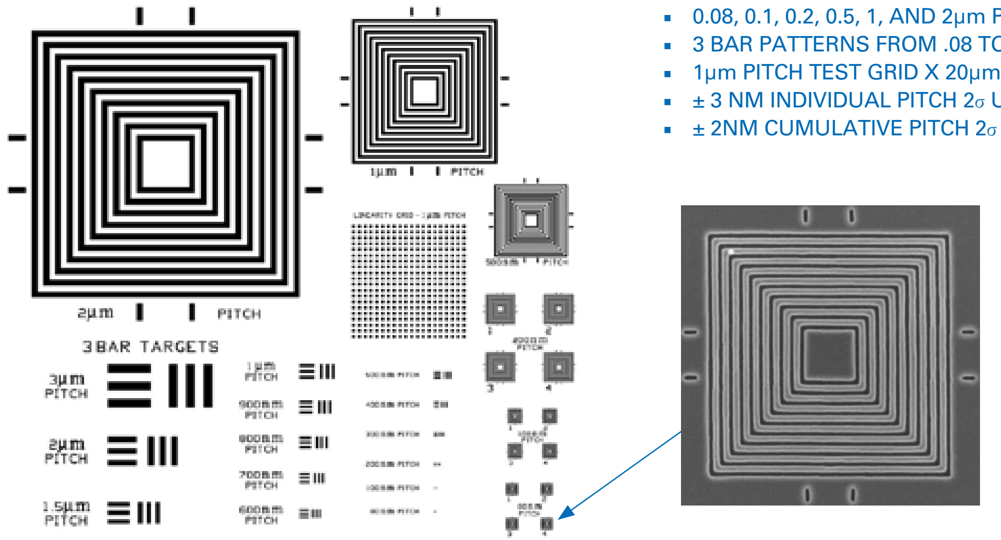
# MRS-6 MAGNIFICATION REFERENCE STANDARD

*Fourth Generation, NIST and NPL (NIST Counterpart in the UK) Traceable, Magnification Reference Standard and Stage Micrometer. For Instrument Calibration from 1,500x – 1,000,000x (80nm min. pitch).*




- 0.08, 0.1, 0.2, 0.5, 1, AND 2µm PITCH PATTERNS
- 3 BAR PATTERNS FROM .08 TO 3µm
- 1µm PITCH TEST GRID X 20µm
- ± 3 NM INDIVIDUAL PITCH 2σ UNCERTAINTY!
- ± 2NM CUMULATIVE PITCH 2σ UNCERTAINTY

## INTRODUCTION

Introducing the MRS-6, the next level in a series of magnification calibration standards (the MRS-1, MRS-3 and MRS-4 are currently still available). The MRS series of calibration standards are highly accepted pitch standards, with well over 1,000 being used in laboratories around the world including national laboratories in the US, UK and Germany. Industrial customers include Intel, AMD, and IBM. The MRS-6 is offered as a certified reference material (a traceable standard) or, optionally, without traceability. Also offered is a cleaning service and a recertification program, as required by international quality standards such as ISO, QS-9000 and ISO-17025.

This is the next generation, NIST and NPL (NIST counterpart in the U.K.) Traceable, Magnification Reference Standard and Stage Micrometer. For instrument calibration from 1,500x – 1,000,000x (80nm min. push).

- Electron Microscopy: SEM and FIB/SEM (secondary & backscattered electrons), TEM (for use with a bulk holder) the MRS-6 is conveniently sized at 3.2 x 3.2 x 0.5mm.
- Scanning Microscopies and Profilometry: STM, AFM, stylus and optical, etc. The pattern height is approximately 15nm.
- Optical Microscopy: reflected, bright/dark field, differential contrast, and confocal.
- Chemical Mapping: EDS, WDS, Micro/Macro XRF, XPS, Auger, and others. The pattern is fabricated using 15nm chromium over single crystal silicon.
- Resolution Testing: With a series of 2 bar targets (similar to the USAF 1953 patterns) ranging in size from 80nm to 3µm.
- Linearity Testing: With a 1µm$^2$ pitch over 40 x 40µm.
- A Standard Ahead of Its Time: The MRS-6 represents a challenging next step. The nanotechnology sized patterns will be a good test of your imaging systems.
- Advanced Optical Microscopes now have submicrometer test patterns to measure resolution and linearity.
- Scanning Electron Microscopes have a pattern that will show significant differences between backscattered and secondary electron type I and type II images. Imaging the pattern will also tax their low accelerating voltage capabilities.
- Scanning Probe Microscopes have a pattern that is closely sized to the finest cantilever tips challenging their resolution ability.

