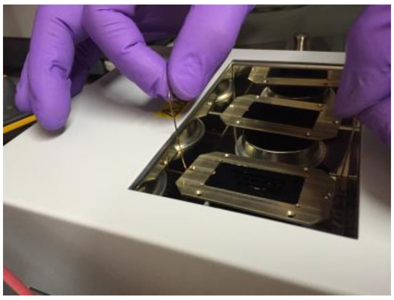
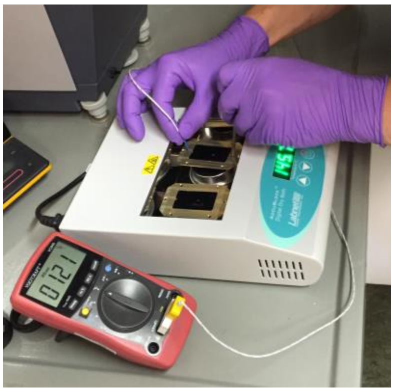
				*Example: Inner seat with 8 glueing dots.*
				*Example: Outer seat with 30 glueing dots.*
2	**Inspection/ Cleaning of Baffle**			
2.1	Inspect baffle from both sides under magnifiying glass. Remove particles with dry and _oil-free_ pressurized air or camel-hair brush.	Use oil-free "Druckluft" from can.		Do _NOT_ use facility's pressurized air, since it is not oil-free.
3	**Sealing of bare CuBe areas from both sides**			

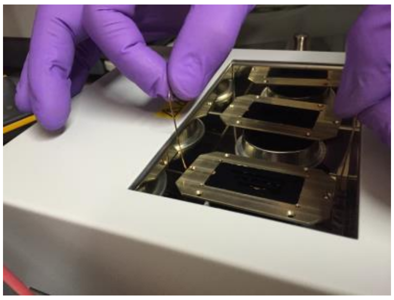
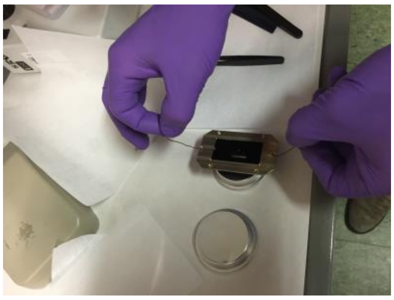
3.1	Apply H20E to bare CuBe spots/ areas using camel-hair brush.			
				
4	**Insert Baffle**			
	Orientate baffle in a way that the artefacts are always located on opposite sides relative to previous one.			
4.1	Lower baffle No. [1, 2, 3, 4, 5] * evenly into seat. * Numbers apply to assembly of baffles 1 to 5			*Inner baffle edge accounts for 99% of strailight damping effectiveness. (Inner edge needs to stay free of H20E under all circumstances.)*
	Use shown insertion method for baffles 1..4			

	Use shown insertion method for baffle5			
5	**Applying leveling pressure**			
5.1	*Caution: Do not place dowel pin of pressure jig into wet H20E => Risk of polluting surrounding area.* *Remove pin previously if applicable.*			
5.2	Place pressure jig No. [1, 2, 3, 4, 5] * on baffle. * Numbers apply to assembly of baffles 1 to 5			*Example: Outer baffle*

5.3	Place setup under force gauge	Make sure it's centered precisely around middle axis of force gauge. Control from two orthogonal sides by eye.		
				
				
5.4	Lower the main slide of force gauge to contact the pressure jig	Carefully lower the force gauge towards the pressure jig.		
5.5	Zero the force gauge.	Zero the force gauge at the		

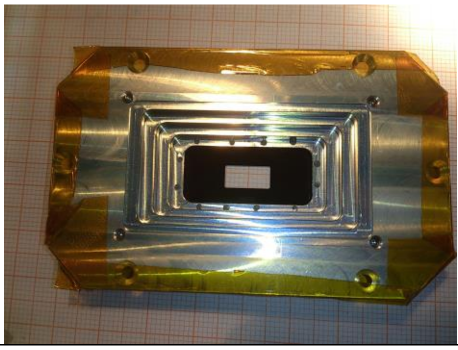
		first significant reading on its display. Pressure plunger should now be in contact with the pressure jig.		
5.6	Apply [8, 12, 18, 24, 30] * 1N of nominal force. ** ** Numbers apply to assembly of baffles 1 to 5	Carefully increase compression force until nominal value has been reached.		
5.7	Adjust force manually to nominal value until settling. [Refer to explanatory section below for workmanship details]			
5.8	3 minute settling time.	Once the decrease rate gets lower or stabilizes fully at the nominal load value wait for 3 minutes.		
5.9	Release force and remove setup from force gauge. Remove pressing jig.			
__ Repeat sections 1 to 4 until all 5 baffles are assembled. __				
6	**Heat Curing**			
	Use handling wire hooks to handle the collimators.			

				
6.1	Place collimators in preheated oven on top aluminium bowls.	Caution: Hot surface. Oven set temp.: 145°C		
6.2	Close oven lid.			
6.3	Wait 30 mins. for temperature to balance			
6.4	Verify surface temperature of collimator by manual contact measurement.	Caution: You need a certain (gentle) pressure to contact the thermocouple to the collim. surface. In order to make sure you don't shift the collim. from the bowl use the rounded end (handle) of a steel (not plastic=> temp!) tweezers to counter the		*Do not start with nominal curing time if temp is < 120°C !*

		part on the opposite side. (see picture) Temperature: min. 120°C.		
6.5	Close oven lid.			
6.6	Heat cure for 15 mins @ 120°C			
6.7	Verify surface temperature of collimator by manual contact measurement to be 120°C			
6.8	Remove from oven	Caution: Hot surface. Use handling wire hooks		
6.9	Place on aluminium bowl on workbench for cooling.			
6.10	Cooling: Wait app. 10-15 mins until part is cooled to ambient condition.	Control by hand.		
7	**Finish assembly**			
7.1	Optical inspection of			

	setup.			
7.2	Wrap in soft, lint-free cloth to prevent scratches.			
7.3	Put in mylar bag and store in cleanroom.			
7.4	Assembly finished.			

Explanatory sections below:

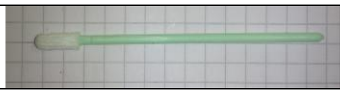
Assembly Step	Summary	Details
	Practise dot size before beginning on mm-scale paper.	Diameter of dots should be of dA app. 1mm .. 1.5mm 
	Readjust compression force due to levelling of glueing dots.	The uncured (still liquid) glue will start to spread under the compression load thinning the glueing dots. This leads to decrease in compression force. In order to maintain a constant pressure the applied load has to be readjusted for the (now) thinner glueing layer. Carefully increase the load at the gauge until the nominal load is reached again.

ANNEX A: EQUIPMENT LISTS

Table A-1 Equipment list to prepare EPO-TEK H20E

Item No.	***Item***	***Details***
1	EPO-TEK H20E (Part A and B)	
2	Aluminium Bowl for mixing H20E	28mm, Eydam 9106240
3	Aluminium Bowl for covering H20E	28mm, Eydam 9106240
4	Precision Scale	Model: Sartorius Basic, precision +/- 0,01g
5	Micro spatula	130mm x 2mm, Eydam 6053239
6	Lint-free cleanroom wipes	
7	Gloves	

Table A-2 Equipment list to perform collimator assembly

Item No.	***Item***	***Details***
1	Force gauge	Aluris FMI 100c5 + Stand
2	Pressing jig/ adapter 1..5	Size 1 .. 5
3	Small camel hair brush	Da Vinci 315 No.1
4	Isoproylalcohol “IPA”	
5	Heating plate/ Oven	Labnet D1200
6	Lint-free cleanroom wipes	
7	Sponge sticks	
8	dA = AWG 24/ 0,5mm single-wire, length app. 10cm	
9	Wire hooks	
10	Ready-to-use H20E	
11	Thermometer	Voltcraft VC840 + type K thermocouple
12	Gloves	

ANNEX B: DATASHEET H20E

EPOXY TECHNOLOGY

EPO-TEK® H20E
Technical Data Sheet
For Reference Only
Electrically Conductive, Silver Epoxy

Number of Components:	Two	Frozen Syringe	Minimum Bond Line Cure Schedule*:	
Mix Ratio By Weight:	1:1		175°C	45 Seconds
Specific Gravity:		2.67	150°C	5 Minutes
Part A	2.03		120°C	15 Minutes
Part B	3.07		100°C	2 Hours
Pot Life:	2.5 Days		80°C	3 Hours
Shelf Life:	One year at 23°C	One year at -40°C		

*Note: Container(s) should be kept closed when not in use. For filled systems, mix contents of each container (A & B) thoroughly before mixing the two together. *Please see Applications Note available on our website.*

Product Description:

EPO-TEK® H20E is a two component, 100% solids silver-filled epoxy system designed specifically for chip bonding in microelectronic and optoelectronic applications. It is also used extensively for thermal management applications due to its high thermal conductivity. It has proven itself to be extremely reliable over many years of service and is still the conductive adhesive of choice for new applications. Also available in a single component frozen syringe.

EPO-TEK® H20E Advantages & Application Notes:

- Processing info: It can be applied by many dispensing, stamping and screen printing techniques.
  - Dispensing: compatible with pressure/time delivery, auger screws, fluid jetting and G27 needles, in a single-component fashion.
  - Screen Printing: best using >200 metal mesh, with polymer squeegee blade with 80D hardness.
  - Stamping: small dots 6 mil in diameter can be realized.
- Misc / Other notes
  - Many technical papers written over 30-40 year lifetime. Contact techserv@epotek.com.
  - Over 1 trillion chips attached at a single company: no failures, Six Sigma and Certified Parts Supplier award winner.
  - Versatility in curing techniques including box oven, SMT style tunnel oven, heater gun, hot plate, IR, convection, or inductor coil.
  - Many custom modified products available, for the following improvements: viscosity and appearance, flexibility and thermal conductivity. Contact techserv@epotek.com for your best recommendation.

Typical Properties: *(To be used as a guide only, not as a specification. Data below is not guaranteed. Different batches, conditions and applications yield differing results; Cure condition: 150°C/1 hour; *denotes test on lot acceptance basis)*

Physical Properties:

***Color: Part A:** Silver **Part B:** Silver
***Consistency:** Smooth, thixotropic paste
***Viscosity (@ 100 RPM/23°C):** 2,200 – 3,200 cPs
Thixotropic Index: 4.63
***Glass Transition Temp.(Tg):** ≥ 80°C (Dynamic Cure 20—200°C /ISO 25 Min; Ramp -10—200°C @ 20°C/Min)
Coefficient of Thermal Expansion (CTE):
Below Tg: 31×10^{-6} in/in/°C
Above Tg: 158×10^{-6} in/in/°C
Shore D Hardness: 75
Lap Shear Strength @ 23°C: 1,475 psi
Die Shear Strength @ 23°C: > 5 Kg / 1,700 psi
Degradation Temp. (TGA): 425°C

Weight Loss:
@ 200°C: 0.59%
@ 250°C: 1.09%
@ 300°C: 1.67%
Operating Temp:
Continuous: -55°C to 200°C
Intermittent: -55°C to 300°C
Storage Modulus @ 23°C: 808,700 psi
Ions: Cl^- 73 ppm
Na^+ 2 ppm
NH_4^+ 98 ppm
K^+ 3 ppm
***Particle Size:** ≤ 45 Microns

Electrical Properties:

***Volume Resistivity @ 23°C:** ≤ 0.0004 Ohm-cm

Thermal Properties:

Thermal Conductivity: 2.5 W/mK
Based on standard method: Laser Flash
Thermal Conductivity: 29 W/mK
Based on Thermal Resistance Data: $R = L \times K^{-1} \times A^{-1}$

Thermal Resistance: (Junction to Case)
TO-18 package with nickel-gold metallized 20 x 20 mil chips and bonded with EPO-TEK® H20E (2 mils thick)
EPO-TEK® H20E: 6.7 to 7.0°C/W
Solder: 4.0 to 5.0°C/W

EPOXY TECHNOLOGY, INC.
14 Fortune Drive, Billerica, MA 01821-3972 **Phone**: 978.667.3805 **Fax**: 978.663.9782
www.EPOTEK.com

Epoxies and Adhesives for Demanding Applications™

Rev. XI
Feb 2010

ANNEX C: EPO-TEK TOOL TIP1: PROPER MIXING & HANDLING OF EPOXIES

www.epotek.com

Tech Tip 1

Proper Mixing & Handling of Epoxies

What > Proper Mixing
Why > Mixing and handling epoxies properly eases the application process and increases the chances of achieving a good bond.

