

Investigation into the fixturing techniques used by the project partners in the EUMINA*fab* consortium

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ABSTRACT

The partners that make up the EUMINA*fab* consortium were questioned on the fixturing capabilities for each of the installations made available for transnational access. A questionnaire was prepared that aimed to gather information on some of the features universal to most manufacturing fixtures so that they could be compared across the partners. The fixturing capabilities were also compared according to the category of installation each fixture was associated with and fixturing techniques common within organisations were compared cross-partner. To conclude, future work to develop the fixturing capabilities of the EUMINA*fab* consortium is recommended.

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Approved on behalf of NPLML by Ian Severn, Head of Engineering Measurement Division

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ACRONYMS

AFM	Atomic force microscope
CMM	Coordinate measuring machine
CRF	Centro Ricerche FIAT
CU	Cardiff University
DOF	Degrees of freedom
DRIE	Deep reactive ion etching
EDM	Electro discharge machining
FIB	Focussed ion beam
KIT	Karlsruhe Institute of Technology
LTPS	Low temperature poly-silicon
MEC	Manufacturing Engineering Centre at Cardiff University
MNM	Micro and nano manufacturing
MNT	Micro and nano technology
NIL	Nano-imprint lithography
NPL	National Physical Laboratory
PVD	Physical vapour deposition
RIE	Reactive ion etching
SCIL	Surface conformal imprint lithography
SEM	Scanning electron microscope
SME	Small and medium enterprise
STEM	Scanning transmission electron microscope
TEM	Transmission electron microscope
UV	Ultra-violet
WEDM	Wire electro discharge machining

1 INTRODUCTION TO EUMINAfab

EUMINAfab, a European Research Infrastructure (ERI), is a 4-year project funded by the European Commission (EC) under the FP7 “Capacities” framework. EUMINAfab aims to lower the barriers that are mainly faced by small and medium sized enterprises (SMEs), when wishing to exploit emerging technologies, by integrating the scientific and technological skills of 10 partners in 8 countries, creating a pan-European toolbox for micro-scale and nano-scale structuring and characterization. This toolbox is open to external users from industry and academia on a proposal basis and the EC supports this transnational access by reimbursing costs of the installation and the travel expenses of the user. [Kautt 2009]

The installations made available by the consortium for transnational access are split into four technology categories:

- 1) Micro- nano-patterning
Microscale and nanoscale patterns, optical components, microscale mechanical components and moulds with micrometre and sub-micrometre precision can be produced by mechanical, lithographic and laser machining methods.
- 2) Thin film deposition
Single and multilayers, and films with thicknesses as narrow as 10 nm can be formed by sputtering methods. Highly regular nanostructures of emitting nano-crystals, metallic and ceramic nanoclusters can be created by exploiting self-assembly methods. Light emitting devices can also be fabricated by layer-by-layer deposition. Etching methods specially adapted for noble metals, which have applications, for example, in heating elements, platinum electrodes and temperature sensors.
- 3) Replication
Short series micro-components from polymers, metal or ceramics can be produced by hot embossing or micro-injection moulding. High geometric accuracies and low tolerances can be achieved for example, by using LIGA fabricated mould inserts. Metal lines can be printed on glass or metal substrates, both over large areas and using several materials, forming *e.g.* conductive structures for high and low temperature applications. High resolution and high aspect ratio structures can be formed by reactive ion etching. In addition to silicon these technologies are suitable for polymers, metals and glass.
- 4) Characterisation
Characterisation methods are available for a broad range of materials and structures and allow for electro-optical characterisation of particles or surfaces, microscopic methods enable the imaging of particles and demonstration of the atomic arrangement within particles. Metrological services are available for systems containing silicon, polymers, metals, ceramics or glass, and traceable surface topography measurement can be carried out with both contact and non-contact techniques.

Within the EUMINAfab consortium, thirty-six installations are available for transnational access. These installations consist of over sixty individual facilities (or machines), which cover an extensive range of micro- and nano-manufacturing, and characterisation. The ten project partners that make up the consortium are: Karlsruhe Institute of Technology (DE), Commissariat à l’Energie Atomique (FR), Centro Ricerche FIAT (IT), Cardiff University (UK), Fraunhofer Institute IPA (DE), Kungliga Tekniska Högskolan (SE), IMS-NANO (AT), National Physical Laboratory (UK), MiPlaza (NL) and TEKNIKER (ES).

2 FIXTURING

“In all fabricated manufacturing, there is no single problem so universally encountered as that of holding the workpiece for machining, forming, assembly, and inspection operations.”
Frank W. Wilson, ASTME

In designing and implementing a fixture for a manufacturing process, there are a multitude of variables to be considered [WILSON 1962]. Manuals and textbooks on the subject of fixture design cover an extensive range of considerations, some of which may have little or no affect on some specific fixturing applications. With this in mind, the selection of fixtures, or their design, manufacture and use, is still heavily reliant on prior knowledge and experience.

Due to the scope of EUMIN $afab$ being micro- to nano-scale, it is unlikely that the consortium will be interested in the advances in fixturing made in the aerospace industry or in woodworking. However, the basic principles of fixturing design do hold for almost all applications, and it is these principles that will be focussed on and discussed in this report.

The following sections will point out some of the most important factors to consider when completing a fixture design process. It must be noted that this report is in no way intended to be an exhaustive review of all aspects of fixturing design and use.

2.1 CLAMPING AND SUPPORTING THE PART

Fixture layout is considered to be the primary task of fixture design, when the number, type and location of the clamps and locators are determined [WANG 2000]. This layout process relies on the six basic functional requirements of the fixture, which can be represented graphically as a pyramid, shown in Figure 1.

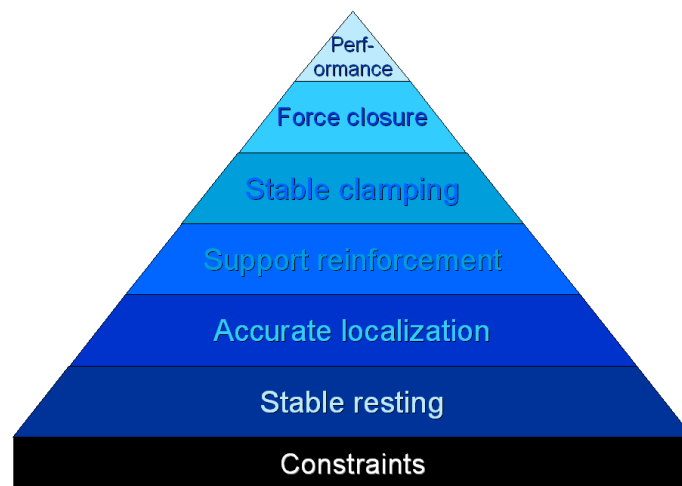


Figure 1 The fixturing pyramid.

Before a designer considers the overall performance and repeatability of the fixture, there are five functions that the fixture is required to perform. Firstly, the work piece must assume a stable resting position when placed in the fixture. This resting position should, through the use of high accuracy

precision locating features, lie at a position predefined by the designer. Any anvils used should then be positioned to reinforce any support the fixture gives and finally the clamps are activated to complete the immobilisation of the part (force closure). Of course, these functions are all subject to any initial constraints such as easy and interference-free loading and unloading.

At the apex of the fixturing pyramid is the performance function, which is fulfilled according to the requirements of the fixture. Usually, the performance metric of the fixture is defined as work piece geometric error encountered during the manufacturing stage. This error can also be expressed by determining the accuracy of the fixture localization as well as the work piece's static and elastic deformation [WANG 2000].

During this design process there are a multitude of situations to consider, including, but not restricted to, the following.

- Is the interaction force high or low? Low such that no clamp is needed or high such that deformation could occur?
- Will the clamping force bend, crush or mar the work?
- Will the clamps spoil the surface finish of the work?
- Is there enough range in the clamp to accommodate allowable variation in the part?
- Is there more than one clamping point, and are these clamping points as widely spaced as is practicable? Is the work piece supported directly under those clamping points?
- Will the clamp, whether open or closed, foul any part of the machine?
- Can the clamping be done as quickly and easily as is practicable?
- Does the operator need any specific tools to operate the clamp?

As with all aspects of fixture design, manufacture and use, an exhaustive list of the critical factors to consider would be too long for this report.

2.2 MEASUREMENT OF THE PART

All critical manufacturing processes require a verification stage where the geometrical accuracy of the work piece will be verified to confirm that it conforms to the engineering plans or specifications. When considering fixturing design, several factors can be considered to ease the verification process. To improve the cost effectiveness of the fixture, additional features can be added to allow easy measurement of the part while still in the fixture. If this is a suitable solution, the fixture should allow easy access to the work piece, for measurement and cleaning. The fixture should also include several datum surfaces or features to allow easy automated measurement of the entire work piece/fixture system.

2.3 SAFE WORKING

Although the resulting geometrical accuracy of the work piece is the main function of a fixture, this should not be obtained through a lack of safety to the operator. Any new piece of equipment should be subject to a risk assessment for the user as well as the process. However, if all the necessary steps have been taken to prevent the parts from being damaged during the operation or in handling to and from it, and if the machine is not likely to be damaged by accidental breakage of the part or tools then it is very likely that the operator, too, is safe at all times and from all eventualities.

2.4 HANDLING AND STORAGE

The practical aspects of fixture design are less essential to the overall function, but must be considered if being used in a large production environment where multiple work pieces are machined. Fixtures should be easy to handle, move and store, and all loose parts should be easily attached securely to the fixture during storage to prevent loss. Also, any delicate parts, such as spacers or precision scales, should be stored in separate cases in a secure and safe environment, if practical to the use of the fixture.

2.5 MANUFACTURE AND MAINTENANCE

It is obvious that cost is a major factor in fixture production, but it is essential to take into account the costs of running the fixture over its entire lifespan. Not only should the design and manufacture of the fixture be considered, but also the subsequent maintenance and replacement. Fixtures should be designed and manufactured according to their specific needs, not only to dimensional requirements, but also manufacturing volume. The overall cost of the fixture should be correctly related to the quantity as well as the cost and quality of the part to be produced.

2.6 OTHER FACTORS

There are a multitude of features that can be included in fixture design. One interesting area of design, which has been at the forefront of fixture research since mass manufacturing of consumer parts became the industrial norm, is fully flexible fixturing versus purpose fixtures [Asada 1985]. Fully flexible fixturing allows for alterations to be easily made to a consumer product with no changes needing to be made to the fixturing. However, for current micro- and nano-scale manufacturing, the design process for such a fixture is highly speculative, because manufacturing technologies and consumer products are changing so rapidly.

Another area of research that is highly applicable to any detachable fixture (whether for mid-process characterisation or for rapid throughput) is the repeatability and accuracy of location after the fixture is replaced. Consideration must be taken into the mechanisms and constraints of the contact points [Culpepper 2004] and the wear of those contact points (which can be mitigated by the use of hard or lubricating coatings) [Culpepper 2003].

3 AIM

The aim of this investigation was to examine the fixturing capabilities of all of the partner organisations. By comparing all the technology available, links can be made between specific manufacturing techniques and fixturing techniques and partners can be made aware of their colleagues' capabilities. Also, if a facility wanted to increase their production scale at any time, initial useful data of other facilities and the requirements for micro-production and characterisation are available through this report.

This investigation has concentrated only on the fixturing capabilities of each installation. No time has been dedicated to analysing the technical merit of each manufacturing process.

3.1 FORMAT

This report reproduces the partner's answers to the questionnaire (Sections 4 to 10). A discussion section then focuses on the capabilities and similarities between technologies.

Information is given about the individual partner organisations at the beginning of each section; however, no information is given on each individual facility. Further information about these facilities can be obtained from the EUMINAFab website (www.EUMINAFab.eu).

4 CARDIFF UNIVERSITY, UK

The Manufacturing Engineering Centre (MEC) at Cardiff University was founded in 1996. The 90-strong MEC conducts world-class research and development in all major areas of Advanced Manufacturing and uses the outputs to promote the introduction of new manufacturing technology and practice to industry. Over 100 industrial partners including Daimler, Hewlett-Packard, IBM, Mitutoyo, Parametric Technology, SAP, Silicon Graphics, Siemens and Zeiss have supported research at the Centre, which has collaborative projects with more than twenty-two countries in Europe, Asia and the Americas. Since its establishment, the Centre has gained international recognition for research in Intelligent Control, Rapid Prototyping and Manufacturing and more recently in Micro/Nano Manufacturing. In particular, a MNM R&D programme was initiated by the Centre in 2001 with a focus on advanced manufacturing research for micro and nano-systems, one of the priority areas in the UK Technology Strategy. In 2005, in recognition of its research achievements and state-of-the-art facilities in MNT the Centre became one of the main nodes within the UK MNT Network. Currently, the MEC MNM programme includes a portfolio of National and EC funded research projects with a total budget in excess of £11M.

The four installations that were considered as part of Cardiff University's facility were:

- Laser Processing I – Category: Micro- to nano-scale patterning
- FIB/SEM Crossbeam XB1540 – Category: Micro- to nano-scale patterning
- Mastermaking – Category: Micro- to nano-scale patterning
- Micro- and nano- Imprinting – Category: Replication

4.1 LASER PROCESSING I

- The fixturing methods are **mechanical** and **vacuum**
- The materials used for the fixture are **metal**, **ceramic** and **plastic**
- The fixture is of **custom** design and manufacture
- The machine is **manually** aligned for the manufacturing process
- The alignment features for the operation are on the **work piece** and the **fixture**
- The work piece is **sometimes** transferred to another manufacturing installation
- This transfer is **sometimes** completed in the same fixture
- The work piece receives **no** routine **characterisation**

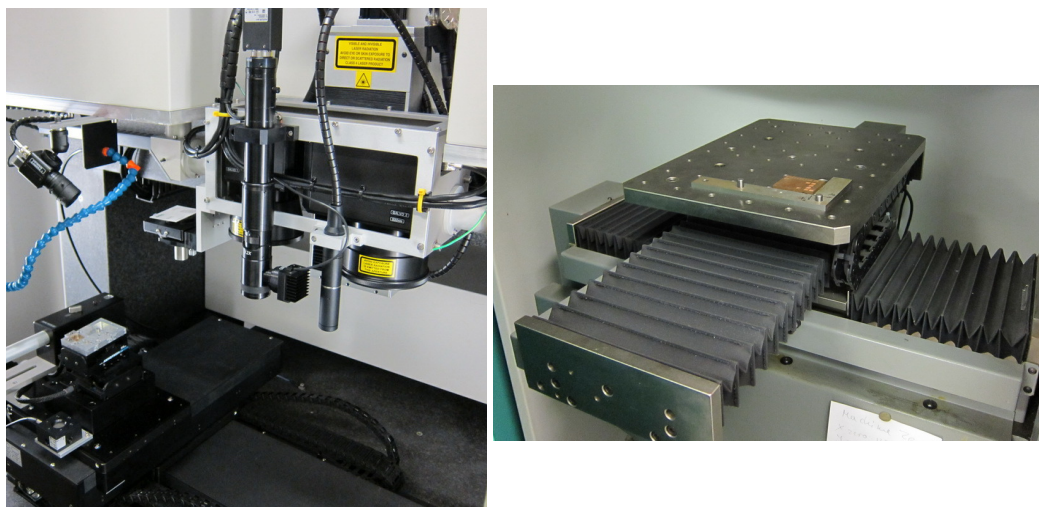


Figure 2 Laser processing I at Cardiff University.