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## PATTERN DESIGN

The MRS-6 is fabricated by using the highest accuracy electron direct write semiconductor manufacturing equipment available today. The pattern is built on a silicon wafer with a 15nm Cr film. This film, which is significantly thinner that that of the MRS-5 has superior edge quality. Imaging contrast in both secondary and backscattered electron mode is possible with field emission SEMs and newer tungsten or LaB6 SEMs. The overall size is ~ 3.2mm X 3.2mm X 0.5 mm thick. The MRS-6 is fully conductive. No coatings are required or desirable. The standard can be cleaned using a low power plasma etcher with oxygen gas.

The geometric design of the MRS-6 and MRS-5 are the same. There are three different types of patterns.

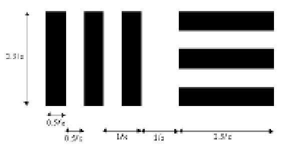
- Groups of nested squares spanning several orders of magnitude with pitches of 80nm, 100nm, 200nm, 500nm, ½µm, 1µm, and 2µm. To allow for more testing the 80, 100 and 200nm patterns are repeated four times.
- Incorporated into the standards is an extension of the 1951 USAF 3-bar targets. These finer patterns have pitches ranging from 80nm to 3µm in 15 steps. They will find good use measuring the resolution of state-of-the-art optical microscopes (UV, confocal, laser scanning, etc.
- The ½µm square test pattern will help analyze your images for all types of dimensional distortions, vibrations and magnetic fields. This pattern contains ½µm squares with a 1µm pitch over a 20µm X and Y field.

Measured and certified are pitches (the distance between repeating parallel lines using center-to-center or edge–to-edge spacing). These are the only type of measurements that can be used to relate measurements from different microscopy techniques (see "Submicrometer Linewidth Metrology in Optical Microscopy", Nyysonen & Larrabee, Journal of the Research of the National Bureau of Standards, Vol. 92, No. 3, 1987). Linewidth measurements (the measurement of a single line or space width) can only be related if the same type of illumination is used as for the calibrating instrument since edge effects lead to uncertainty in the edge locations. Using pitch measurements, errors from edge-to-edge locations cancel as long as like positions are measured.

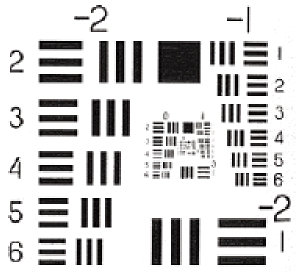
Square boxes and the 1µm pitch square test patterns are used for measuring magnification simultaneously in the X and Y directions. This gives a measure of image skew, barreling, pincushion and other non-linearity's which can have various origins, such as from stray magnetic fields. With the MRS-6 we have provided a large range of pitches to closely match the needs of your instrumentation.

The largest pattern has an overall dimension of 40µm square. It contains lines and spaces that are nominally 1µm wide. This can be used to check magnifications greater than 1,000X. The smaller patterns allow calibrations up to 1,000,000X.

The 3-bar targets were included as a response to many requests for a standard capable of measuring resolving power for patterns smaller than the 1951 USAF targets (see http://www.efg2.com/Lab/ImageProcessing/TestTargets/). They are often found covering a range of 0.25 to 228 cycles/mm. The standard target element consists of two patterns (two sets of lines) at right angles to each other. Each consists of three lines separated by spaces of equal width. The bar length to width ratio is 5X. The patterns change size exponentially in groups and elements. The range in line length for the original target was from 10mm to 0.08769mm. Others have expanded the range towards finer patterns. We now extend the range to a line width of 0.00004mm! With these 15 patterns measurement of modulation transfer functions is made much simpler.



*Standard Resolving Power Test Target Element.*

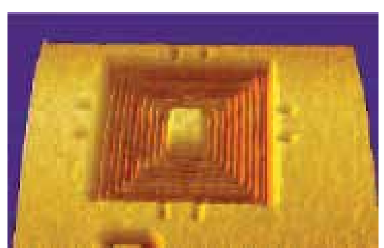



*From MIL-STD-150A: "The patterns of lines are parallel lines 2.5 x millimeters long and 0.5 x millimeters wide with space 0.5 x millimeters wide between the parallel lines, where x equals the number of lines per millimeter."*