Proper mixing and handling epoxies eases the application process and allows for the best possible performance of an adhesive.

For all filled systems, mix contents of each container (part A and part B) before being mixed together. This "premix" re-disperses any filler particles that can sometimes settle. It is also considered good practice to gently mix any one-component systems that contain fillers.

Once the products are thoroughly mixed, weigh out the appropriate amount of each into a third container using a gram scale and the recommended mix ratio found on the data sheet. A minimum of two grams of material should be used each time a product is mixed. This will ensure there is enough material for an adequate cure. Each weighing should remain within +/- 5% of the original ratio for each component. Once the components are weighed out, the product should be mixed for 1-2 minutes in a clockwise fashion and 1-2 minutes in counter-clockwise fashion. This will result in a homogeneous mixture that is ready for application.

Proper storage of the materials is also a key element to material handling. After the weighing of each component is complete, the jar threads should be wiped clean and the caps replaced. If the materials are supplied in the same type of jars, make sure not to mix the caps of the two jars. This could cause cross-contamination and may start to cure or gel any adhesive within the lid threads, causing the jar to seal shut.

Hygiene is also very important when working with epoxies. Most EPO-TEK® epoxies are 100% solids systems, so there is no vapor coming off the material. It is still recommended to work with every material in a well ventilated area or under an exhaust hood. Latex or Nitrile gloves are also required in order to reduce any dermal exposure. Gloves should be replaced often and work spaces should be kept clean of any contaminants. Be sure to wash hands thoroughly with soap and water when finished.

For any necessary clean up of spatulas or counter tops, acetone or IPA (isopropyl alcohol) can be used with a paper towel or rag. Be sure to completely remove all solvent residue in order to avoid any contamination.

EPOXY TECHNOLOGY
Innovative Epoxy Adhesive Solutions for Over 40 Years™

Epoxy Technology Inc. • 14 Fortune Drive • Billerica, MA 01821
phone 978-667-3805 fax 978-663-9782 Toll Free 800-227-2201 techserv@epotek.com

ANNEX B

EPO-TEK® H20E

Technical Data Sheet

For Reference Only

Electrically Conductive, Silver Epoxy

Number of Components:	Two	Frozen Syringe	Minimum Bond Line Cure Schedule*:	
Mix Ratio By Weight:	1:1		175°C	45 Seconds
Specific Gravity:		2.67	150°C	5 Minutes
Part A	2.03		120°C	15 Minutes
Part B	3.07		100ºC	2 Hours
Pot Life:	2.5 Days		80°C	3 Hours
Shelf Life:	One year at 23°C	One year at -40°C		

*Note: Container(s) should be kept closed when not in use. For filled systems, mix contents of each container (A & B) thoroughly before mixing the two together. *Please see Applications Note available on our website.*

Product Description:

EPO-TEK® H20E is a two component, 100% solids silver-filled epoxy system designed specifically for chip bonding in microelectronic and optoelectronic applications. It is also used extensively for thermal management applications due to its high thermal conductivity. It has proven itself to be extremely reliable over many years of service and is still the conductive adhesive of choice for new applications. Also available in a single component frozen syringe.

EPO-TEK® H20E Advantages & Application Notes:

- Processing info: It can be applied by many dispensing, stamping and screen printing techniques.
  - Dispensing: compatible with pressure/time delivery, auger screws, fluid jetting and G27 needles, in a single-component fashion.
  - Screen Printing: best using >200 metal mesh, with polymer squeegee blade with 80D hardness.
  - Stamping: small dots 6 mil in diameter can be realized.
- Misc / Other notes
  - Many technical papers written over 30-40 year lifetime. Contact techserv@epotek.com.
  - Over 1 trillion chips attached at a single company: no failures, Six Sigma and Certified Parts Supplier award winner.
  - Versatility in curing techniques including box oven, SMT style tunnel oven, heater gun, hot plate, IR, convection, or inductor coil.
  - Many custom modified products available, for the following improvements: viscosity and appearance, flexibility and thermal conductivity. Contact techserv@epotek.com for your best recommendation.

Typical Properties: ***(To be used as a guide only, not as a specification. Data below is not guaranteed. Different batches, conditions and applications yield differing results; Cure condition: 150°C/1 hour; *denotes test on lot acceptance basis)***

Physical Properties:

***Color: Part A:** Silver **Part B:** Silver
***Consistency:** Smooth, thixotropic paste
***Viscosity (@ 100 RPM/23°C):** 2,200 – 3,200 cPs
Thixotropic Index: 4.63
***Glass Transition Temp.(Tg):** ≥ 80°C (Dynamic Cure 20—200°C /ISO 25 Min; Ramp -10—200°C @ 20°C/Min)
Coefficient of Thermal Expansion (CTE):
Below Tg: 31 x 10^{-6} in/in/°C
Above Tg: 158 x 10^{-6} in/in/°C
Shore D Hardness: 75
Lap Shear Strength @ 23°C: 1,475 psi
Die Shear Strength @ 23°C: > 5 Kg / 1,700 psi
Degradation Temp. (TGA): 425°C

Weight Loss:
@ 200°C: 0.59%
@ 250°C: 1.09%
@ 300°C: 1.67%
Operating Temp:
Continuous: -55°C to 200°C
Intermittent: -55°C to 300°C
Storage Modulus @ 23°C: 808,700 psi
Ions: Cl^- 73 ppm
Na^+ 2 ppm
NH_4^+ 98 ppm
K^+ 3 ppm
***Particle Size:** ≤ 45 Microns

Electrical Properties:

***Volume Resistivity @ 23°C:** ≤ 0.0004 Ohm-cm

Thermal Properties:

Thermal Conductivity: 2.5 W/mK
Based on standard method: Laser Flash
Thermal Conductivity: 29 W/mK
Based on Thermal Resistance Data: $R = L \times K^{-1} \times A^{-1}$

Thermal Resistance: (Junction to Case)
TO-18 package with nickel-gold metallized 20 x 20 mil chips and bonded with EPO-TEK® H20E (2 mils thick)
EPO-TEK® H20E: 6.7 to 7.0°C/W
Solder: 4.0 to 5.0°C/W

EPOXY TECHNOLOGY, INC.
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www.EPOTEK.com

Rev. XI
Feb 2010

EPO-TEK® H20E Suggested Applications

- **Semiconductor IC Packaging**
  - Die-attaching chips to leadframes; compatible with Si and MEM's chips, 260ºC lead-free reflow and JEDEC Level I packaging requirements.
  - Capable of being snap cured in-line, as well as traditional box oven techniques.
  - Adhesive for solderless flip chip packaging and ultra fine pitch SMD printing.
- **Hybrid Micro-electronics**
  - A comparable alternative to solder and eutectic die attach, in terms of thermal peformance; very commonly no more than 1-2ºC/watt difference in thermal resistance.
  - Die-attaching of quartz crystal oscillators (QCO) to the Au posts of TO-can style lead-frame.
  - Used with GaAs chips for microwave/radar applications up to 77GHz.
  - SMD attach adhesive which can be cured simultaneously with die-attach processes.
    - Compatible with Au, Ag, Ag-Pd terminations of capacitors and resistor SMDs.
  - NASA approved low outgassing adhesive.
  - Adhesive for EMI and Rf shielding of Rf, microwave and IR devices.
- **Electronic & PCB Circuit Assembly**
  - Used to make electrical contacts in acoustical applications of speakers/microphones.
  - Electrical connection of piezo's to PCB. Pads of PZT are connected to many kinds of circuits using H20E, including ink jet heads, MEMs and ultrasound devices.
  - Automotive applications include pressure sensing and accelerometer circuits.
  - Electrically conductive adhesive (ECA) for connections of circuits to Cu coils in Rf antenna applications such as smart cards and RFID tags.
  - ECA for attaching SMDs to membrane switch flex circuits. Compatible with Ag-PTF and carbon graphite PCB pads. A low temperature "solder free" solution.
  - Solar-Photovoltaic industry
    - ECA for the electrical connection of transparent conductive oxide (TCO) to PCB pads.
    - Replacement of solder joints of Cu/Sn ribbon wire, from cell-to-cell; a common "solar cell stringing" adhesive.
    - Die-attach of III-V semiconductor chips to substrates used in solar concentrator technology, such as CdTe and GaAs.
    - An effective heat-sink on thermal substrates using Cu, BeO, aluminum nitride, etc.
    - Ability to be dispensed in high volumes via dots, arrays, and writing methods.
- **Medical Applications**
  - USP Class VI adhesive for circuits requiring implantation/biocompatibility.
  - Die-attaching photo diode arrays in X-ray circuits.
  - Vibration resistant adhesive for ultrasound applications < 20 MHz frequency; making the electrical connection of PZT to Au/PCB substrate.
  - Electrical connections of die, SMDs and QCO for pacemaker hybrid circuits.
  - A common ECA for hearing aid applications using hybrid, ECM or MEMs technology.
- **Opto-Electronic Packaging Applications**
  - Adhesive for fiber optic components using DIP, Butterfly or custom hybrid IC packages. As an ECA, it attaches waveguides, die bonds laser diodes and heat sinks the high power laser circuits.
  - Die-attaching IR-detector chips onto PCBs or TO-can style headers.
  - Die-attaching LED chips to substrates using single chip packages, or arrays.
    - Adhesion to Ag, Au and Cu plated leadframes and PCBs.
  - Electrical connection of ITO to PCBs found in LCD industry.
    - A low temp ECA for OLED displays and organically printable electronics.

