NISTIR 5193

Report on a Workshop for Improving Relationships Between Users and Suppliers of Microlithography Metrology Tools

Robert D. Larrabee

U.S. DEPARTMENT OF COMMERCE
Technology Administration
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and Technology
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June 1993

U.S. DEPARTMENT OF COMMERCE
Ronald H. Brown, Secretary

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
Arati Prabhakar, Director

DISCLAIMER

The "Improving the User-Vendor Interface Workshop" [1] was a discussion about user-vendor issues in which many opinions were expressed very freely and without "finger pointing" with the hope that someone would listen and do something about them. This report is intended to be a summary of that discussion for the purpose of disseminating those opinions for that intended purpose. Except for the material in the Preface and the supplemental list of concerns, which represents some opinions and comments of the author, the material in this report represents a summary of opinions and comments of the participants of the workshop as perceived by the author. These opinions do not necessarily have the endorsement of the National Institute of Standards and Technology.

PREFACE

The United States semiconductor industry is under competitive "attack" on a number of fronts, and the industry's response is fragmented and not as effective as it could be. The problems of national competitiveness are compounded by the fact that many users and suppliers are international in scope, so the issue of U.S. national competitiveness is blurred. Many organizations besides NIST are trying to help the U.S. semiconductor industry (e.g., SEMATECH, Semiconductor Research Corporation, ASTM*, SEMI, etc.). One "crack" in our national defenses is located at the interface between users and suppliers of the metrological tools used by the semiconductor industry. There is a tendency for each "side" of this crack to depend on the other side to solve some of the more difficult problems: problems of obtaining meaningful and well-documented instrument specifications; problems of acceptance testing; problems of calibration, maintenance, and repair; and problems of making measurements using sound metrological theory and practice. This report is aimed at identifying some of the problems at this crack and, if possible, also aimed at identifying ways to solve them.

The semiconductor industry is destined always to be at the cutting-edge of technology and continually needs metrological tools that should be beyond that cutting edge. Over the past three decades, there has been a tremendous effort to improve microlithography that has seen the minimum feature size decrease from about 25 micrometers in the early 1960s to less than a micrometer today, with projections approaching 0.1 micrometer by the turn of the century. Unfortunately, there has not been a corresponding effort of comparable size to keep the metrological tools ahead of that cutting edge. This may have fostered a "we"/"they" attitude between users and suppliers of metrology tools that is counterproductive and not in the best interests of national competitiveness. This report documents the results of a workshop aimed at identifying some of the problems at the user/supplier interface that might be solved (or mitigated) by a better understanding by all concerned. The workshop was held as part of the 1993 SPIE Symposium on Microlithography held from February 28 to March 5 at the Fairmont Hotel in San Jose, California. The present document is an informal report on that workshop.

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[1] "Improving the User-Vendor Interface Workshop," held in connection with the 1993 SPIE Symposium on Microlithography, Fairmont Hotel, San Jose, California, March 3, 1993.
* See list of acronyms on page 6.

I would like to submit one final item for thought. In a business course in graduate school, I was required to generate an objective one-line criterion for a hypothetical company manufacturing "widgets." Traditionally, the objective of a manufacturing company is to maximize the bottom line. I argued otherwise. To blindly follow an objective to maximize profits, the company would have to cut its expenses to the bone by: cheating its suppliers; dumping its manufacturing wastes into the air or nearby river; providing minimal environmental health, safety conditions, and salary for its employees; manufacturing cheap products; failing to honor its warranties; exaggerating its advertising claims; etc. One would anticipate that such a company would quickly go out of business after, perhaps, maximizing its profits for a few years. I argued that the objective of the widget company should be to guarantee its long-term growth and survival. The instructor did not agree with me because my time horizon was too long. As I look at the semiconductor industry out there, I get the feeling that maybe parts of the semiconductor industry do not agree with me either, because I could interpret some attitudes of users and suppliers as an overemphasis on the short term. If true, I see one purpose of this workshop being to identify issues of this kind as a first step in correcting the situation.