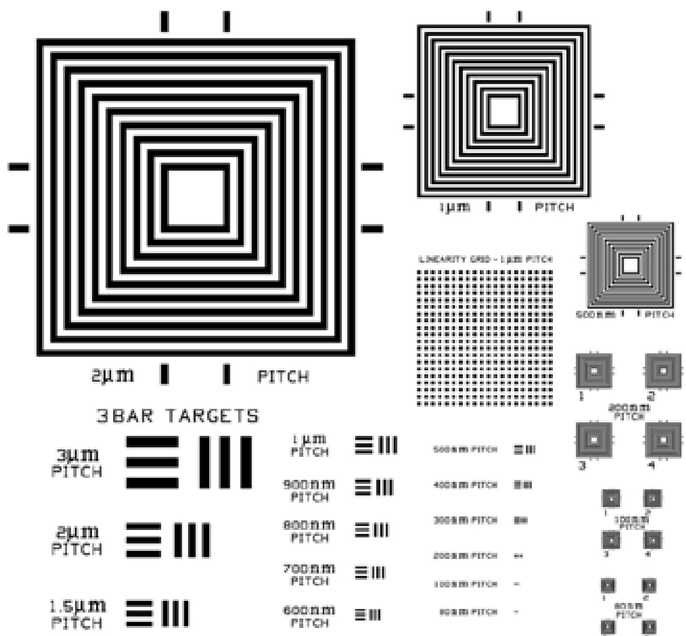
*The patterns can also be used for determining imaging and chemical spatial resolution and chemical mapping.*

The patterns can also be used for determining imaging and chemical spatial resolution and chemical mapping.

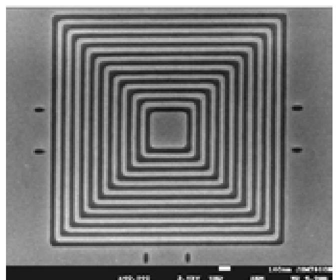
| PATTERN | PITCH SPACINGS | | | | | |
|---|---|---|---|---|---|---|
| Nested Boxes | 2µm | 1µm | 500nm | 200nm 4 each | 100nm 4 each | 80nm 4 each |
| 3 Bar Targets | 3µm | 2µm | 1µm | 1.5µm | 1µm | 900nm |
| 3 Bar Targets, Continued | 800nm | 700nm | 600nm | 500nm | 400nm | 300nm |
| 3 Bar Targets, Continued | 200nm | 100nm | 800nm | | | |

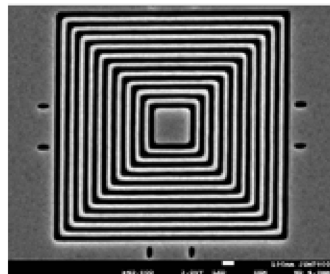


*AFM image taken with sharpened tip (NPL) - 80nm pitch pattern*




## TRACEABILITY


*Scanning electron microscope, type I secondary electrons*


*Scanning electron microscope, type II secondary electrons*

Why should you consider a traceable standard? Beyond the requirements of national and international quality standards, purchasing a CRM (certified reference material) from a national laboratory or a traceable standard from a certifying body (such as Geller MicroÅnalytical Laboratory) guarantees dimensions. Most commercially available standards have unknown accuracies. Measurements determined by optical methods measuring pattern frequency do not tell you about the individual variations in pitch measurements- and this is what you image. The MRS-6 is offered with or without traceability. The nontraceable standard differs only in documentation and cost. Traceability in the X and Y dimensions is established from a MRS-5 that has been measured by NPL (National Physics Laboratory), the NIST counterpart in the U.K. We are in the process of having the MRS-6 measured by a national laboratory and expect measurements with lower uncertainties. The non-accumulative 2$\sigma$ pitch uncertainty is ±3 nm. Through international agreements our ACLASS accreditation provides equivalency with NAVLP and A2LA.

See http://www.gellermicro.com/quality_control/QC.html. Through national laboratory mutual recognition agreements NPL measurements are equivalent to NIST. Traceable measurements are only provided for the 2, 1 and 0.1 µm pitch patterns. Details can be found on the provided measurement certificates.

## RECERTIFICATION PROGRAM

We are often asked why the MRS needs re-certification. Under ISO-17025 guidelines your quality department should determine the re-certification interval as they are most familiar with your company's quality system requirements. Recertification is a common practice for devices such as gage blocks and electronic instruments. Over the years we have found several standards which could not be recertified due to physical damage and excessive contamination. In a few cases we have seen electron beam damage and corrosion from storage in a contaminating environment. Re-certification insures your standard will perform its proper task and that you will be meeting your quality system directives. Recertification includes cleaning.

## MAGNIFICATION MEASUREMENTS

Optical Microscope magnifications can be measured only in the reflection mode by directly on viewing CRTs, in reticles mounted within the ocular, or directly on photomicrographs. Please note the contrast is not particularly high. For instruments with verniers or electronic calipers distance measurements can be verified using a pitch pattern of appropriate size. Magnification is simply the image size divided by the object size (be careful to use the same units).

Scanning Electron Microscopes and FIB/SEMs can use the secondary electron signal at an accelerating voltage of <=25keV preferably with type II secondary electrons to get more of a surface image. Backscattered electron imaging is possible but only for high sensitivity detectors.
To avoid pattern damage use <1 nA electron beam current.