4.2 FIB/SEM CROSSBEAM XB1540

- The fixturing method is **mechanical**
- The material used for the fixture is **metal (aluminium alloy)**
- The fixture is of **commercial** design and manufacture
- The machine is **manually** aligned for the manufacturing process
- The alignment features for the operation are on the **work piece**
- The work piece is **sometimes** transferred to another manufacturing installation
- This transfer is **not** completed in the same fixture
- The work piece receives **no** routine **characterisation**

There are two main types of fixture used in the FIB/SEM Crossbeam: a 'vice' type fixture (most commonly used) and a 'screw-press' type fixture (used for SEM/STEM sample characterisation). These are shown in Figure 3

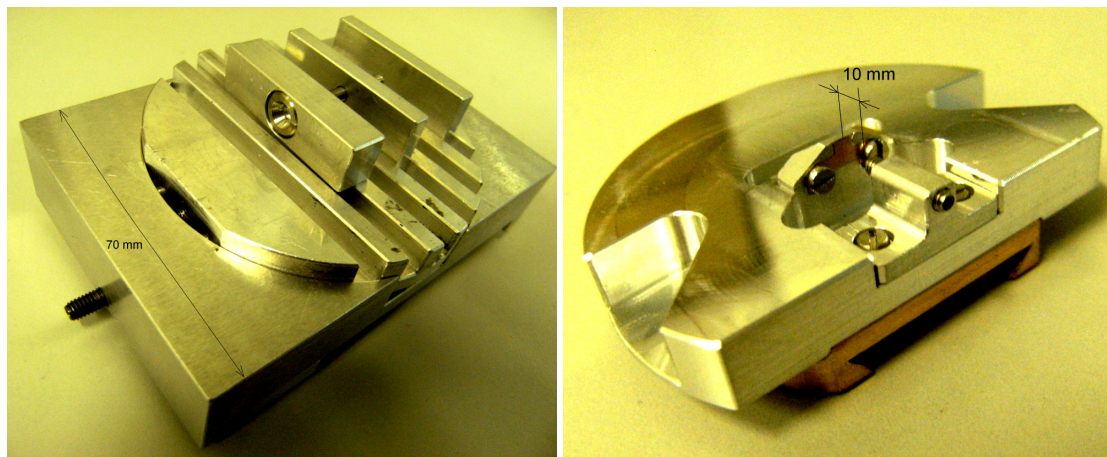


Figure 3 FIB/SEM Crossbeam XB1540 at Cardiff University – the ‘vice’ (left) and ‘screw-push’ (right) type fixtures.

4.3 MASTERMAKING

- The fixturing methods are **mechanical** and **magnetic**
- The materials used for the fixture are **steel** and **tool steel**
- The fixtures are of **commercial** and **custom** design and manufacture
- The machine is **manually** and **automatically** aligned for the manufacturing process
- The alignment features for the operations are on the **work piece**
- The work piece is **sometimes** transferred to another manufacturing installation
- This transfer is **not** completed in the same fixture
- The work piece receives **no** routine **characterisation**

Some of the work pieces are laser machined with alignment features before being processed in the Mastermaking facility.

The Mastermaking installation consists of multiple facilities. Some of the most common fixturing technologies, along with the alignment methodology, are shown in Figure 4 to Figure 8.

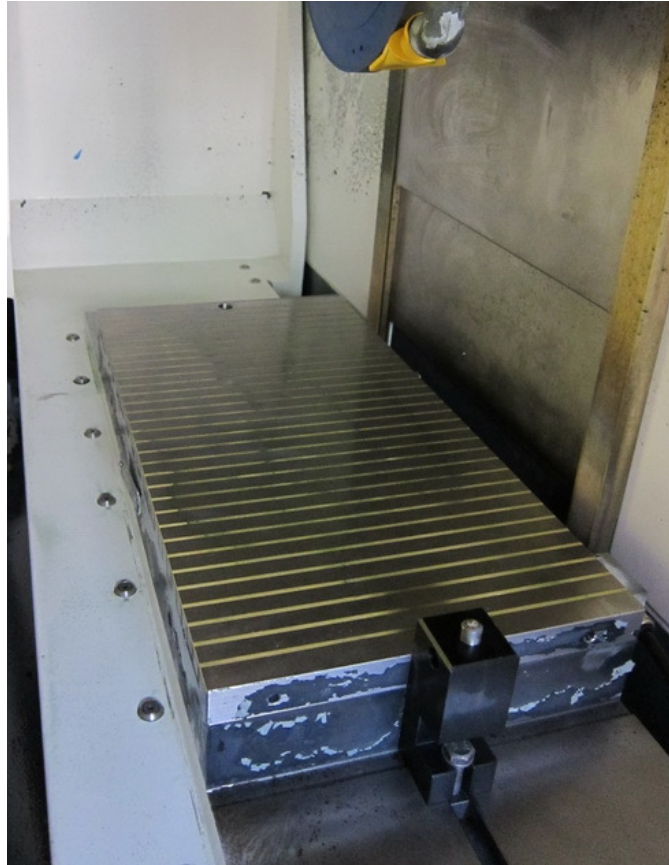


Figure 4 Mastermaking at Cardiff University – precision grinding using a magnetic fixture. No alignment is required.

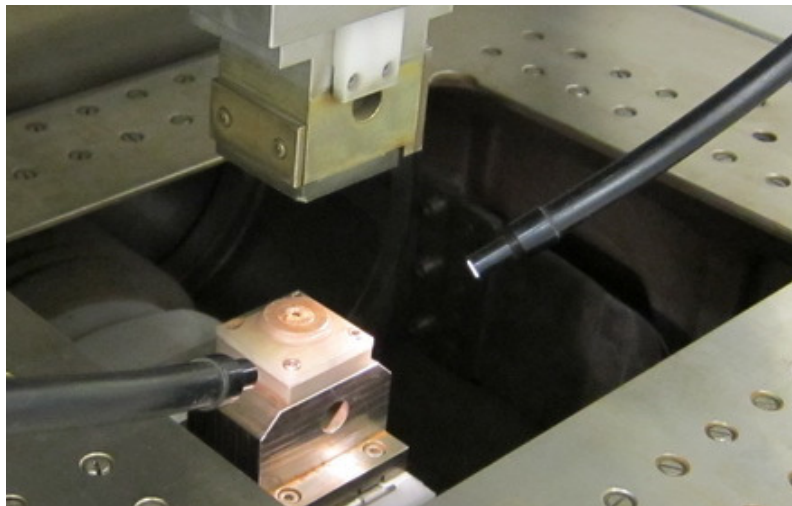


Figure 5 Mastermaking at Cardiff University – WEDM using a vice and screw type fixture. Alignment is achieved by touching the work piece with the EDM wire.

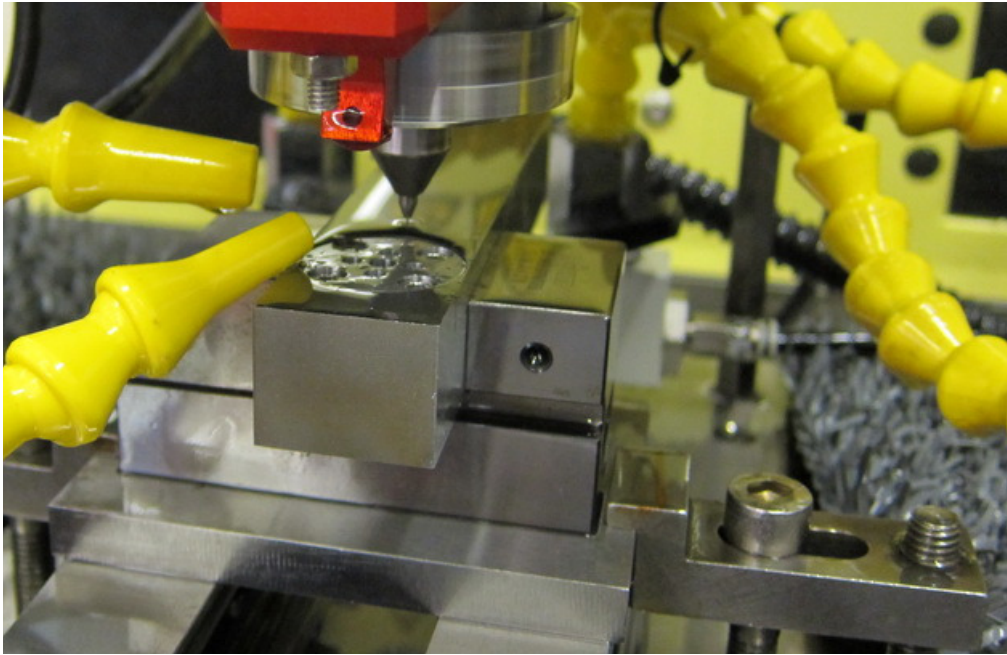


Figure 6 Mastermaking at Cardiff University – EDM micro milling using a vice fixture. Alignment is achieved by touching the electrode to the work piece.



Figure 7 Mastermaking at Cardiff University – micro precision milling using a vice fixture. Alignment is achieved by using a touch probe.

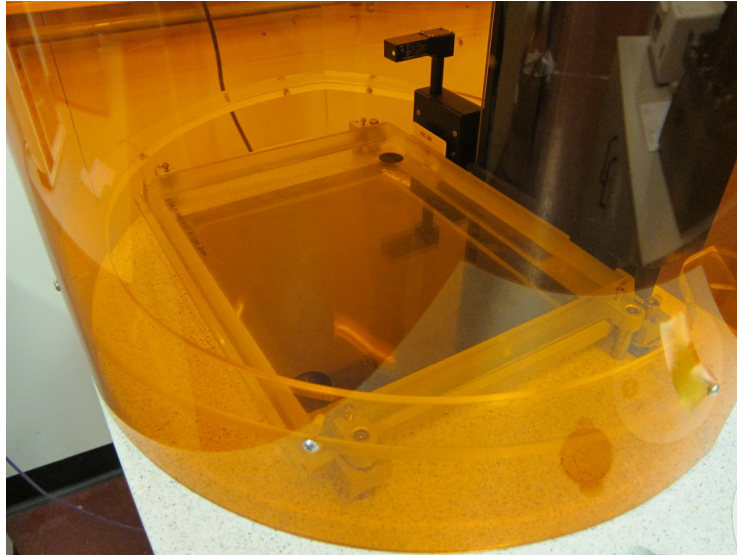


Figure 8 Mastermaking at Cardiff University – micro rapid prototyping: no fixturing or alignment required.

4.4 MICRO- AND NANO- IMPRINTING

- The fixturing method is **vacuum**
- The material used for the fixture is **metal**
- The fixture is of **custom** design and manufacture
- The machine is **automatically** aligned for the manufacturing process
- The alignment features for the operation are on the **work piece**
- The work piece receives **no** routine **characterisation**

5 CENTRO RICERCHE FIAT, IT

The Micro and Nanotechnologies Department (CRF-MN) is a Centro Ricerche FIAT facility active in future and emerging technologies for automotive and non-automotive applications since the early nineties with a permanent staff of 50 researchers. The automotive industry is one of the largest demanding users of materials and technologies and Micro and Nano Manufacturing technologies (MNMT) will have the greatest impact on components improving safety, on-board well being, environment compatibility and fuel saving. The CRF-MN has a long experience in the design and production of prototypes of optics for standard and LEDs based lighting systems, organic and inorganic thin displays, chemical, electrochemical and catalytic sensors and energy sources (PV, batteries, microFC and thermoelectric materials). The devices are produced by different technologies: i) thick and thin film deposition techniques (screen printing, PVD, sol-gel, self assembly); ii) patterning methods (microlithography, photopolymers, stencilling, imprinting, injection moulding); iii) electro-optical and morphological characterization (AFM with conductive and STM modes, FIB/SEM, spectrophotometry and radiometry).

The four installations that were considered as part of CRF's facility were:

- PVD Cluster – Category: Thin film deposition
- Self Assembly – Category: Thin film deposition
- Screen Printing – Category: Replication
- Electro-optical Characterisation – Category: Characterisation

5.1 PVD CLUSTER FOR ORGANIC DEVICE FABRICATION

- The fixturing method is **mechanical**
- The material used for the fixture is **metal (copper)**
- The fixture is of **custom** design and manufacture
- The machine is **manually** aligned for the manufacturing process
- The work piece is **sometimes** transferred to another manufacturing installation
- This transfer is **sometimes** completed in the same fixture
- The work piece receives **no** routine **characterisation**

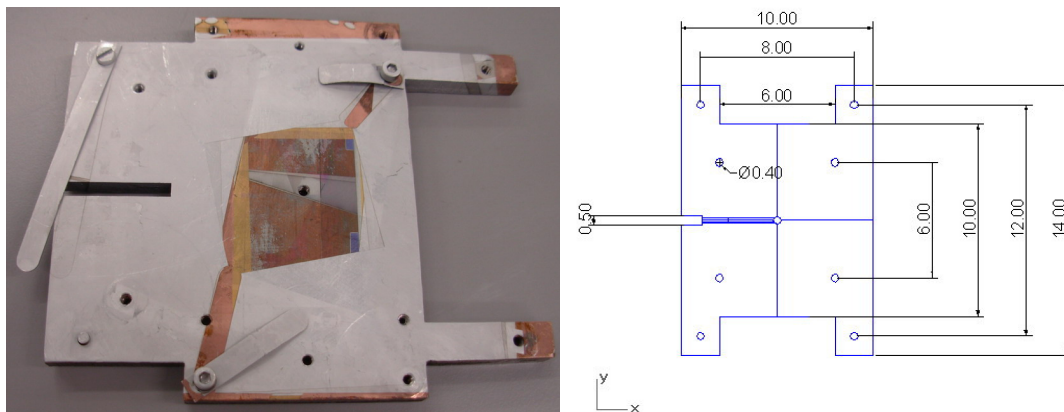


Figure 9 PVD cluster for organic device fabrication at CRF – an actual fixture (left) and a typical design (right).