Robert D. Larrabee
Gaithersburg, Maryland
June 2, 1993

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REPORT ON A WORKSHOP FOR IMPROVING RELATIONSHIPS BETWEEN USERS AND SUPPLIERS OF MICROLITHOGRAPHY METROLOGY TOOLS

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ABSTRACT

This report is a summary of the opinions and comments expressed at the User-Vendor Interface Workshop held in connection with the 1993 SPIE Symposium on Microlithography held in San Jose, California in March, 1993. It was prepared to serve as a starting point for any future activity concerned with improving relations at the interface between the user and supplier of the metrology tools used in the fabrication of integrated circuits, other semiconductor devices, magnetic tape heads, micromachines, etc. The workshop was attended by representatives from the user, supplier, and standards communities representing strong semiconductor interests, and many opinions and comments were expressed about problems and frustrations at the user-supplier interface. Understandably, there were far fewer suggestions on how to solve these problems or mitigate these frustrations. However, identification and clarification of a problem is often the first step in finding a solution.

INTRODUCTION

This workshop was about opinions. They are anonymous and spontaneous, but genuine, opinions based on practical experience from people experienced in interacting at the user/supplier interface. They were expressed in a workshop with the author as moderator and with the help of a panel of 12 practitioners from the user, supplier, and standards communities (see Table 1). A list of the other participants in this workshop is in Table 2. These 36 people may represent a small percentage of the people who have had good or bad experiences in the user/supplier interface, but they are people who are sufficiently concerned about the current situation to actually come to a workshop to discuss the issues.

This workshop was about problems. They are the problems perceived or experienced by the workshop participants. Unfortunately, many of these problems do not have obvious solutions, but the relatively simple expedient of talking about them is an obvious first step toward finding solutions. One class of problems was concerned with definitions of terms used at the user/supplier interface: precision, accuracy, throughput, etc. Another class of problems was concerned with standards for such things as: transferring raw or analyzed data between the measuring instrument and an independent user's computer, making the measurement (i.e., edge criterion in a measurement of critical dimension), qualifying the instrument for performing its intended function, etc. The significant role of organizations such as Semiconductor Equipment and Materials International (SEMI), ASTM, and the National Institute of Standards and Technology (NIST) in interacting with the semiconductor industry to solve both of these classes of problems was not appreciated by all the workshop participants. If any reader is inclined to provide tangible assistance to any of these organizations, please feel free to contact any of their representatives listed in Tables 1 or 2 (or the author of this report) for further information about how they can participate.

This workshop was about solutions. Although some solutions were suggested or implied at the workshop, it was obvious that the solutions to most of the problems presented are not "obvious," and they were not found in this initial two-hour workshop. However, some global suggestions that could lead to solutions were proposed. The suggestion for users, suppliers, and standards laboratories operating at the user/supplier interface to become more active in the activities of the pertinent committees of such organizations as SEMI and ASTM is one suggested approach to further discussion and, possibly, an approach to solutions of some problems involving standards. Another global approach was suggested that could be characterized as "shared responsibility" - the idea that both users and suppliers share the responsibility for guaranteeing the performance of metrology instruments, and thus, transform any "we"/"they" attitudes into an "us" attitude. In this environment, users would assist in the design of the instruments to assure that they were designed and built to measure the desired quantities in an acceptable way with acceptable hardware and software. The users would then better understand the instruments, why they cost so much, how to use them, and what the measurements really mean. On the other hand, the suppliers would collaborate in the design of the user's environment for the instrument as well as in the installation, acceptance testing, routine maintenance, and in making sure that the instrument performs the function desired. The suppliers would then better understand the user's needs and their frustrations in trying to accurately measure useful quantities. Idealistic? Perhaps so, but what was it that Abe Lincoln said about a house divided against itself?

This workshop was NOT about ISO 9000. However, it was discussed with the anticipation that ISO 9000 may eventually have a significant impact on everybody in the semiconductor industry.