Scanning Probe Microscope operators must be aware of the fine dimension of the pitch patterns. The 80nm pitch has a nominal space width of 40nm. The cantilever tip must be smaller to define the pattern. As shown in the AFM image to the left the pattern lines have variable height.

### International Calibration Standards

- ASTM E766–2003: Standard Practice For Calibrating The Magnification Of A Scanning Electron Microscope
- ISO 16700:1994 MICROBEAM ANALYSIS — Scanning Electron Microscopy — Guidelines For Calibrating Image Magnification
- There are no international standards for SPM magnification calibration at this time

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| | | X-Traverse | | Y-Traverse | |
|---|---|---|---|---|---|
| 2µm Pitch | | Left | Right | Top | Bottom |
| | 1 | 2.018 | 2.001 | 2.019 | 2.008 |
| | 2 | 1.998 | 1.997 | 2.011 | 1.998 |
| | 3 | 1.994 | 1.995 | 1.971 | 1.992 |
| | 4 | 1.974 | 2.004 | 1.995 | 1.987 |
| | 5 | 2.015 | 1.986 | 1.995 | 1.987 |
| | 6 | 2.005 | 2.007 | 1.995 | 1.987 |
| | 7 | 1.986 | 1.996 | 2.011 | 2.008 |
| | 8 | 2.006 | 2.001 | 1.966 | 1.982 |
| | 9 | 1.979 | 2.001 | 1.998 | 2.011 |
| Average | | 1.997 | 1.999 | 1.995 | 1.995 |
| 2-Sigma | | 0.031 | 0.012 | 0.035 | 0.022 |

| | | X-Traverse | | Y-Traverse | |
|---|---|---|---|---|---|
| 1µm Pitch | | Left | Right | Top | Bottom |
| | 1 | 0.992 | 0.997 | 0.999 | 0.988 |
| | 2 | 1.003 | 0.999 | 0.978 | 1.009 |
| | 3 | 0.996 | 1.000 | 0.996 | 0.993 |
| | 4 | 0.999 | 1.000 | 1.031 | 1.001 |
| | 5 | 0.997 | 1.001 | 0.978 | 0.997 |
| | 6 | 0.999 | 0.990 | 1.005 | 1.001 |
| | 7 | 1.003 | 1.006 | 0.990 | 0.992 |
| | 8 | 0.992 | 1.002 | 1.004 | 1.001 |
| | 9 | 0.995 | 0.996 | 1.013 | 0.996 |
| Average | | 0.997 | 0.999 | 0.999 | 0.998 |
| 2-Sigma | | 0.008 | 0.009 | 0.034 | 0.013 |

| | | X-Traverse | | Y-Traverse | |
|---|---|---|---|---|---|
| 0.1µm (100nm) Pitch | | Left | Right | Top | Bottom |
| | 1 | 0.103 | 0.098 | 0.107 | 0.102 |
| | 2 | 0.099 | 0.101 | 0.101 | 0.103 |
| | 3 | 0.100 | 0.099 | 0.102 | 0.102 |
| | 4 | 0.099 | 0.096 | 0.103 | 0.103 |
| | 5 | 0.100 | 0.102 | 0.102 | 0.102 |
| | 6 | 0.101 | 0.099 | 0.102 | 0.103 |
| | 7 | 0.100 | 0.101 | 0.101 | 0.101 |
| | 8 | 0.100 | 0.098 | 0.102 | 0.100 |
| | 9 | 0.100 | 0.100 | 0.102 | 0.102 |
| Average | | 0.100 | 0.099 | 0.102 | 0.102 |
| 2-Sigma | | 0.002 | 0.004 | 0.004 | 0.002 |
| Sum | | 0.900 | 0.894 | 0.922 | 0.917 |

| Pitch | Uncertainty | Traceable To: |
|---|---|---|
| 2µm | ±0.031µm | MRS-4 S/N R23-169 |
| 1µm | ±0.030µm | |
| XY Working Standard: MRS-4 S/N R24-171 | | |
| 0.1µm | ±0.00188µm | MRS-5 S/N 1-002 |

*Magnification Reference Standards:*

614-80 MRS-6NT Reference Standard, X, Not Traceable, without Protective Retainer....each

614-81 MRS-6XY Reference Standard, X-Y, Traceable, without Protective Retainer....each

*Adapter:*

614-64 Mounting MRS-6 Standard Commonly Used 1/2" (12.7mm) pin stub with 1/8" (3.2mm) pin....each

*Cleaning:*

614-73 MRS-3/4/5/6 Cleaning and Recoating Only....each

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