5.2 SELF ASSEMBLY

- The fixturing method is **mechanical**
- The materials used for the fixture are **aluminium** and **plastic**
- The fixture is of **custom** design and manufacture
- The machine is **manually** aligned for the manufacturing process
- The work piece is **not** transferred to another manufacturing installation
- The work piece receives **no** routine **characterisation**

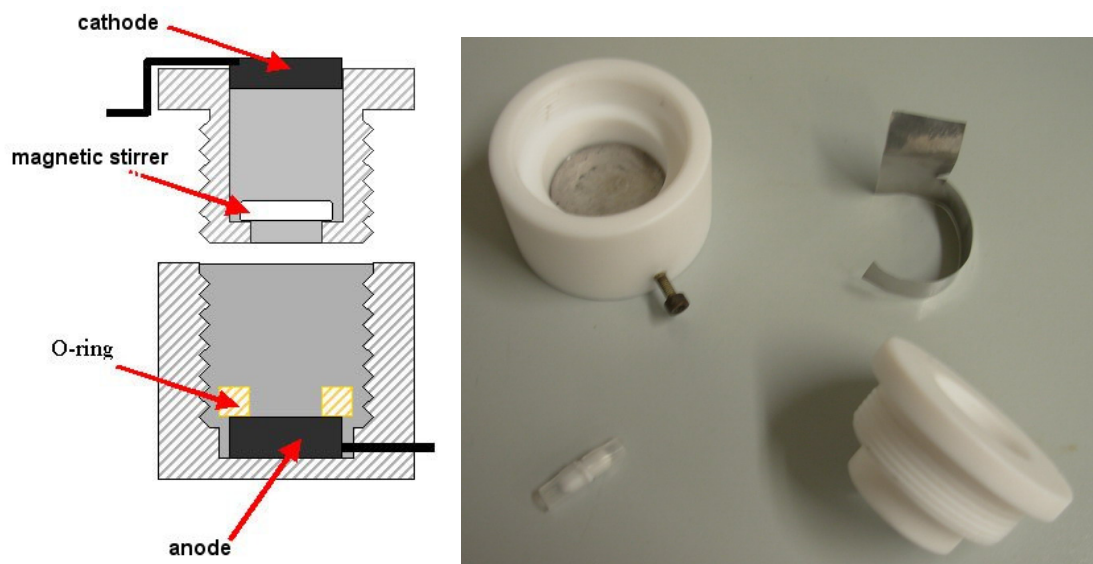


Figure 10 Self assembly at CRF – operating principle (left) and disassembled part (right).

5.3 SCREEN PRINTING

- The fixturing method is **vacuum/air pressure**
- The material used for the fixture is **plastic**
- The fixture is of **commercial** design and manufacture
- The machine is **manually** and **automatically** aligned for the manufacturing process
- The alignment features for the operation are on the **work piece**
- The work piece is **sometimes** transferred to another manufacturing installation
- This transfer is **sometimes** completed in the same fixture
- The work piece receives **no** routine **characterisation**

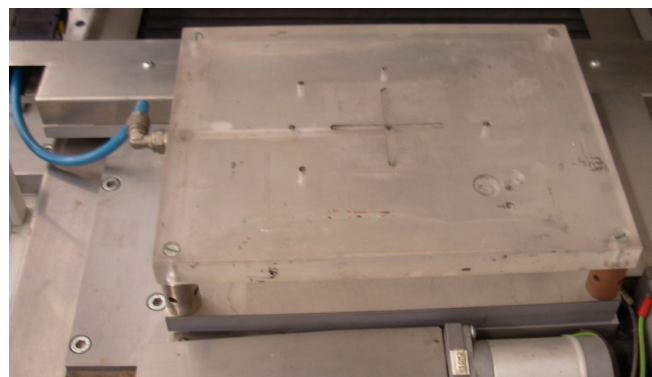


Figure 11 Screen printing at CRF – notice air hose at left of fixture.

5.4 OPTO-ELECTRICAL CHARACTERISATION

- The fixturing method is **mechanical**
- The material used for the fixture is **stainless steel**
- The fixture is of **commercial** design and manufacture
- The machine is **manually** aligned for the characterisation process
- The alignment features for the operation are on the **work piece**

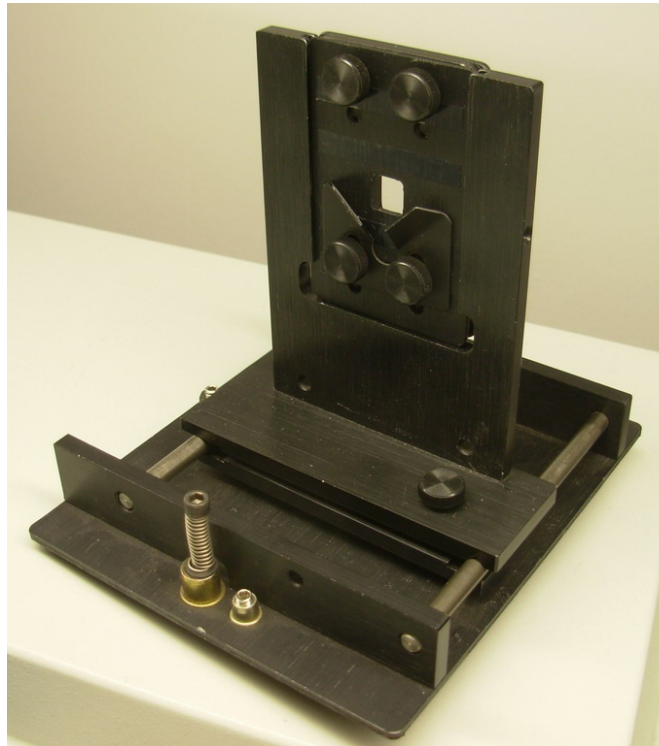


Figure 12 Opto-electrical characterisation at CRF – the holder is a Cary 500/500i solid sample holder.

6 IMS NANOFABRICATION, AT

IMS Nanofabrication AG is an Austrian based high-tech SME, which acts as technology innovator and provider for the semiconductor and nanotech industries. Based on IMS's extensive know how in charged particle projection systems they offer electron and ion multi-beam solutions to directly transfer custom design patterns to resist or to generate resist-less two and three dimensional surface modifications with features below 20 nanometres.

The installation that was considered as part of IMS's facility was:

- CHARPAN – Category: Micro and Nano Patterning

6.1 CHARPAN – CHARGED PARTICLE NANO-PATTERNING WITH MASSIVELY PARALLEL ION MULTI-BEAMS

- The fixturing method is **mechanical**
- The materials used for the fixture are **aluminium, stainless steel** and **other**
- The fixture is of **custom** design and manufacture
- The machine is **manually** aligned for the manufacturing process
- The alignment features for the operation are on the **machine** and **work piece**
- The work piece is **not** transferred to another manufacturing installation
- The work piece receives routine **characterisation**
- The characterisation fixturing method is **mechanical**
- The material used in the characterisation fixture is **aluminium**
- The characterisation fixture is of **commercial** design and manufacture
- The characterisation equipment is **manually** aligned with the work piece

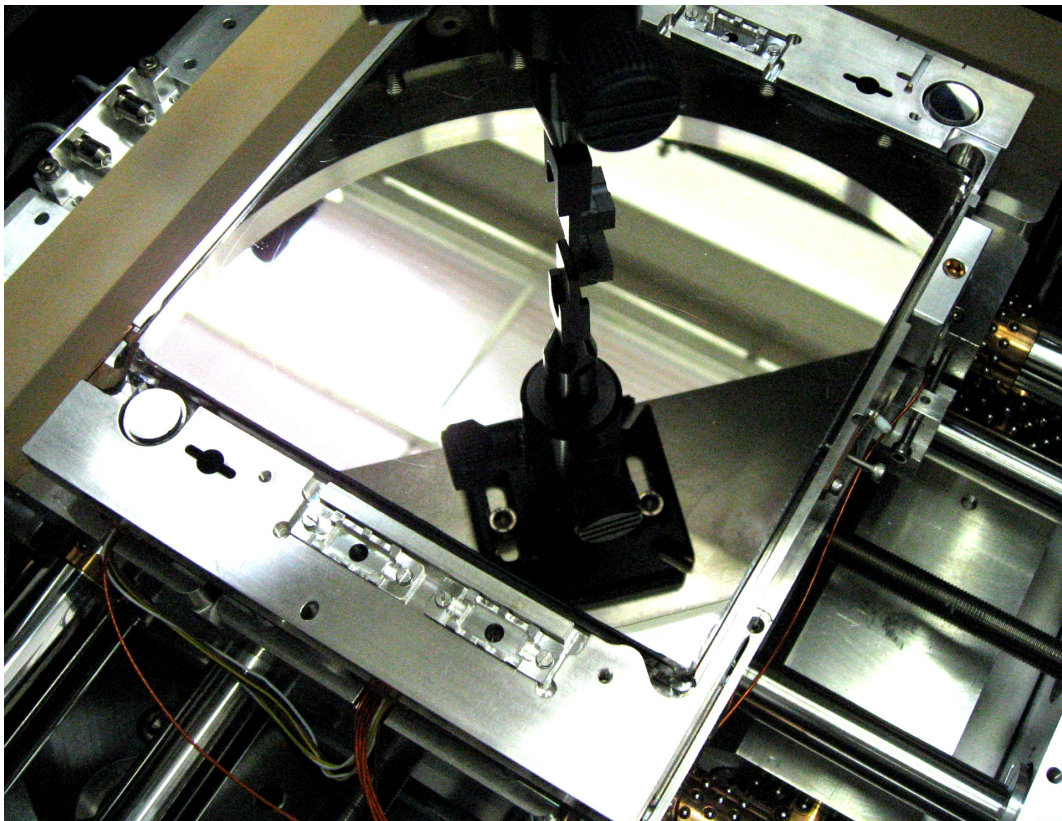


Figure 13 CHARPAN at IMS – an existing chuck that can accept 150 mm Si wafer substrates. Also, 6 inch mask blanks can be loaded.

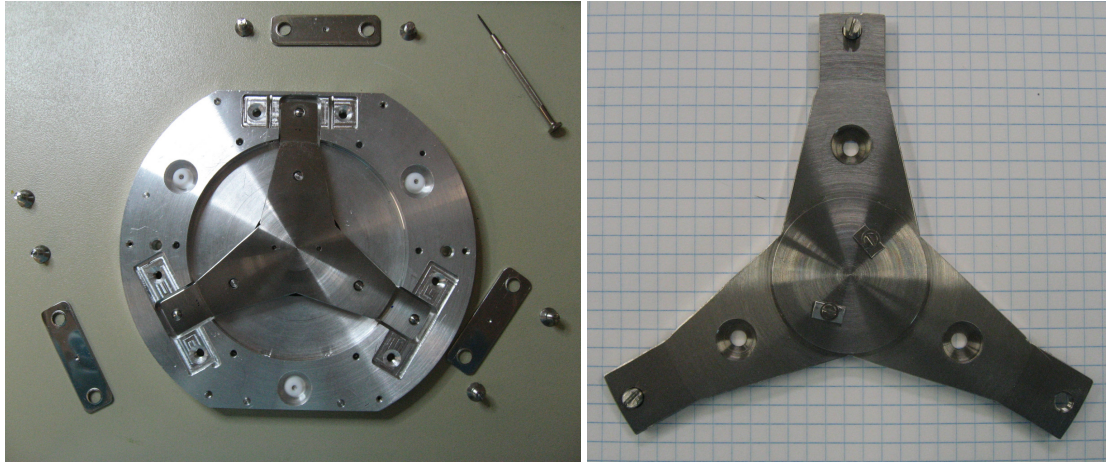


Figure 14 CHARPAN at IMS – the existing chuck can be modified with these fittings to accept smaller sized substrates also.

7 KARLSRUHE INSTITUTE OF TECHNOLOGY, DE

Karlsruhe Institute of Technology is a public corporation and state institution of Baden-Württemberg. It fulfills the mission of a university and the mission of a national research center of the Helmholtz Association. KIT focuses on a knowledge triangle that links the tasks of research, teaching, and innovation.

The five installations that were considered as part of CRF's facility were:

- Dip-Pen nano-Lith – Category: Micro and Nano Patterning
- Direct X-Ray Lith – Category: Micro and Nano Patterning
- E-Beam Lith – Category: Micro and Nano Patterning
- Laser Processing II – Category: Micro and Nano Patterning
- TEM – Category: Characterisation

7.1 LASER PROCESSING II

- The fixturing method is **vacuum**
- The materials used for the fixture are **steel** and **brass**
- The fixture is of **commercial** design and manufacture
- The machine is **manually** aligned for the manufacturing process
- The alignment features for the operation are on the **work piece**
- The work piece is **not** transferred to another manufacturing installation
- The work piece receives routine **characterisation**
- The characterisation fixturing method is **mechanical**
- The material used for the characterisation fixture is **aluminium**
- The characterisation fixture is of **commercial** design and manufacture
- The characterisation equipment is **manually** aligned with the work piece
- The alignment features for the characterisation operation are on the **work piece**

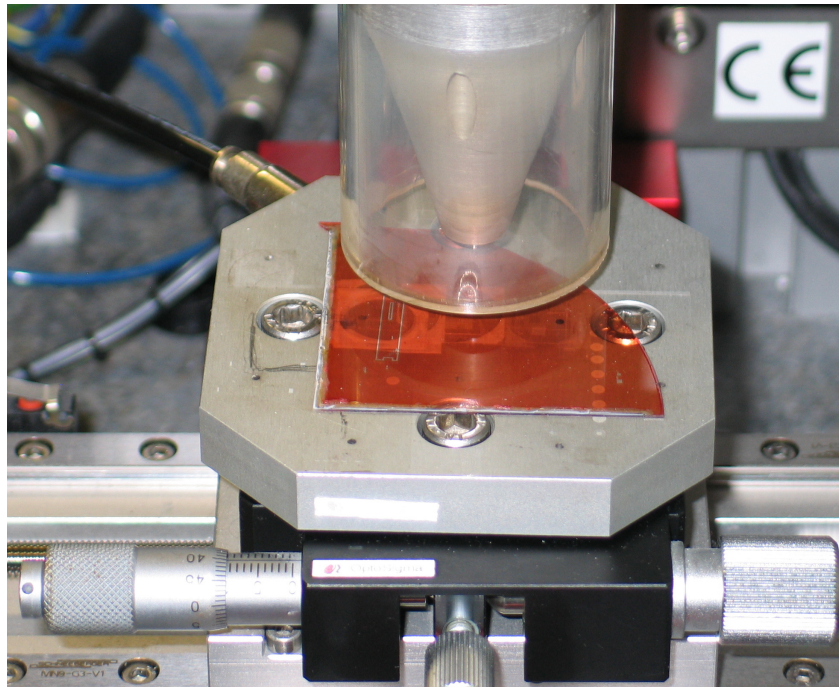


Figure 15 Laser Processing II at KIT.