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ANNEX C

CAU ieap Christian-Albrechts-Universität zu Kiel	**EPT-HET & STEP FM/FS Application procedure of 3M Scotch Weld 2216 B/A**	Reference: SO-EPD-KIE-PR-0027 Issue:1 Revision: 0 Date: 06/11/2015 Page: 1 of 15

SOLAR ORBITER ENERGETIC PARTICLE DETECTOR

Document ID: SO-EPD-KIE-PR-0027
Issue: 1
Revision: 0
Date: 06/11/2015

EPT-HET & STEP FM/FS Application procedure of 3M Scotch Weld 2216 B/A

Signature not needed if electronically approved by route					
Written	**Checked**	**Approved Configuration Control**	**Approved QA**	**Approved Experiment Manager**	**Approved Principal Investigator**
Violetta Knierim **Date and Signature**	**Robert Wimmer** **Date and Signature**	**César Martín** **Date and Signature**	**Date and Signature**	**Date and Signature**	**Date and Signature**

File: SO-EPD-KI-PR-0027_iss1-rev0_application_procedure_3MScotschWeld_2216BA.doc **Pages:** 15

DISTRIBUTION LIST

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CHANGES RECORD

Issue	Revision	Date	Modified by	Section / Paragraph modified	Change implemented
1	0	06/11/2015	V. Knierim	All	Initial release

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1 INTRODUCTION

1.1 Scope

This document contains the procedure for gluing with 3M Scotch Weld 2216 B/A of parts and cables during assembly of EPT-HET and STEP instruments (Figure 1.1-1).

3M Scotch-Weld Epoxy Adhesive 2216 B/A is a flexible, two-part, room temperature curing epoxy with high peel and shear strength. Scotch-Weld epoxy adhesive EC-2216 B/A has been labeled, packaged, tested and certified for aircraft and aerospace applications. [ND-03]

This gluing procedure is in accordance with [ND-03].

The gluing procedure is to be carried out only by trained specialist personnel.

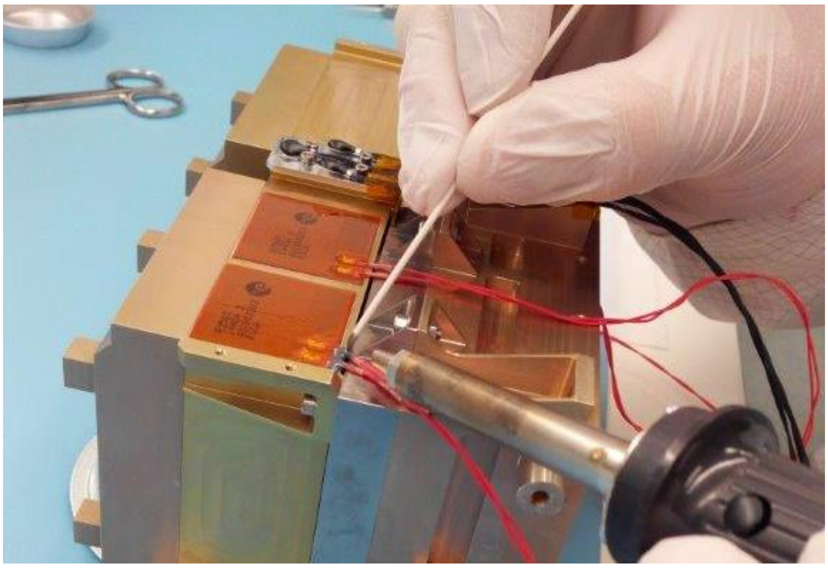

Figure. 1.1-1. Gluing with 3M Scotch Weld on EPT-HET

2 GLOSARY AND DEFINITIONS

2.1 Acronyms and Abbreviations

CAU Christian-Albrechts-Universität zu Kiel

EPD Energetic Particles Detector

FM Flight Model

FS Flight Spare

HET High Energy Telescope

PR Procedure

PQM Proto-Qualification Model

SO Solar Orbiter

3 APPLICABLE AND REFERENCE DOCUMENTS

3.1 Normative Documents

ID.	Title	Reference	Iss./Rev.	Date
ND-01	Safety instructions for IEAP CAU facilities	http://www.ieap.uni-kiel.de/sicherheit/		
ND-02	EPD Cleanliness and Contamination Control Plan	SO-EPD-PO-PL-0005	2/1	28-11-2013
ND-03	3M Scotch-Weld Epoxy adhesive 2216 B/A Technical Data	78-6900-9583-7		December, 2009
ND-04	Repair and modification of printed circuits board assemblies for space use	ECSS-Q-ST-70-28C	2/0	31-07-2008

3.2 Reference Documents

ID.	Title	Reference	Iss./Rev.	Date
RD-01	Lacing Tape (Dacron) DPTH	www.relec.de		
RD-02	High-temperature, chemical-resistant, polyvinylidene Fluoride Tubing (Kynar) RW-175-E Serie Raychem Tubing products	Te-connectivity_ rw175_kynar-heat-shrink-tubing.pdf	9-1773447-9 CIS WR	08/2011

4 REQUREMENTS

4.1 Procedure/Test facility

All gluing procedures should be carried out on an ISO Class 5 clean bench in the clean room Class 100,000 or ISO Class 8 at LS11/05a, IEAP, University of Kiel, Kiel.

4.2 Environmental requirements

- <u>Temperature:</u>

  The room temperature of the facility should be maintained at 22°C +/- 3°C

- <u>Humidity:</u>

  The rel. humidity at room temperature of facility should be maintained at 55% +/- 15%.

- <u>Cleanliness:</u>

  ISO 8

4.3 ESD Protection

ESD Control:

Take care that:

- ESD Mat is in place and grounded in the clean bench
- ESD Straps (Hand-band) are used
- Handling should be done only with gloves

4.4 Cleanliness requirements and handling of parts

- Always use conductive gloves and face mask.
- The whole test should be performed in the cleanroom.
- All equipment has to be cleaned with ethanol or isopropanol before use (except detector and source surfaces).

- The cleanroom and contamination levels must meet the specifications in SO-EPD-PO-PL-0005.
- This test involves many and very sensitive steps. Hence**, "this test is to be performed only by qualified personnel".**

4.5 Participants

The participants and their responsibilities are defined in table 4.5-1.

Table 4.5-1: Participants and their responsibilities.

CAU		
#	**Name**	**Responsibility**
1	Robert Wimmer (Principal Investigator)	Final Approval
2	Michael Richards (Product Assurance)	QA Approval
3	Walter Boogaerts (Product Assurance)	PA/QA Approval, Support
3	César Martín (Project Manager)	Final release
4	Solar Orbiter Team of CAU[1]	Execution; assistant

4.6 Storage of 3M Scotch-Weld 2216 B/A

Store 3M Scotch-Weld 2216 B/A at 16-27°C for maximum storage life. [ND-03]

[1] Only personnel who have been involved in assembling the instruments EPT HET and STEP.

5 PROCEDURE

See Equipment Checklist in APPENDIX for preparation and application of the glue.

5.1 Surface preparation

For high strength structural bonds, paint, oxide films, oil, dust, mold release agents and all other surface contaminants must be completely removed.

1 Clean the surface, if it possible, with wipe with Isopropanol.

2 If a primer is used, it should be applied within 4 hours after surface preparation.

Scotch Weld does not stick onto the Teflon insulation. It is important to know, which the insulation the cables or areas has (Thermistors and coax cables have Teflon insulation). For the gluing of Teflon insulation there are two possibilities:

A) Lacing Tape (Dacron) [RD-01] or

B) Shrink tubing (Kyanar) [RD-02]. Sticking only one end of shrink tubing, because of vacuum!

5.2 Glue mixing

Glue: Scotch-Weld B/A 2216, two component glue (Figure 5.2-1):

- B: Base (white color)
- A: Accelerator (gray color)

Mix Ratio: (by weight):

B: 5 parts or 100

A: 7 parts or 140

For example: 6 Gramm glue= B (2,5 g)+ A (3,5 g)

A = B (grams) * 7/5
B = A (grams) * 5/7

Work Life:

100 g Mass @ 24°C→ 90 minutes.

Figure. 5.2-1: Pots with part A and part B of 3M Scotch-Weld

5.3 Glue preparation

The following step by step description of the mixing the Scotch-Weld (Figure 5.2-2):

1 Place aluminum bowl on the scales and turn the scales on. (Figure 5.2-3)

2 Dip the clean glass rod into the pot with Scotch-Weld component **B** (white).

3 Put 5 parts of component **B** (e.g. 2.5 grams) in aluminum bowl. Put this component on one half of the aluminum bowl surface (Figure 5.2-4).

4 Clean the glass rod with a wipe and Isopropanol.

5 Dip the clean glass rod into the pot with Scotch-Weld component **A** (gray).

6 Put 7 parts of component **A** (e.g. 3.5 grams) possible on the other area of aluminum bowl. So you can better remove of too much of somponent **A** (Figure 5.2-5).

7 Clean the glass rod with a wipe and Isopropanol.

8 Take the aluminum bowls with two components of Scotch Weld and mix it thoroughly with a glass rod. Mix ca. 2-3 Minutes after a uniform color is obtained. (Figure 5.2-6).

9 To remove bubbles in the glue, blow hot air (with small hot air gun) directly on the bubbles during the mixing process. Especially big internal bubbles can affect the strength. Parameter for the hot air: 100°C at full air flow (Figure 5.2-7).

10 Clean the glass rod with a wipe and Isopropanol.

11 Change the gloves after the mixing procedure.

Figure. 5.2-2: Preparation of Glue

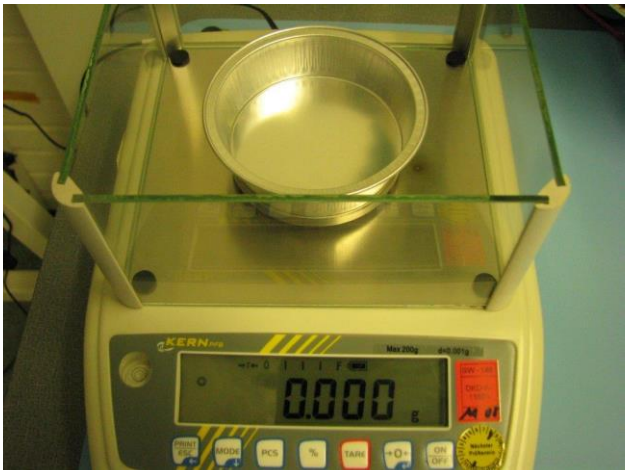

Figure. 5.2-3: Aluminum bowl on scale

Figure. 5.2-4: Component B (white)

Figure: 5.2-5. Component B and A (gray)

Figure. 5.2-6: Mixing with glass rod

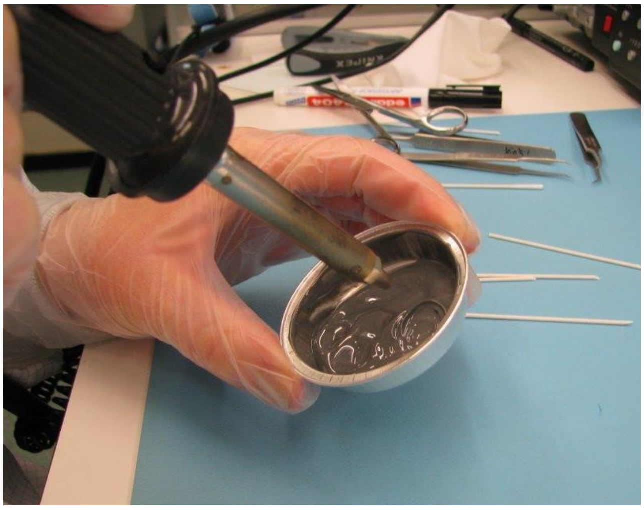

Figure: 5.2-7. Hot air gun for removing the bubbles

5.4 Application/ Handling

1 Prepare the gluing area. Use Teflon mate or wipes, so that the adhesive does not spills everywhere. Put the aluminum bowls onto the wipe (Figure 5.3-1)

2 Prepare the application tool. Use plastic or other cleanroom swabs for applying the glue (Figure 5.3-2).

3 If necessary, mask the area near the glue spots with Kapton tape, which get no contact with the glue.

4 For maximum bond strength, apply product evenly to both surfaces to be joined.

5 For removing the stringy during applying the Scotch-Weld, use hot air gun with parameter 100°C /20% air flow (Figure 5.3-3).

