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Abstract

The document describes the Technical Specifications for the E-TEST Silicon tender.

Document Status

Revision	Date	Comment	Reviewed by	Approved by
0	03/12/2021	Document initiated		

Revision History

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0	03/12/2021	Document initiated

1 Documentation and Acronyms

1.1 Abbreviations/Acronyms

Abbreviation	Description
SPDT	Single Point Diamond Turning
E-TEST	Project about site study and technology development for the Einstein Telescope

2 Scope of supply

The procurement is split into two phases (see General Document) and so does the scope of supply:

- Phase-A (Feasibility study): scope of supply is the production of **four test structures** (hereafter named **samples**) according to the specifications and modality indicated in Section 3.2;
- Phase-B (Production): scope of supply is the production of **six suspension rods** for the E-TEST technology demonstrator according to the specifications and modality indicated in Section 3.3.

3 Silicon suspension rods: description and requirements

3.1 General description

The current design of the E-TEST technology demonstrator features a 100-kg monocrystalline silicon mirror (450-mm diameter, 270-mm thickness) cooled down to 25K temperature by radiation heat exchange. Anticipating the configuration of the Einstein Telescope, the mirror will be suspended from the heat exchanger body as a pendulum (see an overview in Figure 1).

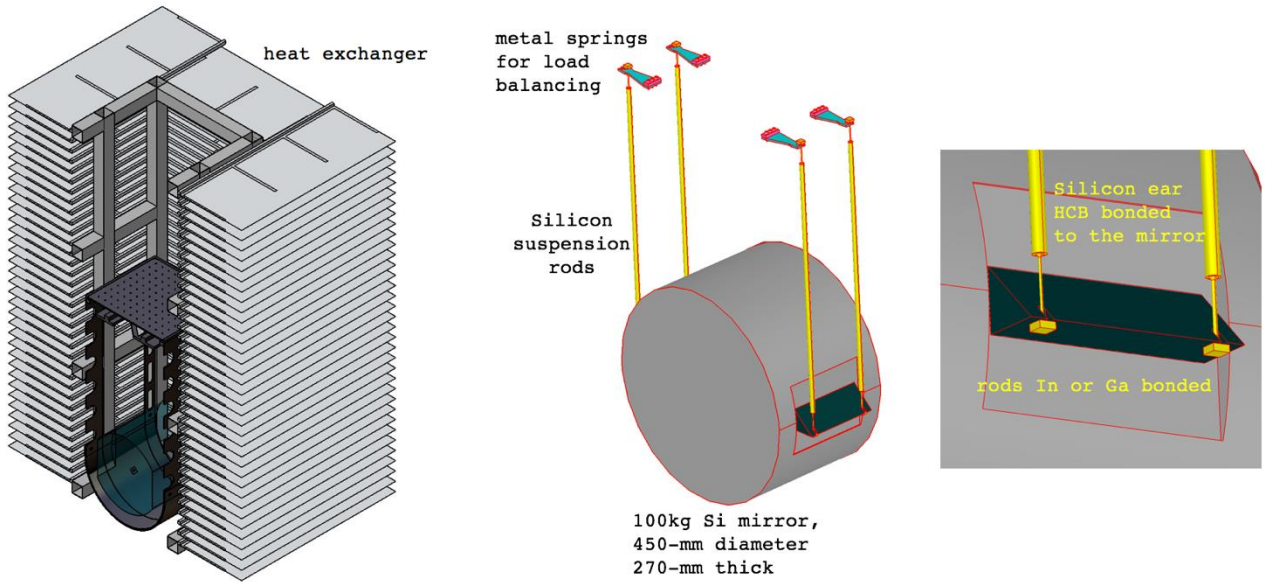

Figure 1 *Detail of the mirror suspension stage in the E-TEST Prototype. The **silicon mirror** is suspended like a pendulum by means of four monolithic crystalline silicon rods (yellow) providing a high thermal conductivity, ultralow mechanical hysteresis interface to the radiation heat exchanger. The rods are bonded to the mirror and to load balancing metal springs by means of low temperature In or Ga brazing.*

The suspension will be realized by means of four thin monocrystalline silicon rods providing the necessary low thermal resistance link to the mirror and ensuring, at the same time, the lowest possible mechanical energy dissipation. This latter is a crucial aspect for the future Einstein Telescope to reach its scientific goals, and is one of the objectives of the E-TEST technology demonstrator to investigate the achievable limits.