7.2 DIP-PEN NANO-LITHOGRAPHY

- The fixturing methods are **mechanical, magnetic** or **none**
- The material used for the fixture is **stainless steel**
- The fixture is of **commercial** design and manufacture
- The machine is **manually** aligned for the manufacturing process
- The alignment features for the operation are on the **work piece**
- The work piece is **sometimes** transferred to another manufacturing installation
- This transfer is **not** completed in the same fixture
- The work piece receives routine **characterisation**
- The characterisation fixturing method is **mechanical** or **none**
- The material used for the characterisation fixture is **glass**
- The characterisation fixture is of **commercial** design and manufacture
- The characterisation equipment is **manually** aligned with the work piece
- The alignment features for the characterisation operation are on the **work piece**

The alignment features have to be introduced by the user directly onto the workpiece (e.g. scratches or lithographic features of previous work steps). Everything that can be seen in an optical microscope may be suitable as a fiducial mark.

The characterisation is done by optical microscopy, either upright or inverse. Bright field and fluorescence microscopy are also possible. The fixture can be therefore any standard glass slide or similar. As with the manufacturing, alignment features have to be introduced onto the sample by the user, everything visible in the optical microscope (brightfield or fluorescence) will suffice.

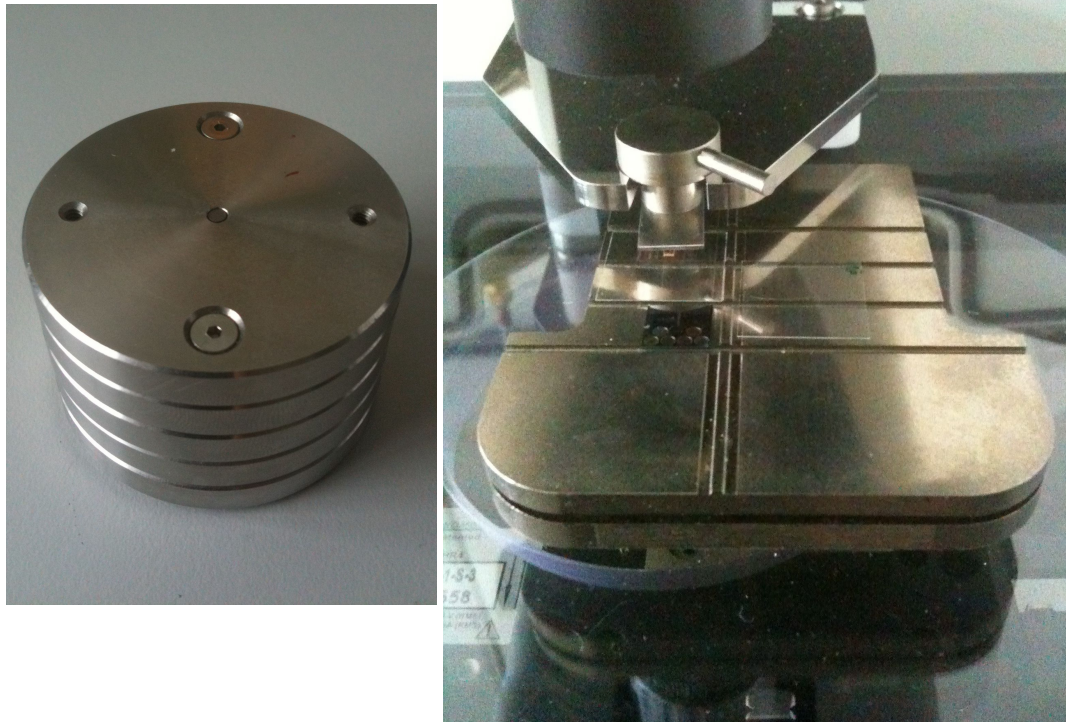


Figure 16 Dip-Pen Nano Lith at KIT.

7.3 DIRECT X-RAY LITHOGRAPHY

- The fixturing method is **mechanical**
- The materials used for the fixture are **stainless steel, titanium** and **brass**
- The fixture is of **custom** design and manufacture
- The machine is **manually** aligned for the manufacturing process
- The alignment features for the operation are on the **fixture**
- The work piece **is** transferred to another manufacturing installation
- This transfer is **not** completed in the same fixture
- The work piece receives routine **characterisation**

A commercial optical microscope is used for characterisation and no fixture is used.



Figure 17 Direct X-ray lithography at KIT – a round mask and a rectangular mask in an adapter (left) and the mask fixture (right).

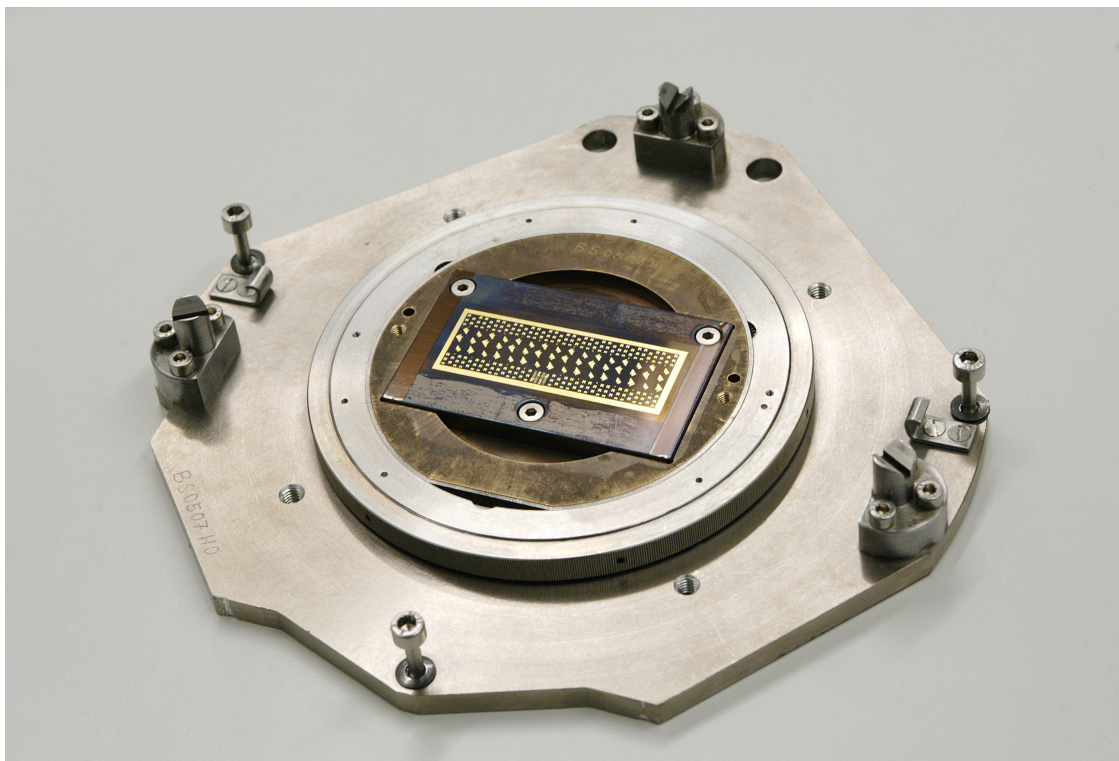


Figure 18 Direct X-Ray lithography at KIT – mask holder with assembled mask.

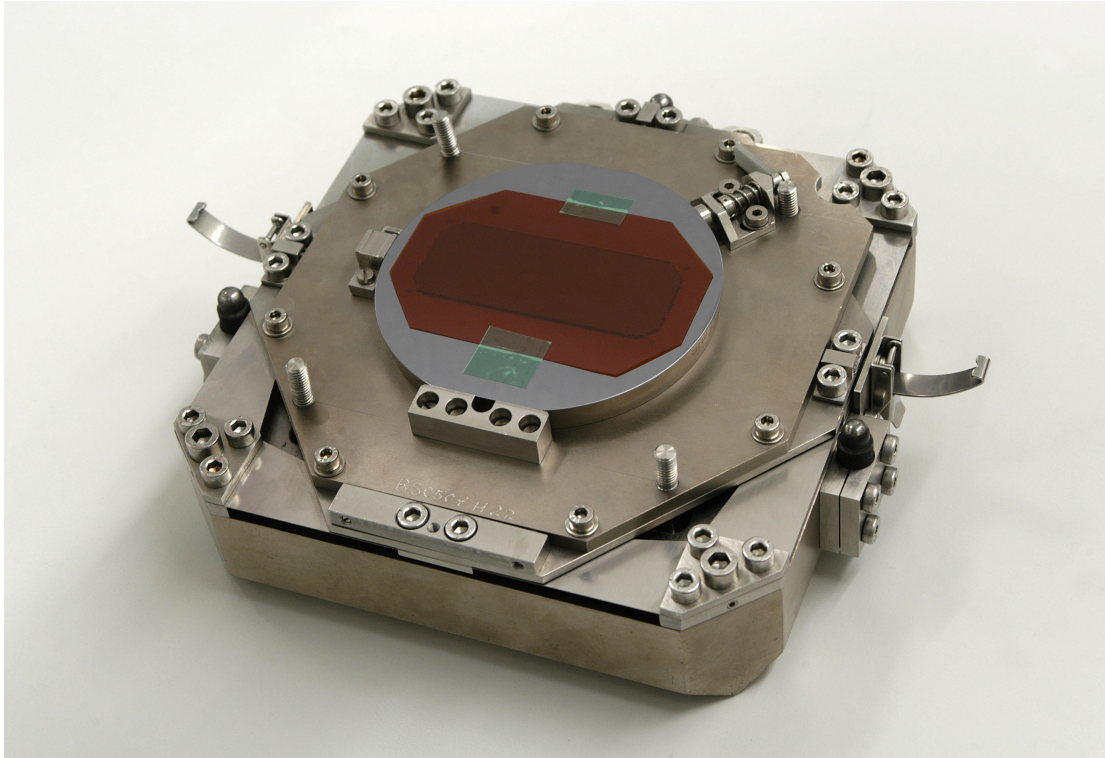


Figure 19 Direct X-Ray lithography at KIT – substrate holder with assembled 4 inch wafer.

7.4 TEM

- The fixturing method is **mechanical**
- The materials used for the fixture are **beryllium** or **copper bronze**
- The fixture is of **commercial** design and manufacture
- The machine is **manually** aligned for the characterisation process
- The alignment features for the operation are on the **work piece**

3.05 mm disk or half-disk sample is held in place by a hex-ring screw with a ~2mm hole in the middle for access. The material used for the fixture is dependant on the material nature of the work piece.



Figure 20 TEM at KIT.

7.5 E-BEAM LITH

- The fixturing method is **mechanical**
- The material used for the fixture is **aluminium**
- The fixture is of **commercial** design and manufacture
- The machine is **manually** and **automatically** aligned with the work piece
- The alignment features for the operation are on the **fixture**

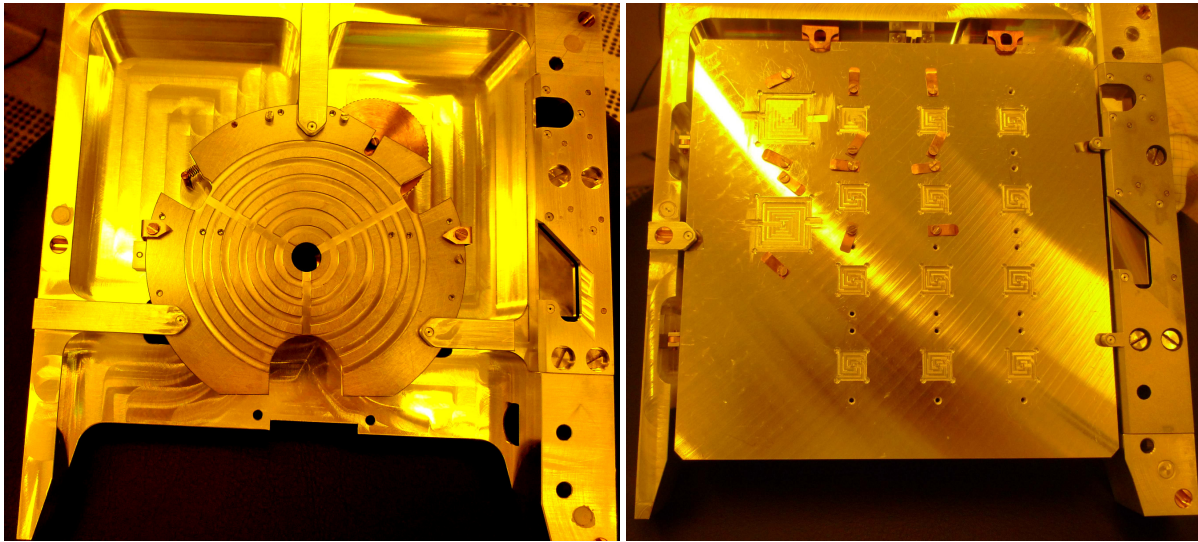


Figure 21 E-Beam Lith at KIT.

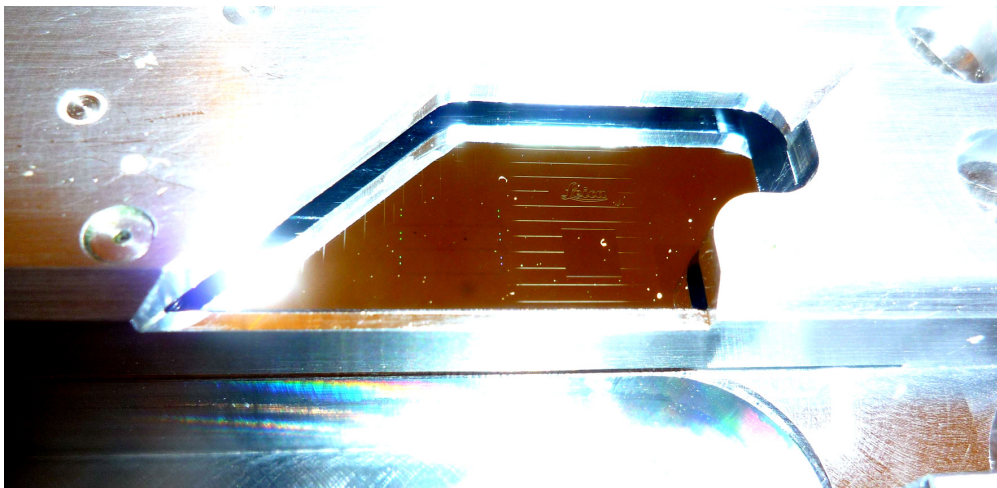


Figure 22 E-Beam Lith at KIT – a precision line scale acts as an alignment feature.