6 Keep parts from moving until handling strength is reached. Use Kapton tape for fixing the parts and pressure (Figure 5.3-4).

Note for gluing of the cables: Glue the cable along its length at intervals of not more than 3 cm, if it is longer than 3 cm. Make the first spot glue just after the wire stress relief. The first glue spot after the soldering is to be max. 15mm [ND-04].

Figure. 5.3-1. Gluing area

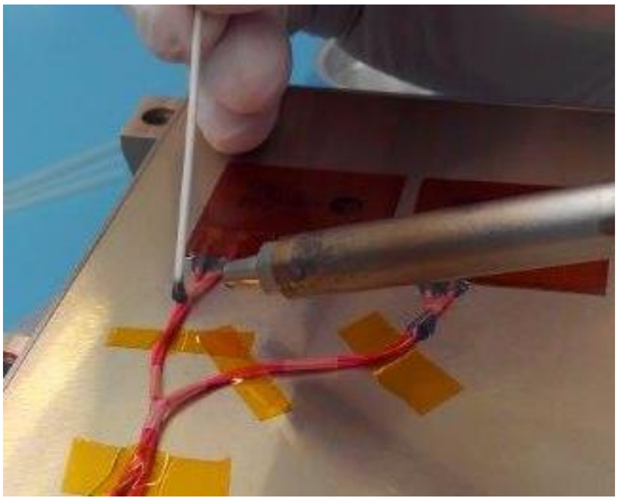

Figure. 5.3-2. Application with swabs

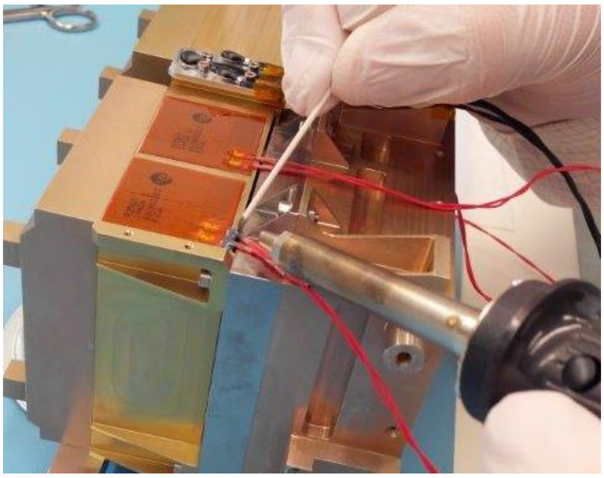

Figure. 5.3-3. Hot air gun during applying

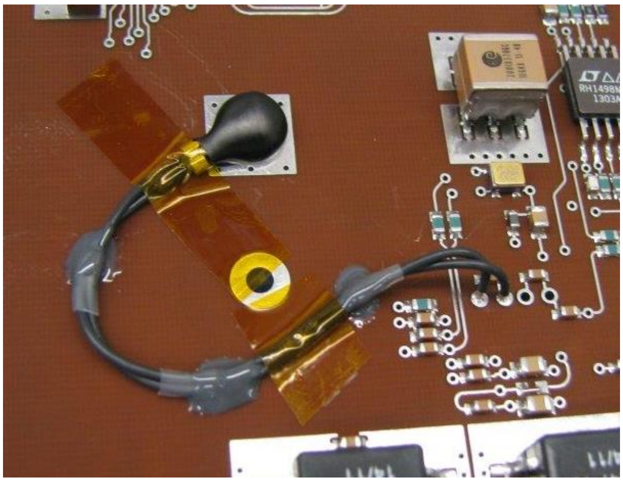

Figure. 5.3-4. Kapton Tape for fixing the glue spots

5.5 Curing

Keep parts from moving until handling strength is reached. Time to Handling strength is 8-12 hrs. [ND-03].

Allow to cure at 16°C or above. Heat, up to 93°C, will speed curing.

The following times and temperatures will result in a full cure (see Tab.5.5-1) [ND-03]:

Cure Temperature	Time
24°C	7 days
66°C	120 minutes
93°C	30 minutes

Table 5.5-1: Full cure time

5.6 Inspection and Documentation

After the gluing inscribe the information about the gluing mix ratio, date and what was gluing on aluminum bowls (Figure 5.5-1).

After the curing, remove the Kapton tape and inspect the glue and glue spots by visual inspection.

The final work should be photographed.

Figure. 5.5-1. Labeling the aluminum bowls with glue.

APPENDIX

Equipment Checklist

Workstation:		
	Clean bench ISO class 5	
	Instrumentation for monitoring temperature, humidity, pressure	
	Photo camera	
Cleaningmaterial:		
	Isopropanol	
	Gloves clean class 100 powder free	
	Alpa wipe (Dastex)	
	Swabs (Dastex)	
	Lint-free class 100 cleanroom wiper	
Preparation tools		
	Aluminium bowls	
	Scale (KERN PFB)	
	Glass rod	
	Kapton tape 3 M, silicon free	
	Shears	
	Scalpels	
	Tweezers	
Application tool		
	Stirring tool (Plastic swabs)	
	Hot air gun (Weller WR3M)	

ANNEX D

3M

Scotch-Weld® 2216 B/A

Zweikomponenten-Konstruktionsklebstoff

Produkt-Information 12/2001

Beschreibung

Scotch-Weld 2216 B/A ist ein flexibler Zweikomponenten-Konstruktionsklebstoff, der bei Raumtemperatur härtet und für das Kleben von Metallen, Keramik, Holz, einer Vielzahl von Kunstoffen wie GFK, Polyester, Fluorkautschuk und anderen Werkstoffen entwickelt wurde.

Gute Scherfestigkeit, besonders hoher Schälwiderstand, Flexibilität und Schlagfestigkeit sowie ein Temperatureinsatzbereich von –55°C bis +80°C zeichnen das Produkt aus.
Zur Verkürzung der Härtezeit ist eine Warmhärtung möglich.

Physikalische Daten

	Basis	Härter
Farbe	weiß	grau
Basis	mod. Expoxidharz	mod. Polyamid
Konsistenz	pastös	pastös
Viskosität bei 26°C*	75.000 – 150.000 mPa.s	40.000 – 80.000 mPa.s
Spez. Gewicht**	1,3 g/cm^3	1,25 g/cm^3
Festkörper**	100 %	
Mischungsverhältnis nach Volumen	2:3	
Mischungsverhältnis nach Gewicht	5:7	

* Brookfield RVF. Spindel 7,20 Upm. ** Durchschnittswerte

Verarbeitungs-merkmale

Methode	Fließen, Spachteln
Verarbeitungszeit	ca. 90 Minuten*
Weiterverarbeitung	6 - 8 Stunden
Härtung	7 Tage bei 23°C 2 Std. bei 65°C
Fixierdruck	2 – 7 N/cm^2

* für 100 g Mischung

Produkt-merkmale

Temperatureinsatzbereich	-55 bis +80°C
Wasserbeständigkeit	gut
Witterungsbeständigkeit	gut
Alterungseigenschaften	gut
Flexibilität	gut

Festigkeitswerte

Die Festigkeitswerte stellen Durchschnittswerte auf geätztem Aluminium und anderen Werkstoffen gemäß der Norm dar.

Schälwiderstand nach DIN 53283

Testtemperatur	Schälwiderstand
-55°C	3,6 N/cm
+24°C	45,4 N/cm
+80°C	3,6 N/cm

Werkstoff: Aluminium, geätzt
Härtung: 2 Std. bei 65°C

Zugscherfestigkeit (DIN 53283) in Abhängigkeit von Temperatur und Härtezyklus

Testtemperatur	Härtung		
	2 Tage / RT	7 Tage / RT	2 Std. / 65°C
-55°C	12 MPa	14 MPa	14 MPa
+24°C	16 MPa	17 MPa	21 MPa
+80°C	2 MPa	2 MPa	3 MPa

Werkstoff: Aluminium, geätzt

Alterungswerte

Zugscherfestigkeitswerte auf gepickelten Aluminium-Prüflingen nach entsprechender Alterung.

Zeit	Einlagerung	Zugscherfestigkeit bei 24°C
14 Tage	100 % Feuchte bei 50°C	20,6 MPa
30 Tage	100 % Feuchte bei 50°C	14,1 MPa
90 Tage	100 % Feuchte bei 50°C	10,5 MPa
14 Tage	Salzsprühtest bei 35°C	16,2 MPa
14 Tage	Leitungswasser bei 23°C	20,6 MPa
30 Tage	Leitungswasser bei 23°C	17,6 MPa
90 Tage	Leitungswasser bei 23°C	14,6 MPa
35 Tage	Trockene Wärme bei 70°C	32,0 MPa
40 Tage	Trockene Wärme bei 150°C	34,5 MPa
7 Tage	Entleisungsflüssigkeit bei 23°C	23,2 MPa
7 Tage	Hydraulikör bei 23°C	26,0 MPa
7 Tage	Düsentreibstoff bei 23°C	22,5 MPa
7 Tage	Kohlenwasserstoff bei 23°C	23,2 MPa

Alle Festigkeitsprüfungen wurden nach 7 Tagen Härtung bei 25°C und einem Druck von 2 N/cm^2 durchgeführt

Oberflächen-Vorbehandlung

Die Oberflächen müssen trocken und frei von Staub, Öl, Trennmitteln und anderen Verunreinigungen sein. Die Art der Oberflächenvorbehandlung hängt von dem jeweiligen Anforderungsprofil (Festigkeit, Alterung etc.) ab.

Für die meisten Anwendungen reichen normalerweise Vorbehandlungen aus, die auf Metallen einen geschlossenen Wasserfilm an der Oberfläche ergeben.

Sowohl für metallische als auch nichtmetallische Werkstoffe wird eine mechanische Oberflächenvorbehandlung mit Scotch Brite 7447 empfohlen, die von einem Vor- und Nachreinigen mit werkstoffverträglichen Lösemitteln unterstützt wird.

Anwendung

Die günstigste Verarbeitungstemperatur für Konstruktionsklebstoff und Werkstoff liegt zwischen 20°C und 25°C.

Mischen

Die beiden Komponenten werden im angegebenen Mischungsverhält-nis zu einer schlierenfreien homogenen Masse manuell oder maschinell gemischt. Für ca. 100 g Mischung beträgt die Verarbeitungszeit ca. 90 Minuten, bei größeren Ansätzen verkürzt sich die Verarbeitungszeit entsprechend.