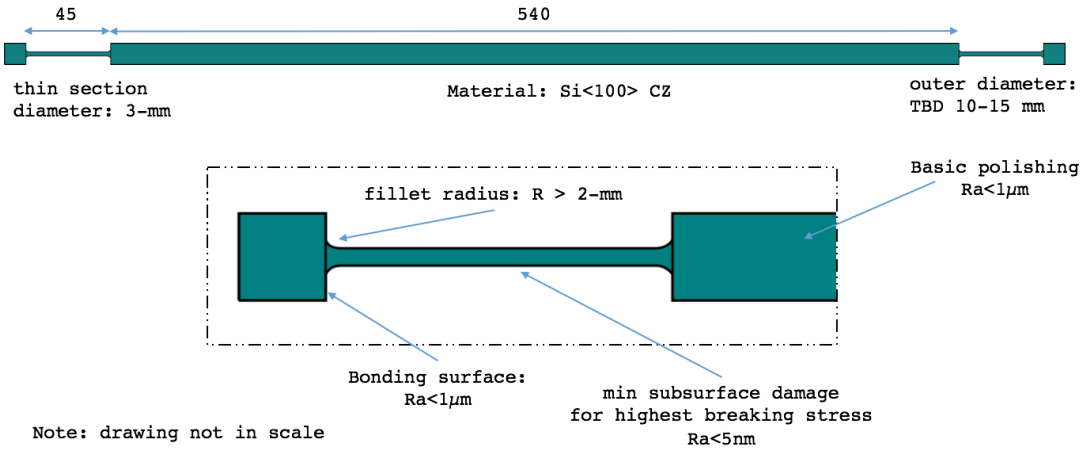

Figure 2 *Conceptual design of the E-TEST Prototype suspension rods. This is not a manufacturing drawing which is made available in separate files. Gross dimensioning of the rod and required quality of the surface at different locations are indicated.*

The preliminary design of the suspension rods is shown in Figure 2. The rods have cylindrical shape with two thinner sections acting as flexures and allowing the suspension to work as a pendulum.
While the surface quality of the larger diameter portion of the rod is not critical and can be achieved with standard grinding methods, the two **flexure sections** require the best possible finishing.
The main reason for this is that the stress concentrates in the flexures. Being monocrystalline silicon a brittle material, its breaking strength is largely influenced by the quality of the surface (presence of flaws and micro-cracks) and by the depth of the sub-surface damage induced by the machining process. For the suspension to be safe and reliable it is therefore essential that the last two parameters are the best possible. For this reason, **single-point diamond turning**, typically providing surface roughness better than 5 nanometers RMS, has been identified as the most suitable method for machining the flexure sections of the rods.
Two more features characterize the preliminary design:

- **fillets** with radius R>2-mm (safe value determined by Finite Element Analysis) prevent dangerous stress concentrations at the transition between small and large diameter portions of the rod.
- **flat bonding surfaces**, perpendicular to the rod axis, are provided for low temperature brazing to the mirror ears and to the balancing cantilever springs.

3.2 Samples: production specifications

The supplier is asked to deliver **four samples** machined via SPDT according to the production design as specified in 3.2.3, starting from cylindrical monocrystalline silicon rods provided by Nikhef (see specifications in 3.2.1).

3.2.1 Raw material specifications

Nikhef will provide the stock material for the production of the samples (see specifications in Table 1).

Material	Monocrystalline Silicon
Orientation	<100> ± 5deg
Purity	99.999%
Type	P
Resistivity	> 10 Ohm-cm
Quantity	10 pieces
Shape	rod
Diameter	13±0.2 mm
Length	125±0.5 mm
Perpendicularity	≤0.005" (0.127mm)
Surface roughness	Ra < 0.4 µm

Table 1 *Specifications of the stock material for the production of the samples.*

3.2.2 Reference design

The reference design for the samples is sketched in Figure 3 and consists of a single flexure portion of the suspension rod. It provides the bidder indications about the relevant geometrical and surface finishing properties of the samples.