TOPICS DISCUSSED

There were many topics raised at the workshop. Some were just mentioned while others were discussed in some detail. Looking at these topics from a generic point of view, they included:

1. Need for standards that do not exist today.

    A. Everyone wants new and improved standards, but only a few people want to participate in producing them (e.g., working on ASTM or SEMI committees), or supporting or collaborating in developing them (e.g., helping NIST).

    B. Need for standardization of the terms used in metrology and, in particular, in specifications of instruments and in the quantities measured for quality control.

2. Need for qualification procedures for metrological instruments.

   A. Who designs and performs the qualification tests (i.e., user, supplier, or both), and whose samples are used and at what location?

   B. How can collaboration between user and supplier be encouraged in qualification or acceptance testing?

   C. Should the supplier guarantee instrument performance over the life of the instrument?

3. Need for the user to have access to the raw measured data as well as the processed data in some standardized machine-readable form and available for communication over some standardized interface.

   A. Need for the user to know the basic metrology of the measurement including how the raw data are obtained and how they are processed.

   B. Need for the user to be able to change the way the raw data is processed to accommodate special needs or to incorporate new metrology developments.

4. Need to eliminate unpleasant "surprises" after purchase of the instrument.

The following is a list of some more specific subjects and topics that were either discussed in correspondence between the author and the panel members before the workshop or discussed by the participants at the workshop.

1. Definitions of metrological terms are important, but so are the standardization of the procedures and samples used to measure them. Would an ideal calibration or evaluation specimen be meaningful when the calibrated instrument is subsequently used on product samples that are not necessarily ideal?

2. Has the industry been misguided into accepting poor (or less than state-of-the-art) metrology by an overemphasis on other things such as: user-friendly software, throughput, cost, two-dimensional TV-image data format with processing of single TV-scan lines (with its pixel and other limitations) instead of measuring with a greater pixel density when profiling the feature of interest, etc?

3. Should standardization of procedures be developed for comparing different machines of the same basic type (e.g., SEM, confocal, scanning probe, etc.) and of different manufacture or different models of the same manufacture? Such standardization would require not only precise definitions of the measured quantities, but also standardization of the way they were measured and possibly even of the samples used for the measurements. Should suppliers supply a calibration standard with each instrument?

4. What should be the role of beta site testing in the development of a new generation machine? What are the benefits and responsibilities of the user and supplier of instruments being beta tested? What should be included as part of the beta site testing (e.g., should the user just evaluate and use it as if it were a purchased product, or should additional tests be made)?

5. Should suppliers be required to perform acceptance tests both before and after shipment to the customer and should they be required to use both their own and typical customer's samples for such tests? Alternatively, should the user share some of this responsibility?

6. How should edge roughness be measured and reported in a critical-dimension measurement? It is obvious that if the roughness is bad enough, it will seriously effect the measurement. However, even if it is small enough to have a small effect on the measurement, it compromises the very definition of "dimension" and impacts the accuracy of the measurement.

7. Is standardization required on the definitions and methods of measurement of the input parameters to cost of ownership models? Should more attention be paid to the sensitivity of the results to the varied input parameters? Is the instrument with the lowest cost of ownership actually the "best" instrument?

8. Is there a best way to measure reliability, to perform accelerated tests to failure and to determine what confidence limits should be used in analyzing statistical data of this kind?

9. What is required to claim traceability to NIST? Does NIST determine or certify traceability (answer = no)? Who has the responsibility for instrument calibration (i.e., suppliers, users, or metrology laboratories)?

10. The International Standards Organization (ISO) is promulgating new standards that will probably affect all users and suppliers of metrology instruments to some extent. The general nature of ISO 9000 and the reasons why one would consider obtaining compliance should be understood by all users and suppliers. ISO 10012 is more specific with regard to "Purchasers" and "Suppliers." The possibility of strict future ISO standards regarding electromagnetic interference (EMI) was mentioned.

The following supplemental list of several additional items was generated by the author in planning the workshop, but were not brought out in connection with the workshop itself.

1. The question of sensitivity of the instrument to detect small changes in the measured quantity is often not specified. For example, an instrument for quality control should be able to reliably detect changes in the measured quantity that are 3 to 10 times smaller than the change required to go from design value to the control limit. Note that sensitivity is not the same as precision. In fact, a totally insensitive machine can be very precise (i.e., it will always give the same result).