Auftrag

Mit geeigneten Verarbeitungsgeräten wie Spachtel, Fließpistole, etc. wird der Klebstoff auf beide zu klebende Werkstoffe gleichmäßig aufgetragen. Optimale Festigkeiten werden bei Klebstoffschichtdicken von 0,05-0,15 mm erzielt.
Eine einheitliche Klebstoffschichtdicke kann durch Einlegen von entsprechenden Abstandhaltern, wie z. B. Glasfasern, sichergestellt werden. Die Teile werden zusammengefügt und durch Klammern, Vorrichtungen, Druck etc. gegen Verrutschen während der Härtung fixiert.

Härtung

Die Härtung der Klebstoffe erfolgt bei Raumtemperatur, kann jedoch durch Wärme beschleunigt werden. Die Festigkeitszunahme bei einigen Klebstoffen ist so zügig, dass die Teile nach 6 – 8 Stunden weiter-verarbeitet werden können.

Die Endfestigkeit ist nach ca. 7 Tagen bei RT erreicht.

Reinigung

Rückstände von nicht gehärtetem Klebstoff und Verarbeitungsgeräten können mit einem Lösungsmittel wie Methylethylketon entfernt bzw. gereinigt werden. Bei Gebrauch des Lösemittels sind die notwendigen Sicherheitsvorschriften zu beachten. Gehärteter Klebstoff kann nur mechanisch entfernt werden.

Lagerung und Handhabung

Die beste Lagerfähigkeit hat der Klebstoff bei Temperaturen zwischen 15°C und 25°C. Höhere Temperaturen verkürzen die normale Lager-fähigkeit. Niedrigere Temperaturen verursachen vorübergehend eine höhere Viskosität.

Umfasst das Lager Gebinde aus mehreren Lieferungen, so sollten diese in der Reihenfolge ihres Einganges verarbeitet werden.

Sicherheitshinweise

Gefahrenklasse nach VbF	Flammpunkt	Lagerfähigkeit*
-	Teil B: - Teil A: -	24 Monate bei 20±5°C

* ab Versanddatum Werk/Lager

Gefahrenhinweise für Teil B

R 36/38: Reizt die Augen und die Haut.
R 43: Sensibilisierung durch Hautkontakt möglich.

Sicherheitsratschläge für Teil B	S 24/25:	Berührung mit den Augen und der Haut vermeiden.
	S 37/39:	Bei der Arbeit geeignete Schutzhandschuhe, Schutzbrille und Gesichtsschutz tragen.
	S 2020:	Bei Berührung mit Haut sofort mit Wasser und Seife waschen.
	S 26:	Bei Berührung mit den Augen sofort gründlich mit Wasser abspülen und Arzt konsultieren.
	S 2015:	Beschmutzte Kleidung sofort reinigen, ungereinigte Kleidung nicht benutzen.
	S 2055:	Enthält epoxidhaltige Verbindungen. Hinweise des Herstellers beachten.

Gefahrenhinweise für Teil A	R 41:	Gefahr ernsthafter Augenschäden.
	R 1002:	Kann die Haut reizen.

Sicherheitsratschläge für Teil A	S 25:	Berührung mit den Augen vermeiden.
	S 2003:	Längeren oder wiederholten Kontakt mit der Haut vermeiden.
	S 37/39:	Bei der Arbeit geeignete Schutzhandschue, Schutzbrille und Gesichtsschutz tragen.
	S 26:	Bei Berührung mit den Augen sofort gründlich mit Wasser abspülen und Arzt konsultieren.
	S 2020:	Bei Berührung mit Haut sofort mit Wasser und Seife waschen.
	S 2015:	Beschmutzte Kleidung sofort reinigen, ungereinigte Kleidung nicht benutzen.

Notizen:

3M

3M Deutschland GmbH
Industrie-Klebebänder, Klebstoffe und Spezialprodukte

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Telefon 0 21 31 / 14 33 30, Telefax 0 21 31 / 14 38 17

Gedruckt auf chlorfrei gebleichtem Papier

ANNEX E

Kiel, 06.02.2015

MLI stand offs reference for EPT-HET PQM

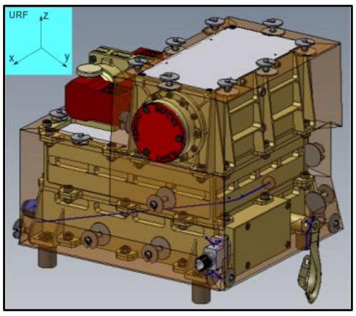
Reference: **“KI001-F-00100_20150120.stp”**

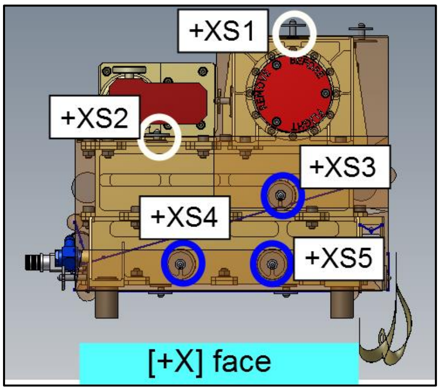
Ali Ravanbakhsh, IEAP, Uni-Kiel , ravanbakhsh@physik.uni-kiel.de, (+)49 431 880 2491.
Lars Seimetz, IEAP, Uni-Kiel , seimetz@physik.uni-kiel.de, (+)49 431 880 3225.

○ (Standoff + bracket) mounted on the EPT-HET

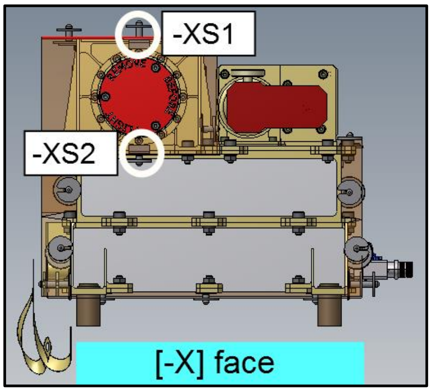
○ Only standoff mounted on the EPT-HET

+XS1	MLI standoff No.1 associated with [+X] face
-XS1	MLI standoff No.1 associated with [-X] face
+YS1	MLI standoff No.1 associated with [+Y] face
-YS1	MLI standoff No.1 associated with [-Y] face
-ZS1	MLI standoff No.1 associated with [-Z] face

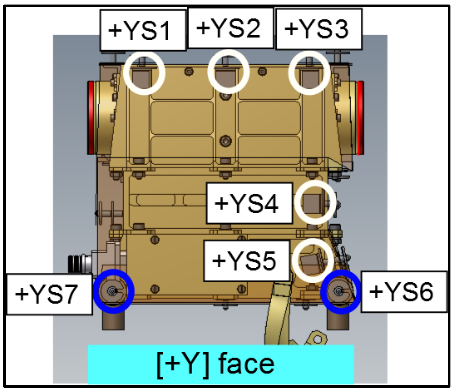




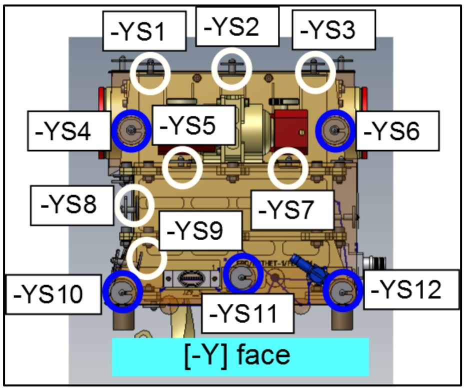
[+X] face



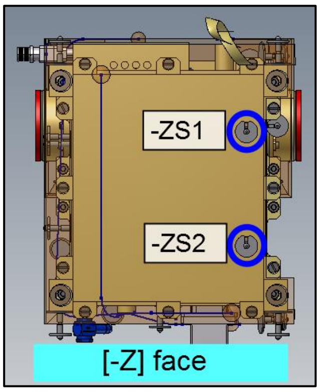
[-X] face



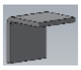
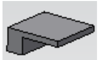
[+Y] face



[-Y] face



[-Z] face

Total No. of stand offs = 28	
Long = 10	
Medium = 12	
Short = 6	
Total No. of brackets = 16	
Normal = 13	
Small = 3	

[+X] face	**+XS1**		
	+XS2		
	+XS3		NA
	+XS4		NA
	+XS5		NA
[-X] face	**-XS1**		
	-XS2		
[+Y] face	**+YS1**		
	+YS2		
	+YS3		
	+YS4		
	+YS5		
	+YS6		NA
	+YS7		NA
[-Y] face	**-YS1**		
	-YS2		
	-YS3		
	-YS4		NA
	-YS5		
	-YS6		NA
	-YS7		
	-YS8		
	-YS9		
	-YS10		NA
	-YS11		NA
	-YS12		NA
[-Z] face	**-ZS1**		NA
	-ZS2		NA

ANNEX F

Hi Francesca,

please find below missing or detailing informations regarding your comments about our RFA.

Best regards,
Lars.

To: Ken Hernan/estec/ESA@ESA
From: Francesca Muratore/estec/ESA
Date: 05/15/2017 03:27PM
Cc: Andrew Norman/estec/ESA@ESA, Kristin Wirth/estec/ESA@ESA
Subject: Re: Fw: RfA and actions from MPCB4 for EPD/Kiel

Hello Ken,

I have prepared a Memo on the RFAs for non-metallic materials & processes and this morning I had a look at this RFA (which was the only one missing in my list).

This EPD RFA covers three glueing processes: one is on EPO-TEK H20E used for bonding the STE baffles to the collimator housing, one is for bonding the MLI standoffs with Scotchweld EC2216 and the other one swagelok tube stiffner and pall filter bonding with Scotchweld EC2216. Please find below my comments.

This seems to be a typo, because the tube stiffener and the filter are glued using H20E, as correctly described in the RFA.

As a summary, for all the processes, there are no tests performed at samples level and bonding procedures are attached in the RFA. For all the adhesives there is a calculation of the MoS. However, can the lap shear strength (from the material datasheet) be used in the formula to evaluate the MoS? This value should be fine for polished stainless steel substrates (and I would say for "easy" - in terms of surface finishing - metallic substrates), but could not be correct / representative for non-metallic materials / MLI.

The generic equation for determining a margin of safety has been taken from the "Threaded Fastener Handbook, ECSS-E-HB-32-23A, 16 April 2010, chapter 5.3.2". In this formula generic loads are compared. It is our understanding that as long as the same general load types (e.g. shear compared with shear, more specifically for our case: shear load induced from structural loading the parts vs. the lap shear strength) the given relationship is applicable.
Furthermore it is assumed that the relationship is valid for linear material behaviour. Since the resulting loads are small due the low masses of the components it is also valid to assume the applicability for metallic and also non-metallic material of this equation.

Moreover, for the MoS evaluation, it is not clear where the worst case loads come from (e.g. mechanical analysis?).

For optaining worst case loads, the maximum analytically obtained QSL-loads from "STEP notching / SO-EPD-KIE-RD-0017, Iss.1, Rev.2" regarding the specific axis have been applied. In the scope of this RFA, the security factor of 2 is multiplied.

For the EPO-TEK H20E, a bonding procedure has been prepared ad hoc to cover the process with several bonding dots; no tests have been performed

A destructive lab test has been performed and is described in the RFA. It's intention was to test the bonding quality (adhesive or cohesive failure) and the maximum load level necessary to break the first bonding point. A MoS has been calculated using the measured values between the above the analytically obtained worst case load (see above) and the measured load. The presented MoS against tensile failure of the bond joint is app. 128.

but the vibration and thermal vacuum tests passed (I assume by visual inspection).