8 MIPLAZA, NL

MiPlaza (Microsystems Plaza) is part of Philips Research and provides fast and cost-effective access to the advanced technology and know-how. Located at the High Tech Campus Eindhoven, The Netherlands, MiPlaza operates in an Open Innovation environment, working with high-tech global companies, start-ups, research institutes and entrepreneurs in a networked ecosystem, forming a cradle of innovation and business creation.

The installations that were considered as part of MiPlaza's facility were:

- E-Beam – Category: Micro and Nano Patterning
- SCIL – Category: Micro and Nano Patterning
- LTPS Line – Category: Thin Film Deposition
- Nobel Metal stepper – Category: Thin Film Deposition
- Nobel metal contact aligner – Category: Thin Film Deposition
- DRIE and RIE – Category: Replication

8.1 DRIE AND RIE

There is **no fixing** used for this method of manufacture

8.2 LTPS LINE

- The fixturing method is **vacuum**
- The material used for the fixture is **stainless steel**
- The fixture is of **commercial** design and manufacture
- The machine is **manually** aligned for the manufacturing process
- The alignment features for the operation are on the **work piece**
- The work piece **is** transferred to another manufacturing installation
- This transfer is **not** completed in the same fixture
- The work piece **sometimes** receives routine **characterisation**

8.3 SCIL

- The fixturing method is **vacuum**
- The material used for the fixture is **aluminium**
- The fixture is of **custom** design and manufacture
- The machine is **manually** aligned for the manufacturing process
- The alignment features for the operation are on the **work piece**
- The work piece **is** transferred to another manufacturing installation
- This transfer is **not** completed in the same fixture
- The work piece **sometimes** receives routine **characterisation**

No alignment is made because SCIL is used for first layer deposition. Alignment to a SCIL printed layer is possible as the SCIL master includes alignment marks.

8.4 E-BEAM

- The fixturing method is **mechanical**
- The material used for the fixture is **unspecified alloy**
- The fixture is of **commercial** design and manufacture
- The machine is **automatically** aligned for the manufacturing process
- The alignment features for the operation are on the **fixture**
- The work piece **is** transferred to another manufacturing installation
- This transfer is **not** completed in the same fixture
- The work piece **sometimes** receives routine **characterisation**

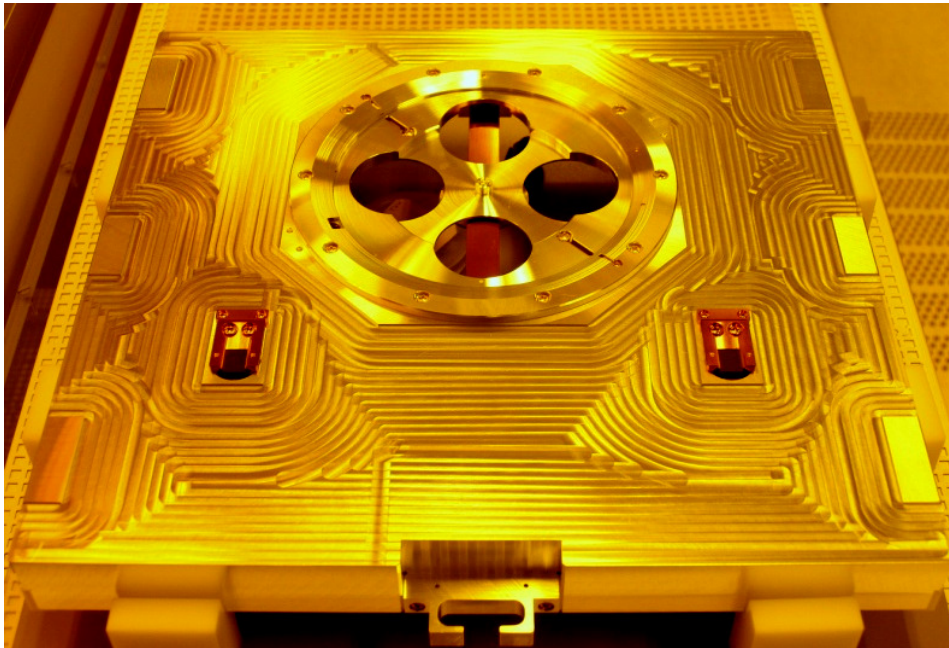


Figure 23 E-Beam and SCIL at MiPlaza – wafer holder.

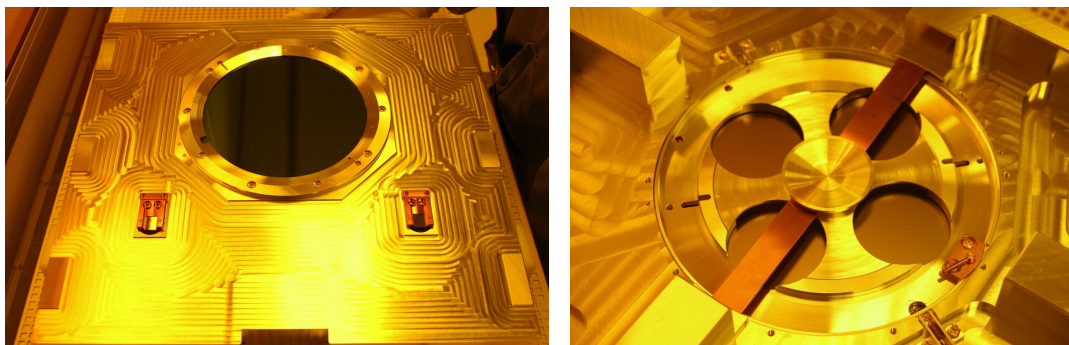


Figure 24 E-Beam and SCIL at MiPlaza – wafer holder with wafer (left) and back-side (right).

8.5 NOBEL METAL STEPPER

- The fixturing method is **vacuum**
- The material used for the fixture is **a low expansion glass**
- The fixture is of **commercial** design and manufacture
- The machine is **automatically** aligned for the manufacturing process
- The alignment features for the operation are on the **work piece**
- The work piece **is** transferred to another manufacturing installation
- This transfer is **not** completed in the same fixture
- The work piece **sometimes** receives routine **characterisation**



Figure 25 Nobel Metal Stepper at MiPlaza – stepper fixture.

8.6 NOBEL METAL CONTACT

- The fixturing method is **vacuum**
- The material used for the fixture is **steel**
- The fixture is of **commercial** design and manufacture
- The machine is **automatically** aligned for the manufacturing process
- The alignment features for the operation are on the **work piece**
- The work piece **is** transferred to another manufacturing installation
- This transfer is **not** completed in the same fixture
- The work piece **sometimes** receives routine **characterisation**

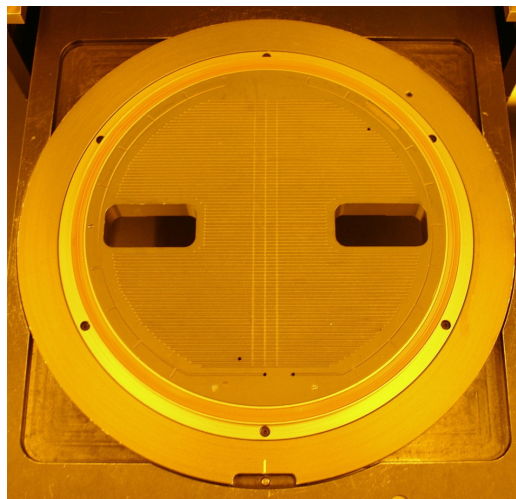


Figure 26 Nobel Metal Contact at MiPlaza – contact fixture.

9 TEKNIKER, ES

FUNDACION TEKNIKER is a private non profit Research Centre for the metalworking, automotive and aeronautic industry financed by contractual research and development activities. TEKNIKER has approximately 190 employees and 20 grant-funded students. The final aim of every activity of TEKNIKER is to increase competitiveness of metalworking, automotive and aeronautic industry by improving its technological level. The micro- and nano-technologies department at TEKNIKER covers the development of manufacturing processes to enable to generate structures in different materials on a scale from 10 nm to 100 μm . The ultimate aim is to obtain replication methods efficient enough to allow competitive mass production. The processes worked on are many and varied: nanoimprint lithography, soft lithography, UV lithography, fine deposition, plasma etching or micro-milling, micro-WEDM and laser ablation with pulses in the femtosecond range.

The installations that were considered as part of Tekniker's facility were:

- NIL Lab – Category: Micro and Nano Patterning
- ULTRA Lab – Category: Micro and Nano Patterning
- REP Lab – Category: Replication
- METRO Lab – Category: Characterisation

9.1 NIL LAB

The Tekniker NIL Lab facility contains the following facilities:

9.1.1 NIL

- The fixturing methods are **mechanical** or **none**
- The material used for the fixture is **stainless steel**
- The fixture is of **commercial** design and manufacture
- The machine is **manually** aligned for the manufacturing process
- The alignment features for the operation are on the **work piece** and on the **machine**
- The work piece is **sometimes** transferred to another manufacturing installation
- The work piece **sometimes** receives routine **characterisation**

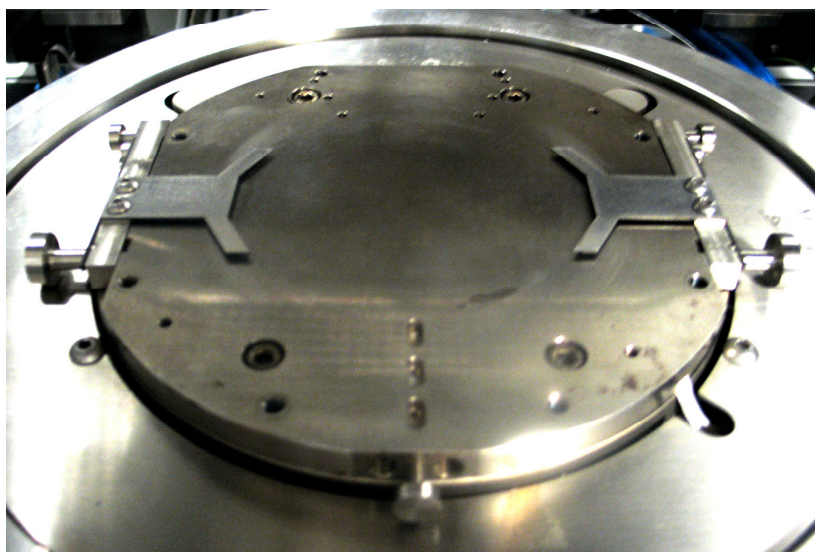


Figure 27 NIL Lab at Tekniker – NIL fixture.

9.1.2 DRIE

- The fixturing method is **mechanical**
- The material used for the fixture is **plastic**
- The fixture is of **commercial** design and manufacture
- The machine is **not** aligned with the work piece
- The work piece is **sometimes** transferred to another manufacturing installation
- The work piece **sometimes** receives routine **characterisation**

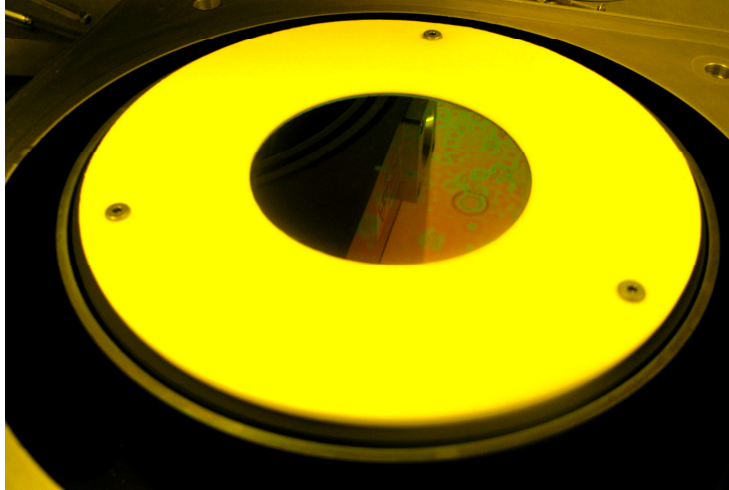


Figure 28 NIL Lab at Tekniker – DRIE fixture.

9.1.3 UV

- The fixturing method is **vacuum**
- The material used for the fixture is **plastic**
- The fixture is of **commercial** design and manufacture
- The machine is **manually** aligned for the manufacturing process
- The alignment features for the operation are on the **work piece** and on the **machine**
- The work piece is **sometimes** transferred to another manufacturing installation
- The work piece **sometimes** receives routine **characterisation**

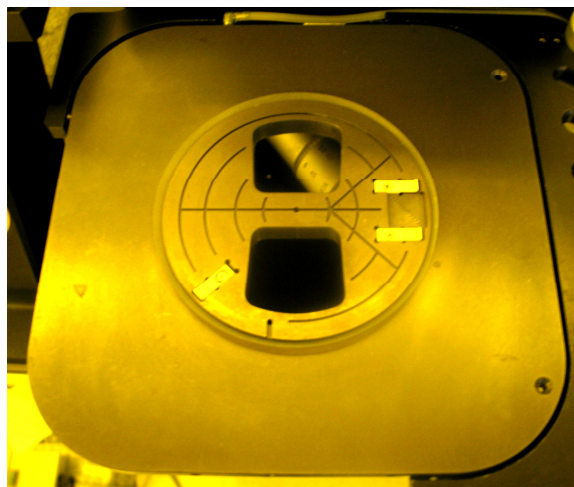


Figure 29 NIL Lab at Tekniker – UV fixture.

9.1.4 PVD

- There is **no physical** fixturing for this installation
- The material used for the fixture is **metal (stainless steel)**
- The fixture is of **custom** design and manufacture
- The machine is **manually** aligned for the manufacturing process
- The machine is **not** aligned with the work piece
- The work piece is **sometimes** transferred to another manufacturing installation
- The work piece **sometimes** receives routine **characterisation**

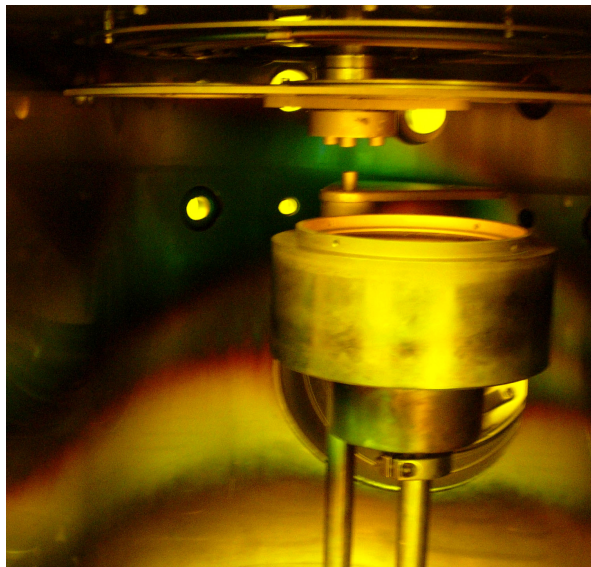


Figure 30 NIL Lab at Tekniker – PVD fixture.