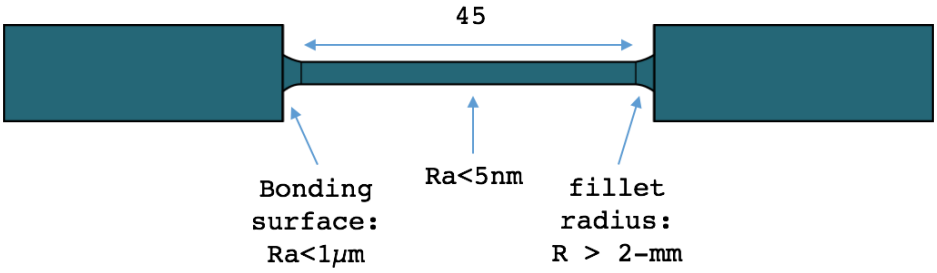

Figure 3 *Conceptual design of the sample. This is not a manufacturing drawing which is made available in separate files. Gross dimensioning and required quality of the surface at different locations are indicated for what concern the SPDT machining.*

3.2.3 Production design

The production design may partially differ from the reference one in 3.2.2, based on the suggestions that each bidder is invited to propose as part of the Quotation Annex Document, and on the findings of the feasibility study. Design changes are acceptable as long as they won't affect the functionality of the part. Boundaries that the bidder should take into consideration when proposing design changes in the Quotation Annex Document are listed as follows:

- length and diameter of the straight thin section, respectively 45-mm and 3-mm, cannot be changed;
- the fillet at the two ends of the straight thin section cannot be omitted and it has to have a radius of at least 2-mm;
- best surface finishing (Ra<5nm) must be guaranteed both over the straight thin section and over the two fillets since they are the region with the highest stress level;
- the bonding surface perpendicular to the rod axis represents the ideal solution for brazing the rod to other parts; however, the bidder can propose modifications that may ease the fabrication;
- the length of each of the two large diameter terminations cannot be less than 30-mm.

3.3 Suspension rods: production specifications

The supplier is asked to deliver **six suspension rods** machined via SPDT according to the production design as specified in 3.3.3, starting from cylindrical monocrystalline silicon rods provided by Nikhef (see specifications in 3.3.1).

3.3.1 Raw material specifications

Nikhef will provide the stock material for the production of the suspension rods. Properties will be the same as in Table 1 except for the physical dimensions (dependent on the production design) and for the silicon purity: higher purity, higher resistivity silicon will be used to benefit from better thermal conductivity at low temperature.

3.3.2 Reference design

The bidder should take the sketch in Figure 2 as the reference design for the suspension rods.

3.3.3 Production design

The production design may partially differ from the reference one in 3.3.2, based on the results of the feasibility study. Changes will be agreed upon by Nikhef and the contracting company at the beginning of the Phase-B of the procurement. Design changes are acceptable as long as they won't affect the functionality of the part. Boundaries that the bidder should take into consideration when calculating the price for the production of the six rods are listed as follows:

- length and diameter of the straight thin section, respectively 45-mm and 3-mm, cannot be changed;
- the fillet at the two ends of the straight thin section cannot be omitted and it has to have a radius of at least 2-mm;

- best surface finishing (Ra<5nm) must be guaranteed both over the straight thin section and over the two fillets since they are the region with the highest stress level;
- the bonding surface perpendicular to the rod axis represents the ideal solution for brazing the rod to other parts; modifications that may ease the fabrication will be agreed upon by Nikhef and the contracting company.

4 Quotation Annex document requirements

The Quotation Annex document will be used to evaluate the quality of the bid and shall include:

- detailed list of machining and test equipment available to the company;
- references of previous works involving SPDT machining of crystalline materials;
- development, manufacturing and delivery plan for the samples, including suggestions and recommendations about the samples and suspension rods design;
- manufacturing and delivery plan for the suspension rods.

5 Annex drawings package

The reference design drawings, 2D in pdf format and 3D as step files, for the samples and the suspension rods are attached as a .zip file
“silicon_suspension.zip”