Correct. A visual inspection has been performed after each test.

For this process I have a concern on the application of the adhesive on the Acktar coating (which is not the best option) and I would like to have confirmation on the foreseen temperature range, especially on the minimum temperature.

Prior to glue on the vacuum black surface the supplier of the material has been contacted. We have been told that the adhesion vacuum black can be considered strong enough to act as an bonding agent for following processes. For your information please find attached two papers provided by the manufacturer which describe bonding on the vacuum black coating on Al-6061 as applicable:

- *16-paperISMSE 2009.pdf*
- *acktar_test_fractal_bonding.pdf*

The predicted temperatures (including +/- 10 degC of margin) for STEP baffles during the mission range from -65 to +65 degC according to the latest Thermal Analysis Report *"SO-EPD-KIE-RP-0031-iss4_rev0_STEP-Thermal Analysis Report.pdf"*.

As referenced in the RFA joint underwent 9 full cycles at qual temp range (PQM themal cycling test), and 5 cycles at acceptance temperature range (PFM thermal cycling test). The tests have been passed without anomalies.

For the standoffs bonding, the procedure for the Scotchweld application looks fine, but it is a quite general procedure (standoffs are not even mentioned). Could EPD confirm the temperature foreseen for curing the adhesive for this application?

The curing schedule is fully compliant with the manufacturer's material information: 7 days at 21°C to obtain full cure.

Moreover, the vibration test was carried out with no MLI and there is no evidence that the standoffs will pass the qualification once loaded (as mentioned before the MoS calculation does not really convince me in this case). What is the operative temperature range foreseen in-flight?

The calculated margin of safety (app. 748) is seen as applicable evidence that the bonding joints will tolerate the induced loads.

The predicted temperatures (including +/- 10 degC of margin) for STEP MLI standoffs during the mission range from -65 to +60 degC according to the latest Thermal Analysis Report *"SO-EPD-KIE-RP-0031-iss4_rev0_STEP-Thermal Analysis Report.pdf"*.

The predicted temperatures (including +/- 10 degC of margin) for EPT-HET MLI standoffs during the mission range from -47 to +54 degC according to the latest Thermal Analysis Report *"SO-EPD-KIE-RP-0030-iss3_rev0_EPT-HET-Thermal Analysis Report.pdf"*.

For the stiffener / filter bonding, what are the bonded interfaces?

Although the RFA states the specific DMPL entry, please find the material properties hereunder:

Swagelok tube stiffener (DMPL 56.1.1): Material: Stainless steel 1.4401, surface preparation: sand paper abrasion, IPA wipe.
Pall filter: Stainless steel AISI 304L (1.4306), surface preparation: ultrasonic cleaning in IPA solution.

The same glueing procedure for applying H20E as cited in part I has been used to glue and cure the filter in the stiffener.

What is the minimum temperature expected in-flight?

The filter sits at the end of purging tube which again is located inside the S/C panel-attached purge interface. Looking at the current S/C cad-model it appears, that all purging related armatures are covered with MLI, including the mentioned S/C purging interface. If this assumption is correct, the temperature of the filter will follow the temperature of the purging interface with a certain delta, but most probably quite close. Consequently the minimum in-flight panel temperature of the MY (EPTHET1 and SEP) and PY/ PZ panel (EPTHET2) in close proximity of the specific instrument's location should be adequate to be assumed here.

For reference, the expected temperature range is from -40 degC to +50 degC (EID-A, SOL-EST-RCD-0050, issue 5 revision 0 – 16 Mar 2015) at the unit conductive interface with the S/C. We expect the purge line to follow this temperature very closely if it is beneath the S/C MLI.

In this case the MoS has not been calculated and no ad hoc bonding procedure has been prepared.

That is correct. As mentioned above the procedure cited under part I of the RFA has been used to glue the stiffener and the filter. It has been stated in the RFA that the masses and the relevant mechanical loads are comparable and consequently a comparably high MoS in this joint is expected compared to the baffles' interface as presented in part I. However, the relevant missing MoS is presented hereunder:

MoS = (Allowed Load / (Limit Load * sf)) -1, sf=2

Allowed Load = sig_lap_H20E = 1475 psi = 10.17 N/mm**2 (according to the datasheet presented in the RFA).

For calculating the limit load the QSL of the relevant location at the purging interface on the above mentioned S/C panel need to be used, but are unknown.
In order to become able to compare the MoS of both interfaces and because this joint is considered non-strucural the vague assumption is made here that the loads at the S/C panel in close proximity of the instruments are comparable or less compared to the loads at the instruments' locations. Following this approach the worst case QSL (X-axis of the STEP instrument, according to STEP notching / SO-EPD-KIE-RD-0017, Iss.1, Rev.2) of QSL_STEP_X=63,45 is assumed to conduct the calculation of the limit load.

Limit load: shear force induced to the glueing interface between the filter and the stiffener: sig_shear_gjoint.

Limit Load = sig_shear_gjoint = F_shear/ A_gjoint = m_filter * g * QSL_STEP_X / A_gjoint

using m_filter=0,37e-3kg, g = 9,81m/s**2 and the area of the gluing joint considered to be a ring shaped area with an outer diameter dA=5,2mm and and inner diameter of dI=2,3mm. This leads to a relevant glueing area of A_gjoint = pi * ((5,2-2,3)/2)**2 = 6,61 mm**2.

sig_shear_gjoint = 0.23 N/ 6,61 mm**2 = 0.03 N/mm**2

MoS = (10,17 N/mm**2 / (0,03 N/mm**2 * 2)) - 1 = 168.5

The margin of safety against shear failure of the filter interface (part 3 of the RFA) is significantly positive and it is concluded that the glueing joint is applicable given the to be expected mechanical loads.

-

Best Regards,
Francesca.

Annex A

QUALIFICATION OF ACKTAR™ BLACK COATINGS FOR SPACE APPLICATION.

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1. ABSTRACT

Acktar™ black coatings are among the blackest coating known. The very low reflectivity of the Acktar coatings makes them attractive for use in optical systems and particularly in space optics. An extensive program of testing was performed in order to qualify the Acktar coatings for use in space applications. The total integrated reflectivity of the Acktar™ Vacuum black and Magic black coatings were lower than 3 % at 250-2000nm

Outgassing tests consistently show very low values of CVCM. Elevated values of TML and WVR observed are attributed to water vapor captured as a result of the porosive morphology of the coating. An extended WVR test carried out indicates that approximately 96 hours are required for the surface to reach saturation. QCM and RGA tests further confirm that only water vapor is released (as opposed to organic/other contaminations that are released from paints) when the coating is exposed to vacuum. The overall outgassing is lower than that for paints as a result of the much smaller actual mass of the Acktar coatings (several micrometers thick) compared to paints (30-100 micrometers thick).

Exposure to Atomic Oxygen does not alter the reflectivity of the coating or its adhesion to the substrate. In the framework of end-of-life tests small numbers of microcracks were detected.

The adhesion of the Acktar coatings to a wide range of substrates is excellent and adhesive bonding can be performed directly on the coating.

2. INTRODUCTION

Acktars™ inorganic coatings are fabricated using Acktar™ proprietary vacuum deposition technology. A very high specific surface area coating is created with a tightly controlled morphology to produce a very low reflectance level. The coating thickness is a few micrometers (typically 3-5 µm) and its density is typically ~1.8 g/cm^3. The deposition process is carried out at wide range of temperatures depending on the substrate. By controlling the composition and morphology of the layer microstructure it can be tailored to achieve desired levels of absorption or reflectance over a wide range of wavelengths.

The coating performance is stable in a wide range of temperatures. The emissivity and absorptivity of fractal black was studied at temperatures in the range of 10 K to 300 K and was found to be very attractive [1]. Under separate study performance after exposure to 270^{0}C for 72 hours was evaluated. Adhesion and optical properties were found unchanged. In addition, coating withstood up to 1500 cycled of 77K-room temperature, and was found to be stable [2].

Vacuum Black coating was found to be compatible with class 1 clean-rooms due to no particulation [3].

Acktar™ offers several types of coating including, among others, Fractal Black, Magic Black, and Vacuum Black. Vacuum Black – which has the smallest coating thickness of the three, was thoroughly tested at ElOp and Soreq NRC in order to qualify its usage for space applications.

3. EXPERIMENTAL

3.1 Test Samples

Metal test samples were coated with Acktar™ Vacuum Black, Magic Black and Fractal Black coatings. The samples were made from 5 main types: Clear anodized Al 6061, sand-blasted Al 6061, sand blasted Ti-CP3, Ti-6Al-4V, and Ti-6Al-4V with Tiodize type II.

For outgassing tests a 12 µm thick aluminum foil, coated on both sides with Acktar™ Vacuum Black, was used.

3.2 Optical characterization

The optical reflectance of the coating was measured in the visible and NIR range (250-2000nm) using a

spectrophotometer with an integration sphere configuration (Jasco 570V). The total reflectance (diffusive and spectral) was measured. The system was calibrated using a white reference.
The samples were visually examined using a Leica MZ16 optical microscope at low magnifications (x7).
SEM micrographs were obtained using a Quanta 200 FEI microscope in Low Vacuum mode, which enables measurements without the need of a thin conducting overlaying film.

3.3 Outgassing tests

The tests were carried out in accordance with ASTM E-595 [4]. The tests were performed on 12 µm thick aluminum foil, coated on both sides with Acktar™ Vacuum Black. WVR values were determined after the standard 24 h and after 96 and 144 hrs.
The outgassing criteria for space qualification are as follows: Total mass loss (TML) $\leq$ 1%, Collected volatile condensable material (CVCM) $\leq$ 0.1%, Retrievable mass loss (RML) $\leq$ 1% (calculated as RML=TML-WVR). Water vapor regain (WVR) is measured as an indication of water adsorption for use in calculating the RML value.

3.4 Outgassing kinetics – QCM studies

To measure the kinetic parameters of the outgassing process, the outgassing system was modified by replacing one of the collectors with a gold-coated 15 MHz QCM crystal with a sensitivity of 6.21×10^{-10} g/Hz (QCM Research, Model MK10). The experimental method is described in mode details elsewhere [5]. The following experimental procedure was applied: (1) a stepwise increase of the sample temperature from 25ºC to 125ºC, keeping the QCM at a constant temperature of 5ºC; (2) cooling the sample to room temperature while still maintaining the QCM temperature at 5ºC, so that re-evaporation kinetics of the contaminants is monitored (QCM at 5ºC); (3) increasing the QCM temperature stepwise to 15-25ºC to study the effect of the temperature on the re-evaporation kinetics of contaminants. The maximum pressure inside the vacuum chamber was always below 5×10^{-6} Torr.

3.5 RGA measurements: Volatile products:

Residual Gas Analysis (RGA) measurements were carried out in a UHV system using a Balzers QME 200 instrument. The sample (Vacuum Black coating) was maintained at a temperature of 175°C and the base pressure of the system at room temperature is $5\text{x}10^{-9}$ Torr.