9.1.5 Electroplating

- The fixturing method is **mechanical**
- The material used for the fixture is **plastic**
- The fixture is of **commercial** design and manufacture
- The machine is **not** aligned with the work piece
- The work piece is **sometimes** transferred to another manufacturing installation
- The work piece **sometimes** receives routine **characterisation**

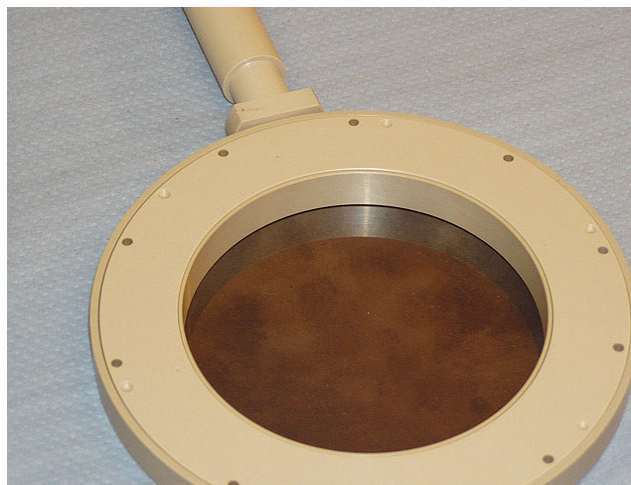


Figure 31 NIL Lab at Tekniker – electroplating fixture.

9.2 ULTRA LAB

The Tekniker NIL Lab facility contains the following facilities:

9.2.1 Diamond turning

- The fixturing method is **vacuum**
- The material used for the fixture is **aluminium**
- The fixture is of **commercial** design and manufacture
- The machine is **manually** aligned for the manufacturing process
- The alignment features for the operation are on the **work piece**
- The work piece is **sometimes** transferred to another manufacturing installation
- The work piece **sometimes** receives routine **characterisation**

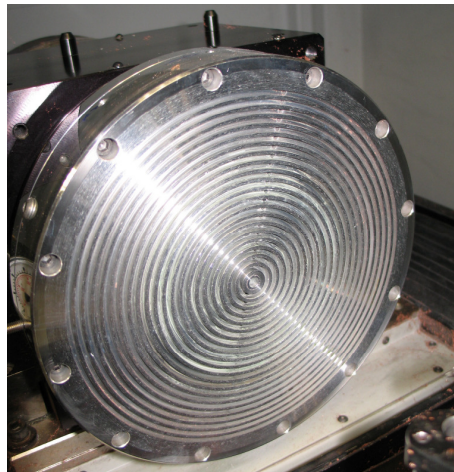


Figure 32 ULTRA Lab at Tekniker – diamond turning fixture.

9.2.2 Laser

- The fixturing method is **mechanical**
- The material used for the fixture is **aluminium**
- The fixture is of **commercial** design and manufacture
- The machine is **manually** aligned for the manufacturing process
- The alignment features for the operation are on the **work piece**
- The work piece is **sometimes** transferred to another manufacturing installation
- The work piece **sometimes** receives routine **characterisation**

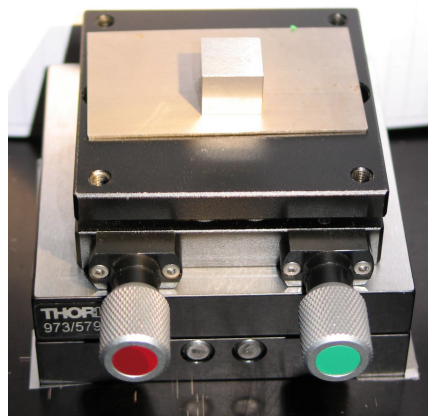


Figure 33 ULTRA Lab at Tekniker – laser fixture.

9.2.3 Micro-EDM

- The fixturing method is **mechanical**
- The material used for the fixture is **stainless steel**
- The fixture is of **commercial** design and manufacture
- The machine is **manually** aligned for the manufacturing process
- The alignment features for the operation are on the **work piece**
- The work piece is **sometimes** transferred to another manufacturing installation
- The work piece **sometimes** receives routine **characterisation**

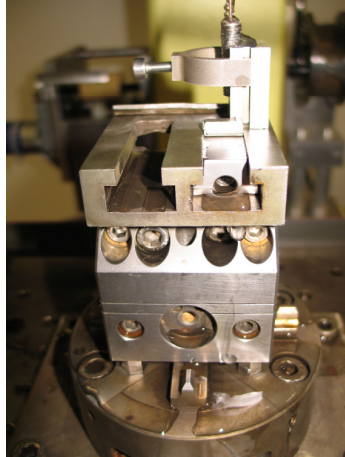


Figure 34 ULTRA Lab at Tekniker – micro-EDM fixture.

9.2.4 Micro-milling

- The fixturing method is **mechanical**
- The material used for the fixture is **stainless steel**
- The fixture is of **commercial** design and manufacture
- The machine is **manually** aligned for the manufacturing process
- The alignment features for the operation are on the **work piece**
- The work piece is **sometimes** transferred to another manufacturing installation
- The work piece **sometimes** receives routine **characterisation**



Figure 35 ULTRA Lab at Tekniker – micro-milling fixture.

9.2.5 WEDM

- The fixturing method is **mechanical**
- The material used for the fixture is **stainless steel**
- The fixture is of **commercial** design and manufacture
- The machine is **manually** aligned for the manufacturing process
- The alignment features for the operation are on the **work piece**
- The work piece is **sometimes** transferred to another manufacturing installation
- The work piece **sometimes** receives routine **characterisation**

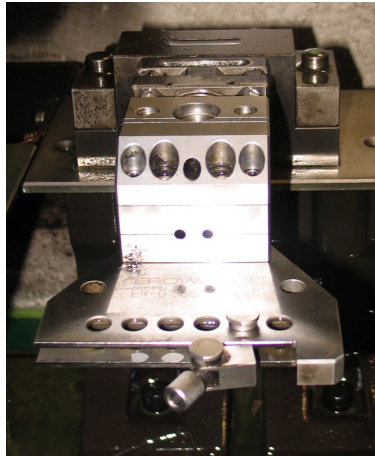


Figure 36 ULTRA Lab at Tekniker – WEDM Fixture.

9.3 REP LAB (HOT EMBOSSING)

- The fixturing method is **mechanical**
- The material used for the fixture is **stainless steel**
- The fixture is of **commercial** design and manufacture
- The machine is **manually** aligned for the manufacturing process
- The alignment features for the operation are on the **work piece**
- The work piece is **sometimes** transferred to another manufacturing installation
- The work piece **sometimes** receives routine **characterisation**

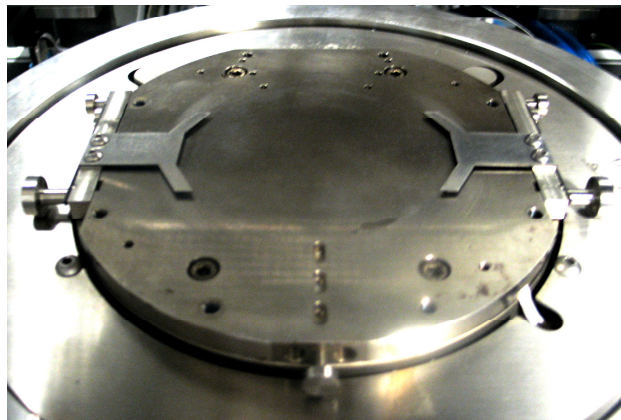


Figure 37 REP Lab at Tekniker – hot embossing fixture. Notice it is the same as the NIL fixture (Figure 27).

9.4 METRO LAB

The Tekniker METRO Lab facility contains the following facilities:

9.4.1 AFM

- There is **no physical** fixturing for this installation
- The material used for the fixture is **stainless steel**
- The fixture is of **commercial** design and manufacture
- The machine is **manually** aligned for the characterisation process
- The alignment features for the operation are on the **work piece**

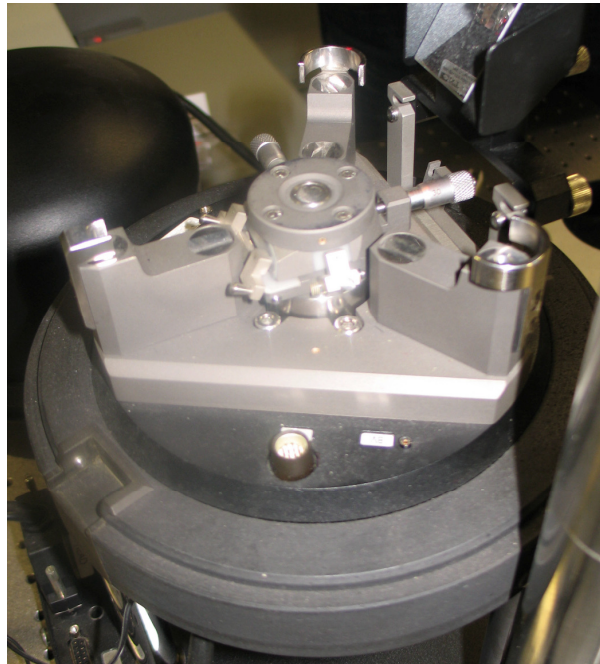


Figure 38 METRO Lab at Tekniker – AFM fixture.

9.4.2 Confocal microscope

- There is **no physical** fixturing for this installation
- The material used for the fixture is **stainless steel**
- The fixture is of **commercial** design and manufacture
- The machine is **manually** aligned for the characterisation process
- The alignment features for the operation are on the **work piece**

9.4.3 White light interferometer

- There is **no physical** fixturing for this installation
- The material used for the fixture is **stainless steel**
- The fixture is of **commercial** design and manufacture
- The machine is **manually** aligned for the characterisation process
- The alignment features for the operation are on the **work piece**

9.4.4 2D light microscope

- There is **no physical** fixturing for this installation
- The material used for the fixture is **stainless steel**
- The fixture is of **commercial** design and manufacture
- The machine is **manually** aligned for the characterisation process
- The alignment features for the operation are on the **work piece**

9.4.5 Profilometer

- There is **no physical** fixturing for this installation
- The material used for the fixture is **stainless steel**
- The fixture is of **commercial** design and manufacture
- The machine is **manually** aligned for the characterisation process
- The alignment features for the operation are on the **work piece**

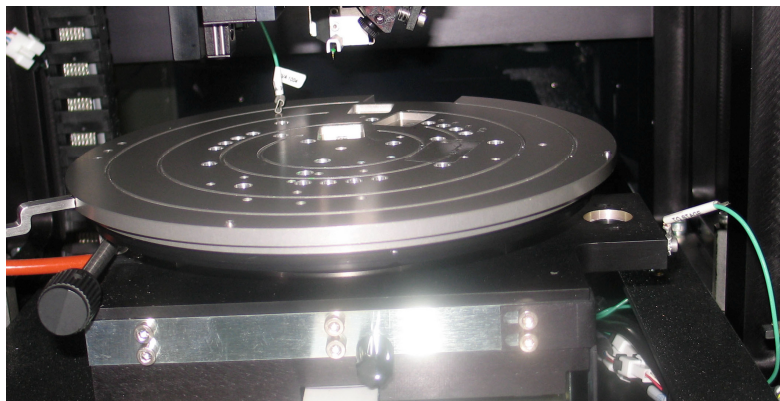


Figure 39 Metrolab at Tekniker – profilometer fixture.

9.4.6 SEM

- The fixturing method is **mechanical**
- The material used for the fixture is **aluminium**
- The fixture is of **commercial** design and manufacture
- The machine is **manually** aligned for the characterisation process
- The alignment features for the operation are on the **work piece**

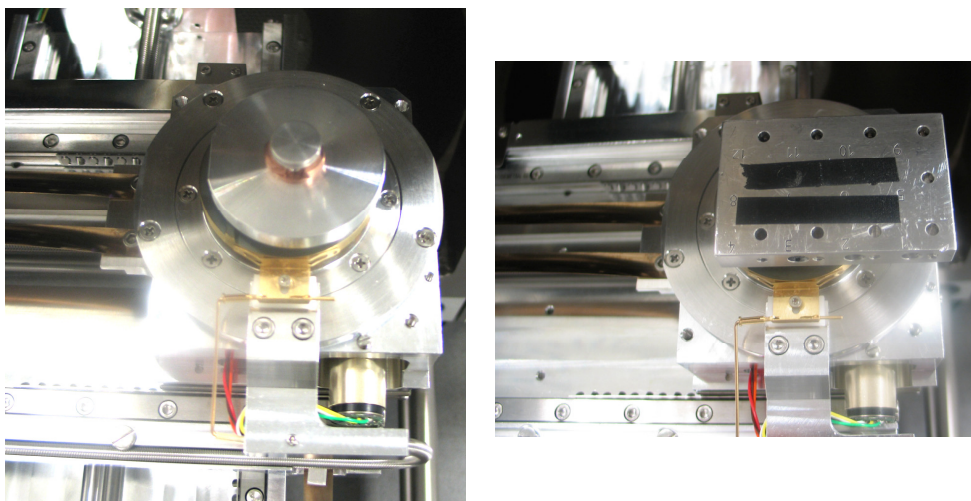


Figure 40 METRO Lab at Tekniker – SEM fixtures.

10 NATIONAL PHYSICAL LABORATORY, UK

The National Physical Laboratory (NPL) is the UK's National Measurement Institute, a world-leading centre of excellence in developing and applying the most accurate measurement standards, science and technology. NPL develops and maintains the UK's primary measurement standards. These standards underpin an infrastructure of traceability throughout the UK and the world that ensures accuracy and consistency of measurement. NPL is based in Teddington, South West London, and employs over 600 staff, including 450 research scientists and engineers, of which over 500 are degree or PhD qualified. The Engineering Measurement Division provides a comprehensive range of high quality research, measurement, calibration and consultancy services in the areas of dimensional, force, humidity, mass, temperature and torque metrology. In the dimensional area, research builds on this core measurement expertise to focus on micro-scale, nano-scale and large-scale metrology, and in-process freeform metrology. Scientific research programmes at NPL are funded both by the UK Government and other parties.

The installation that was considered as part of NPL's facility was:

- Metrology

10.1 METROLOGY AT NPL

At NPL, the following micro- and nano-metrology facilities are available for transnational access:

10.1.1 NanoSurf IV

- There is **no physical** fixturing for this characterisation installation
- The material used for the characterisation fixture is **Zerodur**
- The characterisation fixture is of **custom** design and manufacture
- The characterisation equipment is **manually** aligned with the work piece
- The alignment features for the characterisation operation are on the **work piece**

NanoSurf IV is the UK's primary instrument for surface texture. This instrument measures only standard artefacts of specific dimensions and quality. It is used to calibrate transfer standards, which are in turn used to calibrate commercial machines (optical and tactile). Measurements made using NanoSurf IV guarantees are traceable.

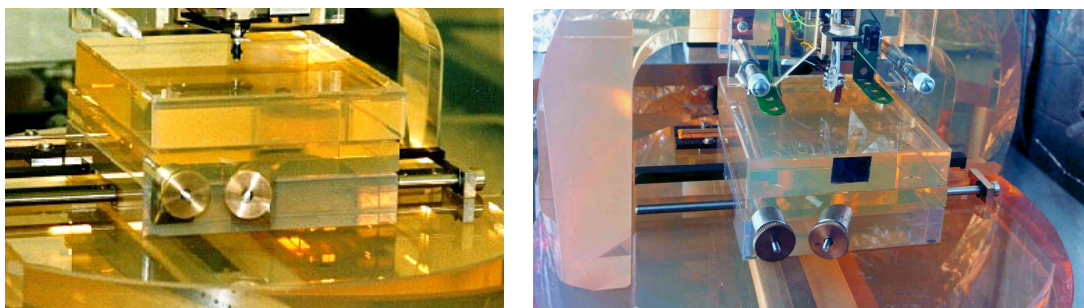


Figure 41 Metrology at NPL – NanoSurf IV zerodur work piece platform (two views).

10.1.2 Metrological AFM

- There is **no physical** fixturing for this characterisation installation
- The materials used for the characterisation fixture are **Zerodur** and **Invar**
- The characterisation fixture is of **custom** design and manufacture
- The characterisation equipment is **manually** aligned with the work piece
- The alignment features for the characterisation operation are on the **work piece**

The NPL Metrological AFM is the UK's primary instrument for atomic force microscopy. This instrument measures only standard artefacts of specific dimensions and quality. It is used to calibrate transfer standards, which are in turn used to calibrate commercial AFMs. Measurements made using the Metrological AFM are traceable.

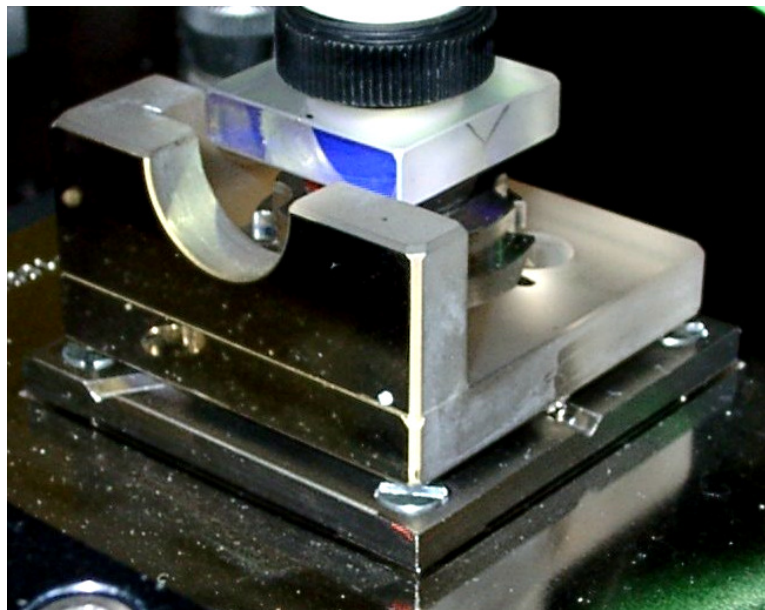


Figure 42 Metrology at NPL – the NPL Metrological AFM sample holder.

10.1.3 Ellipsometer

- The characterisation fixturing method is **vacuum**
- The material used for the characterisation fixture is **stainless steel**
- The characterisation fixture is of **commercial** design and manufacture
- The characterisation equipment is **automatically** aligned with the work piece
- The alignment features for the characterisation operation are on the **work piece**

10.1.4 NPL Areal Instrument

- There is **no physical** fixturing for this characterisation installation
- The materials used for the characterisation fixture are **Zerodur** and **Invar**
- The characterisation fixture is of **custom** design and manufacture
- The characterisation equipment is **manually** aligned with the work piece
- The alignment features for the characterisation operation are on the **work piece**

The NPL Areal Instrument is the UK's primary instrument for areal surface texture. This instrument measures only standard artefacts of specific dimensions and quality. It is used to calibrate transfer standards, which are in turn used to calibrate commercial machines (optical and tactile). Measurements made using the NPL Areal Instrument are traceable.

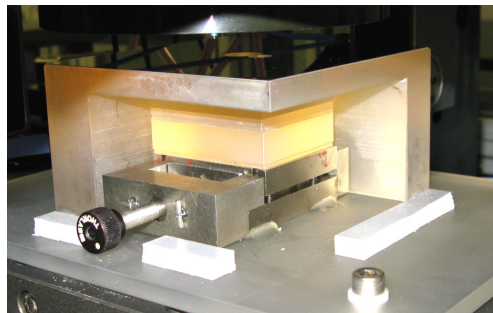


Figure 43 Metrology at NPL – the NPL Areal Instrument.

10.1.5 Vertical scanning white light interferometer (WLI)

- There is **no physical** fixturing for this installation
- The material used for the characterisation fixture is **metal**
- The characterisation fixture is of **commercial** design and manufacture
- The characterisation equipment is **manually** aligned with the work piece
- The alignment features for the characterisation operation are on the **work piece**

The WLI is a commercial machine used for surface texture and step height measurement. It is verified by measuring a transfer standard that has been calibrated on a primary machine (such as NanoSurf IV or the NPL Areal Instrument). Measurements on this machine are taken in accordance with NPL's Good Practice Guide for the Measurement of Smooth and Rough Surface Topography using Coherence Scanning Interferometry (NPL Good Practice Guides 108 and 116).

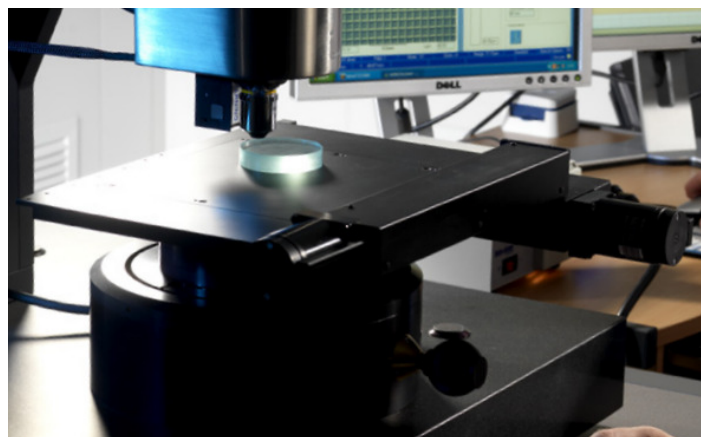


Figure 44 Metrology at NPL – the precision 5 DOF stage for the NPL WLI.

10.1.6 Micro-CMM

- The characterisation fixturing method is **mechanical**
- The material used for the characterisation fixture is **metal, plastic and ceramic**
- The characterisation fixture is of **commercial** and **custom** design and manufacture
- The characterisation equipment is **manually** and **automatically** aligned with the work piece
- The alignment features for the characterisation operation are on the **work piece** or **the fixture**

The NPL micro-CMM is a highly versatile coordinate measuring machine, ideal for geometrical verification of work-pieces. A wide range of fixtures are available, the choice of which is dependent on the measurements required. Alignment can be manual or automatic, using alignment features on the work piece or on the fixture. Ideally, measurements should be completed with identical datums to the manufacturing process.

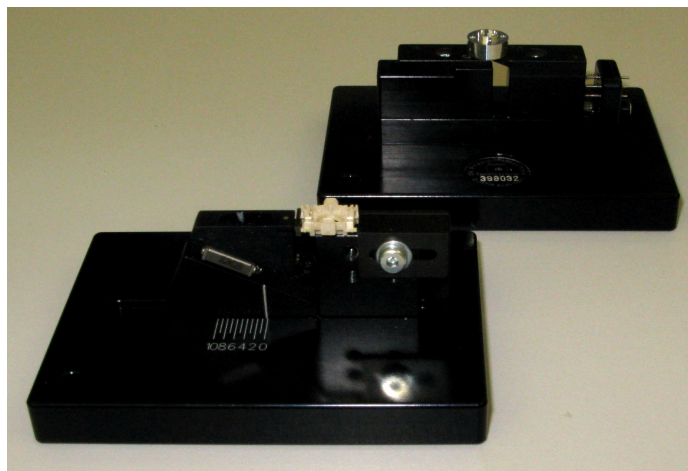


Figure 45 Metrology at NPL – micro-CMM fixtures for high force (back) and low force (front) mechanical fixturing.

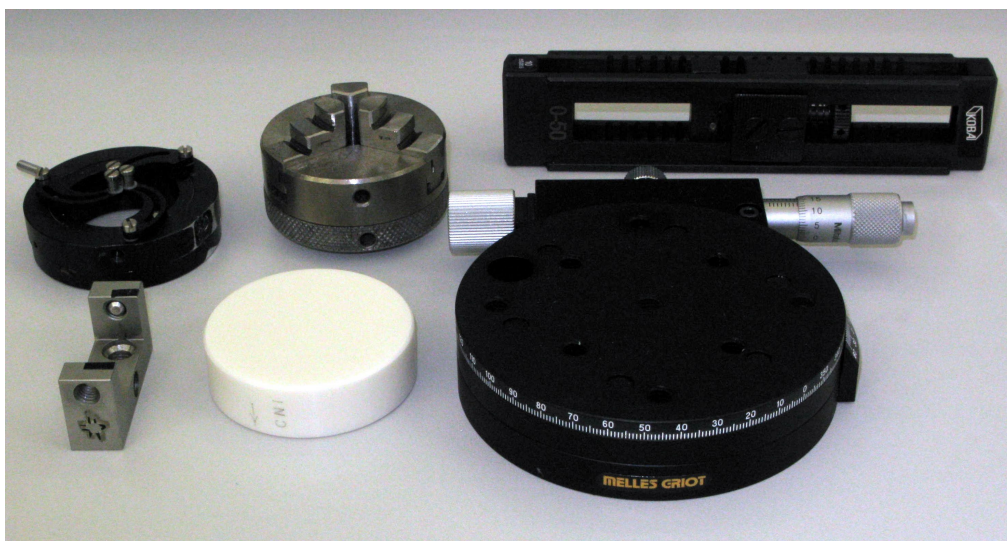


Figure 46 Metrology at NPL – general fixtures for the micro-CMM, including a micro-chuck, a rotation stage and a precision flat.

10.1.7 NPL Low Force Balance

- The characterisation fixturing method is **mechanical** or **none**
- The material used for the characterisation fixture is **low expansion metal**
- The characterisation fixture is of **custom** design and manufacture
- The characterisation equipment is **manually** aligned with the work piece
- The alignment features for the characterisation operation are on the **work piece**

The NPL Low Force Balance is the UK's primary instrument for low force measurement. It is used to calibrate transfer standards, which are in turn used to calibrate commercial machines. The NPL Low Force Balance guarantees that measurements taken at NPL are fully traceable. The NPL Low Force Balance is available for calibration of both of static masses and dynamic transducers.

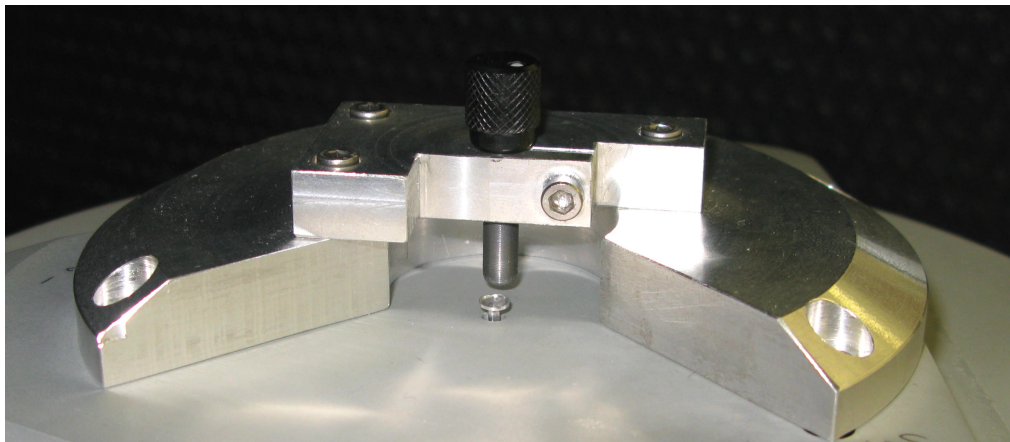


Figure 47 Metrology at NPL – Low Force Balance. The weighing platen is directly below the removable restraining screw.



Figure 48 Metrology at NPL – Low Force Balance. Multiple fixtures can be easily attached above the weighing platen.

11 DISCUSSION

In the previous sections of this report, the technical capabilities of the EUMINAfab partners have been described. The amount of information available in this report is extensive and, therefore, it is essential that this information be broken down into several understandable headings, which will hopefully prove useful for other partners.

The full data set is represented in a condensed form in Table 1.

Table 1 The results of the fixturing investigation. Key: M=micro- to nano-scale patterning, T=Thin film deposition, R=Replication, C=Characterisation, Me=Mechanical, V=Vacuum, Ma=Magnetic, O=Other, Na=None, Met=Metal, Ce=Ceramic, P=Plastic, Cu=Custom, Co=Commercial, Man=Manual, A=Automatic, Wp=on the Work piece, F=on the Fixture, Mac=on the Machine, Y=Yes, N=No, S=Sometimes and ?=Unknown.