3.6 Atomic Oxygen testing

Exposure to thermal atomic oxygen (AO) was done in an RF plasma system (Litmas Model LB1200) equipped with an automatic matching unit and a power of 450 W [6]. The operating pressure was 100 mTorr. The low earth orbit (LEO) equivalent atomic oxygen fluence was calculated based on the mass loss of a 125 µm thick Kapton HN polyimide reference sample. The erosion rate of Kapton was assumed to be equal to 3×10^{-24} cm^3/atom and independent of the AO fluence. The average AO flux in the downstream position, ~120 mm from the RF plasma reactor edge, was estimated to be equal to 1×10^{15} atoms/cm^2sec. Using this system, AO fluences of up to 3×10^{20} atoms/cm^2 were obtained.
The 5 eV AO exposure was carried out using a laser detonation source at Montana State University. Under the operational conditions, a 5 eV AO flux of 3×10^{15} atoms/cm^2sec was obtained [7]. The total AO fluence was 2×10^{20} atoms/cm^2. The atomic oxygen fluence was calculated based on the surface recession of Kapton as measured by step-height analysis using a Dektek 3 profilometer.

3.7 Adhesion tests

The adhesion test was performed in accordance with ASTM D 3359-97 [8], method B using two standard 3M tapes: Scotch tape #250 (rubber adhesive) / 3M Kapton tape #92 (silicone adhesive). The test is performed by scratching a net structure on the surface of the coating, applying a tape and attempting to lift the coating from the scratched area by lifting the tape. The adhesion quality is defined and graded (0B-poor up to 5B excellent) according to the number of squares or partial squares that are lifted from the coating.

3.8 Thermal cycling

The Vacuum Black coated samples were cycled 97 times through temperatures of: -40°C to 100°C in a nitrogen environment. The heating and cooling rates were ~10°C/min and the samples were held for 30 minutes at the high and low temperature ends. The samples were tested for adhesion after thermal cycling using the adhesion testing method described above. After the thermal cycling the samples were analyzed using an optical microscope.

3.9 Bonding tests

Bonding onto Acktar coatings was tested in accordance with ASTM D 1002 [9]. The substrate was Ti-6Al-4V and the adhesive was epoxy. Testing was done on a tensile testing machine (Instron model 4467), equipped with a load cell of 3 ton.

4. RESULTS AND DISCUSSION

4.1 Reflectivity

The total (diffusive and specular) reflectivity of two types of Acktar coatings over the wavelength range is shown in Fig. 1. The reflectivity of both Magic Black and Vacuum Black is below 3% in the visible range (400-700nm).

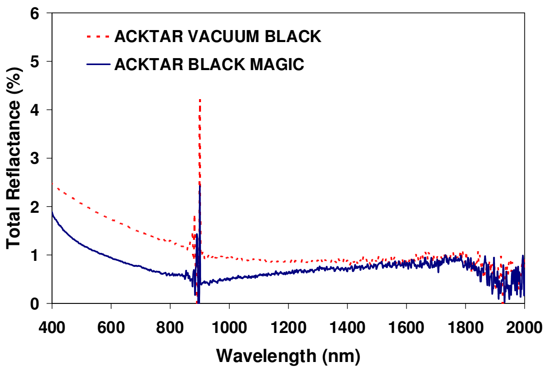


Fig. 1. The total reflectance of Vacuum Black and Magic Black coatings as a function of wavelengths.

These reflectivity values are highly competitive with typical reflectivity values of black paints qualified for space applications in a similar range of wavelengths.

4.2 Outgassing Test Results

Measurements of the standard outgassing parameters are summarized in Table 1. The TML values exceed the requirements of ASTM E 595 (<1.0%). The high values of WVR indicate that the main outgassing product is water vapor. This is supported by WVR measurements made as a function of time (after 24h, according to the standard and after 96h and 144h). The data (shown in Table 2) indicate that the WVR value increases with time (while RML decreases), most likely due to absorption of water by the porous structure.
The overall outgassing per unit of coated area is equivalent to or lower than that of alternative options such as paints, which are usually much thicker (30-100 µm).
Additional experimental support for the water vapor explanation is provided by the significant difference between the TML and WVR values for test #2 as compared with those for test # 1 , 3 and 4. This difference is attributed to the fact that, unlike the others, sample #2 was put in a sealed package after coating and was thereafter not exposed to humidity conditions for any significant length of time. The extended WVR experiment showed that the coating requires about 96 hr to reach saturation and the fact that the sample was kept completely dry prior to the outgassing test is understood to be the reason why it did not have sufficient time to absorb water. The TML and WVR values were accordingly low.

Table 1. Summary of the outgassing tests of Acktar Vacuum black coating.

Test #	TML	CVCM	WVR	RML	Post Treatment
1	3.45	0.01	2.03	1.41	-
2	1.53	0.00	1.22	0.31	2 hr @ 180°C (vacuum) Kept in a sealed package.
3	5.78	0.00	3.76	2.02	-
4	4.38	0.00	3.69	0.70	5 hr @ 160°C (vacuum)

Table 2. WVR and RML of Vacuum Black sample - test #2 as a function of time (TML = 1.529%)

	24 hrs	96 hrs	144 hrs
WVR (%)	1.216	1.506	1.507
RML (%)	0.314	0.023	0.022

4.3 Outgassing kinetics - QCM studies

In Fig. 2 the accumulated QCM mass change is shown as a function of process time. The mass change is normalized to 100 mg of the outgassed material. The graph is divided into two parts: the outgassing phase, when the studied material is heated, and the re-evaporation phase, started at time t_1 when the heating is terminated and the sample is cooled down to room temperature. The accumulated QCM mass sharply increases at the beginning of each heating step. The sharp increase at 75ºC is followed by a decrease in the QCM mass after less than an hour. Heating to 100ºC and 125ºC results in a negligible increase of the QCM mass, which then quickly decreases.
Quantitative analysis of the QCM curves in Fig. 2 shows that the outgassing of the Acktar black coating induces very low QCM mass growth: ~ 0.15 µg in total, although the QCM was kept at 5ºC, as compared to 25ºC for the standard outgassing test. Such a low mass accumulation on the QCM is not surprising bearing in mind the inorganic nature of this coating.
On the right hand side of Fig. 2 ($t > t_1$), the QCM curve of the re-evaporation phase is shown. The accumulated QCM mass rapidly decreases when the QCM is still kept at 5ºC. From the rough extrapolation of the curve it can be seen that only traces of the contaminants would remain after sufficiently long time. Increasing

the temperature to 15 and 25ºC accelerates the contaminants desorption process and results in almost total elimination of the contaminants within a few hours.

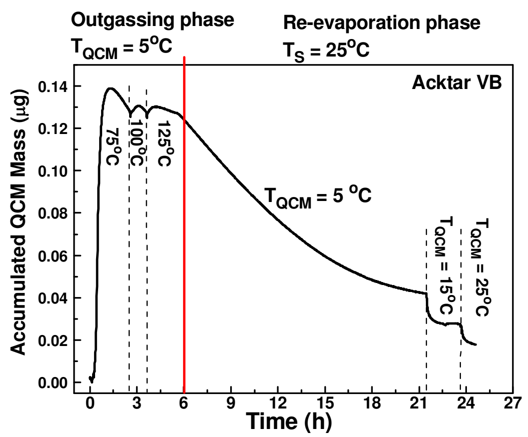


Fig. 2. The accumulated mass on QCM with process time (heating and cooling).

4.4 RGA measurements of outgassing products

The species outgassed from an Acktar Vacuum Black coating when heated to 175°C in a clean ultra high vacuum chamber are shown in Fig. 3(a). The predominant and the only significant outgassing species is water vapor. The characteristic water vapor spectrum is readily identified by the signal peaks at masses 16, 17 and 18 amu. In addition the hydrogen mass peaks at masses 1 and 2 amu are fragmentation products from the water vapor. Two small peaks are observed at the mass positions of 28 and 44 amu, corresponding to CO and CO_2. These are most probably created by the reaction of water vapor on the filament of the RGA ionizer. The small carbon peak at mass 12 is a fragmentation product of CO and CO_2 in the RGA ionizer. Other species outgassed from the heated Acktar Vacuum Black sample are orders of magnitude smaller than those derived from the water vapor.

It is noted that below 100°C the outgassing from Acktar black is very low and increases rapidly with temperature above 115°C, Fig. 3(b).

High concentration of the water vapor released is in good agreement with the results of the outgassing test and WVR measurements as a function of time, shown above.

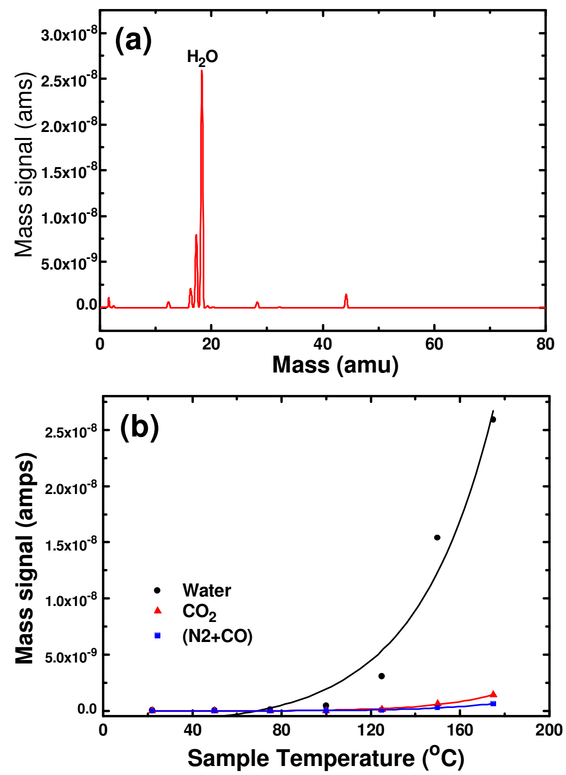


Fig. 3. RGA measurements of the outgassing from Acktar Vacuum Black coating. Typical spectrum at 175ºC (a); outgassing products as a function of temperature (b).

4.5 Atomic Oxygen (AO) testing

4.5.1 RF plasma exposure

The Fractal Black coating was exposed to thermal AO using an RF plasma simulation facility which is considered to be a more severe exposure environment than the 5 eV AO experiment described below. The average AO flux in the downstream position, ~120 mm from the RF plasma reactor edge, was estimated to be equal to 1×10^{15} atoms/cm^{2}sec. Using this system AO fluences amounting up to 3×10^{20} atoms/cm^2 were obtained.

The results of optical tests, surface morphology studies and chemical composition measurements were similar to those obtained after 5 eV AO exposure. Fig. 4 shows total reflectance of fractal black coating before and after exposure to RF plasma (LEO equivalent AO fluence of $3x10^{20}$O/cm^2).

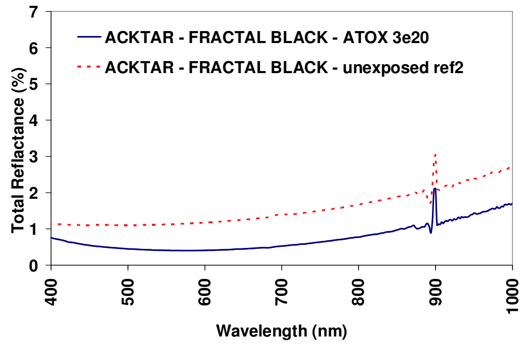


Fig. 4. Total reflectance of fractal black coating before and after exposure to RF plasma (LEO equivalent AO fluence of $3x10^{20} O/cm^2$).

4.5.2 Exposure to atomic oxygen (5 eV) and samples characterization

Under the operational conditions, a 5 eV AO flux of 3×10^{15} atoms/cm^2sec was obtained. The total AO fluence was 2×10^{20} atoms/cm^2. The samples were characterized before and after exposure to atomic oxygen by several characterization methods.
The total reflectance did not change due to the exposure to AO and was kept below 2%. There was also no change in its visual appearance. The total reflectance over the wavelength range before and after exposure to AO is shown in Fig. 5.

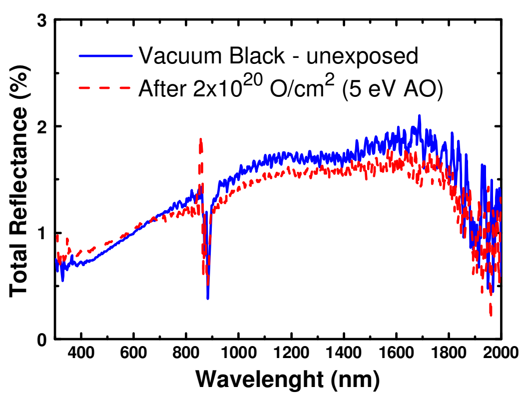
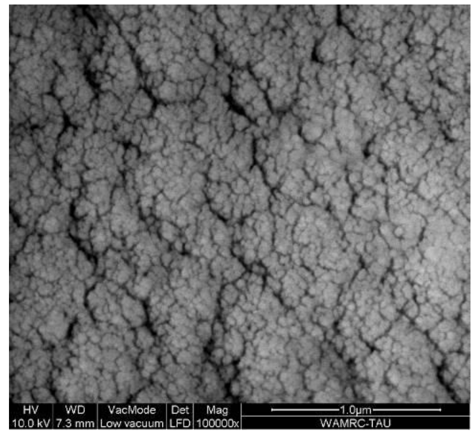


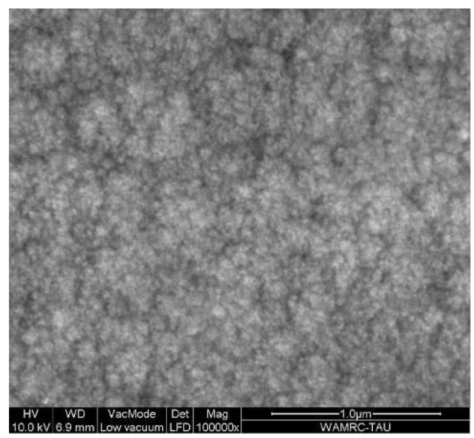
Fig. 5. Total reflectance of Vacuum Black coating prior and after exposure to 5 eV AO ($2x10^{20}$ atom/cm^2) with a Laser Detonation Source (the peak at 900nm is due to lamp change in the spectrophotometer).

The surface morphology of the Acktar coating was modified slightly after exposure to 5 eV AO as observed in Figs. 6-7 by HR SEM microscopy. A number of micro-cracks were found on the surface with a typical width of 0.5 µm and the granular structure of the surface was slightly smoothed. The micro-cracks were most probably formed after exposure to AO similar to end-of-life exposure. No peeling or flaking was observed.



x100,000

Fig. 6. SEM images of unexposed Vacuum black sample.



x100,000

Fig. 7. SEM images of Vacuum black sample exposed to a 5 eV AO fluence of 2×10^{20} atom/cm^2

4.6 Adhesion and thermal cycling results

Adhesion tests for Acktar Vacuum Black on several substrates were performed - before and after thermal cycling (97 cycles at a temperature range of -40°C – 100°C). The adhesion of the coating to all substrates was shown to be excellent - not a single square having been lifted - corresponding to Class 5B according to Fig. 1 in ASTM D3359-02 [5].

After the thermal cycles the morphology of the Acktar Vacuum Black coating was studied using an optical microscope. No cracks were observed after the thermal cycles. The reflectivity of the Acktar Vacuum Black was not affected.

4.7 Bonding on Acktar coating

Bonding to a coated Titanium (Ti-6Al-4V) sample was tested by preparing lap shear samples per ASTM D-1002 [6] Bonding was tested with an epoxy adhesive. Thickness of adhesive was 0.25mm. The lap shear strength for coated samples was compared with that for bare samples.

The results displayed at Table 3 show that the adhesion of the adhesive to the Acktar coating is not inferior to its adhesion to the bare substrate. The results also show the excellent adhesion of the Acktar coating to the substrate.

Table 3: Lap shear tests results with Epoxy adhesive.

	Lap shear strength (kgF/mm^2)	Type of failure
Ti vs. Ti	1.57 1.62 1.53	Cohesive (within the glue)
Ti +Acktar vs. Ti	0.92 1.42 1.56	Mostly cohesive, some within the Acktar coating

5. SUMMARY

Three types of Acktar coatings were tested: Fractal Black, Magic Black, and Vacuum Black. Vacuum Black was thoroughly tested in order to qualify its usage for space applications. Its optical properties, outgassing behavior, morphology and chemical composition were studied on various substrates. Its morphology and optical properties were studied before and after exposure to high fluxes of AO and to thermal cycling.

1. The measured total reflectivity of the Vacuum black coating is very low and is below 2% in the visible and NIR range.
2. The Vacuum Black coating has negligible outgassing potential, especially when compared to black paints. The Acktar coating is highly porous and under ambient atmospheric conditions can accumulate amounts of condensed water leading to non-compliance with the TML and RML criteria of ASTM E595. This effect is cancelled by carrying a baking process of 2 hours at 180°C in a vacuum environment in order to evaporate the trapped water. The stability of the baking effect with time was not tested and therefore should be taken into account in applications where small quantities of outgassed water could be problematic.
3. After outgassing test, more than 24 hours under ambient atmospheric conditions are required to regain the amount of water lost in outgassing.
4. Taking into consideration the small thickness (and mass) of the coatings – the absolute mass of outgassed material per unit of coated area is very small.
5. Mass spectroscopy measurements of Acktar outgassing do not show desorption of components other than water vapor.
6. Total integrated reflectivity was not affected by AO exposure. No peeling or flaking was observed. The surface morphology was slightly modified after AO exposure (probably after end-of-life similar exposure), showing a smoother surface and some micro-cracks (about 0.5µm width). These micro-cracks could compromise the efficiency of a protective coating on polymeric substrates such as Kapton, or on composite materials due to undercutting of the substrate by AO.
7. Acktar Vacuum Black coating was found to be thermally stable between -40°C and 100°C in terms of its morphology and reflectivity as was observed by an optical microscope and a spectrophotometer, respectively.
8. Bonding directly on Acktar coating is practical. The adhesion of the adhesive to the Acktar coating is high and not inferior to its adhesion to the bare substrate.
9. The adhesion of Vacuum Black coating to the substrate was found to be excellent and show no sign of peeling (according to Class 5B according to Fig. 1 in ASTM D3359-02).

6. CONCLUSIONS

Acktar Vacuum black coating can be used in space applications. The tendency of the coating to adsorb water should be kept in mind.

7. REFERENCES

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9. ASTM D-1002, *Metal specimens, single lap joint adhesively bonded, by tension loading (metal to metal), apparent shear strength.*

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Annex B

31/08/2009

Tildocs # 125044

Test of Acktar Fractal Black as a Bonding Substrate

For the purpose of the test ceramic disks were manufactured and bonded – using RTV 560 – into housing plates made of 6061 Aluminum and 416 Stainless Steel. Each housing plate had 5 holes. 3 of the 5 holes were coated with Acktar Fractal Black.

A force was applied to the discs which was gradually increased until failure occurred.

In the course of the test the shear force and the settling of the discs was measured and the shear stress was calculated.

The test results for the coated items were compared with those for the uncoated items.

Conclusion

Examination of the results shows that there is no difference in the ability of the bond to withstand shear between the surfaces coated with Acktar Fractal Black and the uncoated surfaces.

In all the tests it was the adhesive which sheared. No evidence of delamination or other failure of the coating was found.

Conclusion: Acktar Fractal Black has good adhesion to the substrate (6061 Aluminum and 416 Stainless Steel) and can serve as a good bonding surface.

Test Requirements

1. To test the bond strength of discs simulating the lens elements LH1 and LH2
2. Ceramic discs were manufactured with diameters similar to the original lenses DIA 21 and DIA 23 as per drawings no. 30-030313 and 30-030327.
3. Housing plates were manufactured with lens housings for bonding the discs with dimensions identical with those of the actual lens housings (drawings 30-030433 and 30-030427). Each housing plate has 5 lens housings.
4. The bonding surfaces of 3 of the lens housings in each housing plate were coated with Fractal Black according to Acktar Ltd. Process no. 768.
5. The discs were bonded in place using RTV 560
6. The discs are to be loaded with an increasing force with load and disc settlement measured at each stage and the shear stress calculated.

Test Procedure

A loading adaptor was placed on a disc and the load was applied while the settling was measured in parallel – until bond shearing or lens fracture.

Bond Surface – LH1

Disc diameter – 23 mm

Height of the bond surface – 1.35 mm

Bond area - $2\pi r\,xh$ $2x\pi x11.5x1.35 = 97.5\ mm^2$

Disc weight – 4.4 gm

Bond Surface – LH2

Disc diameter – 23 mm ***(typo error in original – should be 21mm)***

Height of the bond surface – 1.1 mm

Bond area - $2\pi r\,xh$ $2x\pi x10.5x1.1 = 72.5\ mm^2$

Disc weight – 2.7 gm

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Measurement Results

LH1

UNCOATED HOUSING_ SETTLING IN MICRONS		COATED HOUSING SETTLING IN MICRONS			SHEAR STRESS KG/MM²	FORCE-KG
2	1	3	2	1		
30	40	80	40	20	**0.01**	1
70	70	120	80	40	**0.02**	2
110	90	160	100	60	**0.03**	3
140	120	180	140	80	**0.041**	4
170	150	210	170	100	**0.051**	5
190	170	adhesive sheared	180	110	**0.061**	6
210	190		190	120	**0.071**	7
240	200		210	140	**0.082**	8
260	220		230	160	**0.092**	9
280	230		240	170	**0.102**	10
300	240		260	180	**0.112**	11
-	250		-	200	**0.123**	12
-	280		-	adhesive sheared	**0.133**	13
adhesive sheared	adhesive sheared		-		**0.143**	14
			-		**0.153**	15
			adhesive sheared		**0.164**	16

LH2

UNCOATED HOUSING_ SETTLING IN MICRONS		COATED HOUSING SETTLING IN MICRONS			SHEAR STRESS KG/MM²	FORCE-KG
2	* 1	3	2	* 1		
70	74	50	30	78	**0.013**	1
100	120	90	64	130	**0.0275**	2
130	140	120	80	180	**0.0413**	3
160	200	150	120	220	**0.055**	4
200	disc failed	170	180	disc failed	**0.069**	5
220		190	220		**0.082**	6
230		210	260		**0.096**	7
240		-	-		**0.11**	8
250		adhesive sheared	270		**0.124**	9
260			280		**0.138**	10
adhesive sheared			adhesive sheared		**0.15**	11

* These tests were performed without loading adaptors which led to a concentrated force at the center of the disc and caused disc failure. (Loading adaptor – a metal cylinder which applies the load uniformly over a large surface on the test item)