Installation	Organisation	Category	Method	Material	Availability	Alignment	Alignment Features	Other Manufacturing	Same Fixture	Routine C	C Method	C Material	C Availability	C Alignment	C Alignment features
CHARPAN	IMS	M	Me	Met	Cu	Man	F, Mac	N		Y	Me	Me	Co	Man	
Dip-Pen nano-Lith	KIT	M	Me, Ma	Met	Co	Man	Wp	S	N	Y	Me, Na	O	Co	Man	Wp
Direct X-Ray Lith	KIT	M	Me	Met	Cu	Man	F	Y	N	Y	Na				
DRIE and RIE	MiPlaza	R	Na												
E-Beam Lith	KIT	M	Me	Met	Co	Man, A	F	?							
E-Beam	MiPlaza	M	Me	Met	Co	A	Wp, F	Y	N	S					
Electro-optical C	CRF	C									Me	Met	Co	Man	Wp
FIB/SEM Cross Beam	MEC	M	Me	Met	Co	Man	Wp	S	N	S	Me	Me	Co	Man	Wp
Laser Processing I	MEC	M	Me, V	Met, Ce, P	Cu	Man	Wp, F	Y, S	Y, S	N					
Laser processing II	KIT	M	V	Met	Co	Man	Wp	N		Y	Me	Me	Co	Man	Wp
LTPS Line	MiPlaza	T	V	Met	Co	Man	Wp	N	S						
Mastermaking	MEC	M	Me, Ma	Met	Co, Cu	Man, A	Wp	S	N	S					
METROLAB	Tekniker	C									Me, Na	Met	Co	Man	Mac
Micro-nano imprinting	MEC	R	V	Met	Cu	A	Wp	?	N						
NIL	Tekniker	M	Me, V, O, Na	Met, P	Co, Cu	Man	Wp, Mac	S		S					
Nobel metal Contact	MiPlaza	T	V	Met	Co	Man	Wp	Y	N	S					
Nobel metal Stepper	MiPlaza	T	V	Ce	Co	A	Wp	Y	N	S					
PVD-Cluster	CRF	T	Me	Met	Cu	Man		S	S	S					
REP	Tekniker	R	Na	Met	Co	Man	Wp	S		S					
SCIL	MiPlaza	M	V	Met	Cu	Man	Wp	Y	N	S					
Screen printing	CRF	R	V	P	Co	Man, A	Wp	S	S	S					
Self assembly	CRF	T	Me	Met, P	Cu	Man		N		S					
TEM	KIT	C									Me	Met	Co	Man	Wp
ULTRA	Tekniker	M	Me, V, O	Met	Co	Man	Wp	S		S					

11.1 DATA ANALYSED BY CATEGORY

The four categories of facility made available for transnational access by EUMIN*fab* (micro- to nano-scale patterning, thin film deposition, replication and characterisation) will be investigated cross-partner to analyse fixturing trends in similar technologies.

11.1.1 Micro- to nano-scale patterning

This is the most extensive of the four categories, incorporating over fifteen separate installations across the partners. These facilities can be split into two distinct groups: classical physical machining (turning, milling, EDM, laser machining, etc.) and lithographic processes. The major differences between these two groupings are resolution and minimum feature size; for classical machining processes the minimum feature size is several micrometres, and for lithographic processes the minimum feature size is several nanometres (in some cases, the minimum feature size for lithographic processes is sub-nanometre). For micro-to nano-scale patterning, the fixturing technology seems to be mostly split along the lines of this grouping. The most used fixturing method for micro- to nano-scale patterning is mechanical fixing, using metal fixtures.

When lithographic processes are being conducted, a precision fixture is used. This fixture is usually custom designed and manufactured and usually contains registration marks for reliable and/or automatic alignment. When more classical machining methods are being used, the fixtures are less refined and are more concerned with the safe and secure clamping of the part. Alignment for these more classical machining processes is usually taken manually and off the work piece.

11.1.2 Thin film deposition

These set of processes tend to prepare substrates for subsequent manufacturing steps (in preparation for lithography) or to deposit layers on already existing structures. Fixturing for these processes are usually used for immobilising the work piece within the deposition chamber. Alignment for these processes is usually manual and taken from features on the work piece (if alignment is taken at all). Even though subsequent steps are carried out on the work pieces, the fixture used in this step is not usually suitable for use in subsequent manufacturing steps. The technology used in the fixture is closely related to the nature of the work piece; mechanical fixturing used for metallic, ceramic and bulk work pieces and vacuum fixturing for silicon wafers.

11.1.3 Replication

This set of processes is least reliant on fixturing, with some of the installations not having any fixturing at all (in the classical sense). The imprinting-style installations have nominal mechanical or vacuum fixtures that are used to restrain the substrate, however, because of the nature of hot embossing and most imprinting operations, no precision is obtained from the fixturing itself, but rather from the manufacturing process.

11.1.4 Characterisation

This category of processes represents a varied set of characterisation methods, including qualitative and quantitative metrology, tactile and optical metrology and several microscopy facilities. Even though only four partners offer specific characterisation installations, all partners were questioned on their metrological processes, specifically if routine characterisation was carried out on the work piece after a manufacturing process was completed. All fixtures used by characterisation installations (if used at all) are used for simple restraint purposes; force closure against the probing forces of the characterisation equipment. For optical characterisation, fixturing is rarely used. Also, apart from the custom built primary machines at NPL, all characterisation is completed in commercial fixtures, either those supplied with the machine or suitable mechanical restraints.

11.2 DATA ANALYSED BY PARTNER

Although Sections 4 to 10 presented the fixturing of each partner, some partners have standard fixturing practices that should be highlighted.

11.2.1 Karlsruhe Institute of Technology

Focusing on the micro- to nano-scale patterning installations, the mechanical fixtures from KIT are of particularly high quality. This allows many of the manufacturing processes to be automated, with alignment features being on the fixture itself. Their work pieces also always undergo routine characterisation, an essential process that is only carried out at KIT and IMS (it must be noted that occasional characterisation is carried out on work pieces by all partners).

11.2.2 MiPlaza

With installations that cover all three manufacturing categories, the most common fixturing method at MiPlaza is commercially produced vacuum (or air pressure) fixtures. Most of the installations produce work pieces that are transferred to subsequent manufacturing steps. However, the work piece is transferred to a new fixture specific to each installation. Also, despite the high quality of the fixtures used, most installations take alignment features off the work piece (this is probably a feature of the lithographic processes completed at MiPlaza).

11.2.3 NPL

NPL is a partner (along with IMS) that focuses on only one category of installation. In NPL's case this category is characterisation. Certain limitations are placed on the method of fixturing depending on the type of characterisation being performed (for example, magnetic fixturing may interfere with precision instrumentation), however, NPL makes use of mechanical and vacuum fixturing. A common request from NPL when setting up a measurement (especially measurements of geometric features) is that the fixture be described, along with any datum features. If possible, the part should be supplied with its fixture.

11.3 DATA ANALYSED BY FEATURE

There are certain design features that can be included in a fixture that can assist with specific process steps in manufacturing or characterisation. The questionnaire aimed to gather information on some of the features universal to most manufacturing fixtures so that they could be compared across the partners.

11.3.1 Fixturing method

The most common fixturing method was mechanical and was predominantly used for micro- to nano-scale patterning processes. However, the micro- to nano-scale patterning category of installations also made use of all reported fixturing methods (mechanical, vacuum, magnetic, no fixing and other). The next most common fixturing method was vacuum or air pressure restraint, which was most common for thin film deposition processes. Also, vacuum fixturing seems to be the most versatile of all fixturing methods, being used across all installations categories.

In some respects, there was good correlation between manufacturing processes and fixturing method, however, the correlation is not exact. Because of the nature of fixturing design, this outcome was somewhat expected.

11.3.2 Materials

The most common materials used were stainless steel and aluminium. Material considerations are dependant on the material properties, the manufacturing process (especially as it could be damaging to the fixture) and the machineability of the material. For high accuracy metrological facilities, low expansion materials such as Invar and Zerodur are also widely used.

11.3.3 Commercial against custom

The design and manufacture of the fixtures reported by the partners is quite evenly split between commercially available fixtures and custom made fixtures. One interesting correlation is that custom made fixtures tend to have been designed to include alignment features for easy automated alignment.

11.3.4 Alignment

Alignment is arguably one of the most important functions a fixture used for manufacturing must perform. This is especially true in micro-nano manufacturing. Predominantly, alignment is completed manually; three installations reported only automated alignment (and three installations reporting both manual and automatic alignment used). Fixtures whose alignment is automated tend to be made of metal, and rely on mechanical or vacuum restraint. As stated in section 11.3.3, fixtures with features to facilitate automated alignment tend to be custom designed and manufactured.

11.3.5 Subsequent steps

Given the nature of micro-nano manufacturing, it is likely that a work piece will need to be completed through multiple process steps. Only four of the installations do not pass work pieces on for subsequent manufacturing. However, of all the installations that pass work pieces on for subsequent manufacturing, only one does so in the same fixture (three installations indicated that they sometimes use the same fixture for subsequent manufacturing). If subsequent manufacturing steps are common and if the fixturing used is suitable, it seems useful to reuse the same fixture as often as possible, especially if alignments can be unified.

11.3.6 Characterisation

Given the size of the features being produced, micro and nano metrology will be of great importance to any manufacturer to enable them to reliably verify the success of their manufacturing process. However, only four of the installations carry out regular characterisation on their work pieces as routine (it must be noted that occasional characterisation is carried out on work pieces by all partners in all installations). If characterisation could be easier to complete, perhaps through the use of the same fixture, then perhaps routine characterisation would become more commonplace. It must also be noted that some verification for micro and nano work pieces, or work pieces with micro and nano features, can also be completed through functional testing. However, in the event of a failed functional test, limited information can be extracted on the responsible manufacturing process. This can only be yielded through traceable metrology.

12 CONCLUSIONS

The area of fixture design is a well-established field, however, it is clear from this report that there is no single universal design and manufacture route for fixtures. Even when investigating a highly specialised and similar set of manufacturing installations, over forty-five different fixtures are regularly used. From the extensive array of fixturing technologies used, it is suggested that the selection of fixtures, or their design, manufacture and use, is still heavily reliant on prior knowledge and experience.

Future work to assist in the development of the fixturing capabilities of the EUMINAfab consortium should be:

- investigating the possibility of streamlining some fixtures to be used in manufacturing as well as characterisation installations;
- investigating the possibility of using single fixtures for multiple manufacturing processes, if multiple steps are common; and
- assisting in the design, manufacture and verification of new fixtures, especially their positional accuracy and repeatability.

“A successful fixture design is the result of the designer’s ability to analyse all information and conditions which are in any way pertinent to a given manufacturing operation and to incorporate design features that offset or eliminate all difficulties or problems associated with the operation.”

Frank W. Wilson, ASTME

13 ACKNOWLEDGEMENTS

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APPENDIX 1 – THE QUESTIONNAIRE



Fixturing questionnaire

Please fill out one questionnaire for **each** manufacturing and inspection installation offered by your organisation to EUMINAFab:

Name of installation:

.....

For all queries, or if you think that this questionnaire would be better filled out during a visit to your facilities, please contact:

James Claverley
Research Scientist
Engineering Measurement Division, National Physical Laboratory
F5-A4 | Hampton Road | Teddington | Middlesex TW11 0LW | United Kingdom
+44 20 8943 6242 | james.claverley@npl.co.uk | www.npl.co.uk

Organisation name:

.....

Contact name:

.....

Contact details:

.....

Category of installation:

- ☐ Micro-nano-patterning – please complete section 1
- ☐ Thin film deposition – please complete section 1
- ☐ Replication – please complete section 1
- ☐ Characterisation – please complete section 2 only

National Physical Laboratory, Hampton Road, Teddington, Middlesex, United Kingdom, TW11 0LW
Switchboard 020 8977 3222 NPL Helpline 020 8943 6880 Fax 020 8614 0446 E-mail enquiry@npl.co.uk www.npl.co.uk

The National Physical Laboratory is operated on behalf of the National Measurement Office by NPL Management Limited, a wholly owned subsidiary of Serco Group plc

EUMINAfab fixturing questionnaire

SECTION 1 – Manufacturing installation

Please insert some pictures of the fixture/fixtures used to hold the work piece.

Please insert picture names here (i.e. picture1.jpg). Attach your pictures to your email reply

What is the fixing method?

(you may tick more than one box)

- ☐ Mechanical
- ☐ Hydraulic
- ☐ Magnetic
- ☐ Electro-magnetic
- ☐ Electro-mechanical
- ☐ Pneumatic
- ☐ Vacuum
- ☐ Other; please specify: Enter text here
- ☐ No fixing (please fill out the remainder of the form with regards to any platform on which the work piece is placed)

What materials is the fixture made of?

(you may tick more than one box)

- ☐ Metal
Please specify: Enter text here
- ☐ Ceramic
Please specify: Enter text here
- ☐ Plastic
- ☐ More than one material
Please specify: Enter text here
- ☐ Other
Please specify: Enter text here

Is the fixture commercially available or is it of custom design and manufacture?

(you may tick more than one box)

- ☐ Commercially available
- ☐ Custom design and manufacture

Please attach copies of any technical documentation, engineering drawings and user manuals that you may have for the fixture

EUMINAfab fixturing questionnaire

How is the machine aligned with the work piece?

(you may tick more than one box)

- ☐ Manually
☐ Automatically

Where are the alignment features?

(you may tick more than one box)

- ☐ On the work piece
☐ On the fixture
☐ On the machine

Please insert a picture of the alignment features: Please insert picture name here (i.e. picture2.jpg). Attach your picture to your email reply

Is the output of the manufacturing installation transferred to any other manufacturing installation?

- ☐ Yes
☐ No
☐ Sometimes
☐ I don't know

If Yes, is the same fixture used?

- ☐ Yes
☐ No
☐ Sometimes
☐ I don't know

Does the work piece receive any routine characterisation?

☐ Yes – Please continue to section 2

- ☐ No
☐ Sometimes
☐ I don't know

} – Thank you for filling out this questionnaire

EUMINAfab fixturing questionnaire

SECTION 2 – Characterisation installation

Please insert some pictures of the fixture/fixtures used to hold the work piece.

Please insert picture names here (i.e. picture3.jpg). Attach your pictures to your email reply

What is the fixing method?

(you may tick more than one box)

- ☐ Mechanical
- ☐ Hydraulic
- ☐ Magnetic
- ☐ Electro-magnetic
- ☐ Electro-mechanical
- ☐ Pneumatic
- ☐ Vacuum
- ☐ Other; please specify: Enter text here
- ☐ No fixing (please fill out the remainder of the form with regards to any platform on which the work piece is placed)

What materials is the fixture made of?

(you may tick more than one box)

- ☐ Metal
Please specify: Enter text here
- ☐ Ceramic
Please specify: Enter text here
- ☐ Plastic
- ☐ More than one material
Please specify: Enter text here
- ☐ Other
Please specify: Enter text here

Is the fixture commercially available or is it of custom design and manufacture?

(you may tick more than one box)

- ☐ Commercially available
- ☐ Custom design and manufacture

Please attach copies of any technical documentation, engineering drawings and user manuals that you may have for the fixture

EUMINAf^{ab} fixturing questionnaire

How is the machine aligned with the work piece?

(you may tick more than one box)

- ☐ Manually
- ☐ Automatically

Where are the alignment features?

(you may tick more than one box)

- ☐ On the work piece
- ☐ On the fixture
- ☐ On the machine

Please insert a picture of the alignment features: Please insert picture name here (i.e. picture4.jpg). Attach your picture to your email reply