2. What about proprietary issues? Does the method of measurement and data reduction have to be proprietary? Should the details of the instrument design be proprietary or, if appropriate, patented? Should the source code of the software in the instrument be made available to the user for modification? If not, is it the obligation of the supplier to offer a modification service?

3. Calibration curves should not be used outside the range of their measurement! Claims to traceability to NIST based on extrapolations of calibration curves are invalid even if the calibration was done with a recognized standard. Calibrations should not be done with standards designed for some other purpose unless the documentation accompanying that standard permits such use. For example, a magnification standard is useful for calibrating the magnification of a microscope - but such a calibration is not sufficient for calibrating that microscope for critical-dimension measurements.

4. What is the impact of cluster tools with imbedded metrology on all of these issues?

5. What new standards are needed for overlay, phase-shift masks, X-ray masks, scanning-probe-based metrology systems, surface roughness, film thickness, pattern placement, etc.?

One last point: In the final analysis, the whole industry shares the "blame" for these problems to some extent (the author included). For example: 1) It is clearly difficult to design a perfect fully automated dimensional metrology tool that has subatomic accuracy, low cost, small footprint, and zero maintenance, coupled with the ability to measure all the features on a 200-mm diameter silicon wafer as it passes through the 250-mm diameter specimen chamber at 100 kilometers per second as the building shakes and the house power fluctuates because of the passage of a long freight train heavily loaded with magnets moving at top speed over poorly maintained track located on just the other side of the thin exterior wall of the clean room; 2) the supplier's job would be easier if the user only made measurements in an orbiting space laboratory: with no forced air flow; no stray electric or magnetic fields; no other nearby equipment; no cosmic rays, neutrinos, or solar wind; and no people or robots within 100 meters of the instrument; 3) clearly, everyone would be satisfied if NIST would simply develop the standards that are needed for initially calibrating these instruments under any and all of the above conditions so that all sources of imprecision and inaccuracy due to inadequate design, inappropriate operating conditions, and poor metrology are "calibrated out" once and for all and traceability to international standards is thus assured without recalibration for the life of the instrument.

Exaggerations? Yes, but exaggerations with some basis of fact as the concerns expressed at this workshop clearly illustrate. If we all remember the theme of these exaggerations and act accordingly, perhaps the problems presented in this workshop will be eventually solved or at least mitigated to some extent.

CONCLUSIONS

Many problems were mentioned, discussed, or implied at this workshop. Many frustrations were also evident. No one took issue with the basic premise that solutions should be sought, although only a few possible solutions were suggested. Where should we go from here? The author posed that question at the close of the workshop and received no definitive answer except that we should go on. Clearly, we can build upon what has been done and summarized above. Hopefully the reader of this report will have had some reaction to the material above and is encouraged to relay any thoughts back to the author for use in planning any follow-on activity (see Table I). Although no definitive plans have been made at the time of preparing this report, the reader should look to the possibility of a second follow-on workshop at the 1994 SPIE Microlithography Symposium and, perhaps, some other follow-on activities in the future by others who share a common interest in better and more constructive user/suppler relationships.

ACRONYMS & ADDRESSES

ASTM:

American Society of Testing and Materials
1916 Race Street, Philadelphia, PA 19103.

NIST:

(formally called National Bureau of Standards or NBS)
National Institute of Standards and Technology, Gaithersburg, Maryland 20899.

SEMI:

Semiconductor Equipment and Materials International, 805 East Middlefield Road, Mountain View, CA 94043-4080.

SPIE:

SPIE - The International Society for Optical Engineering, P.O. Box 10, Bellingham, Washington 98225.

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APPENDIX

SOME INFORMATION ABOUT NIST

Although the present workshop did not identify specific solutions to the many problems and concerns expressed, solutions to some of these problems are undoubtedly being sought by all concerned. The author cannot speak for anyone else, but he can make a few comments about what NIST is doing in the way of standards development. The material on the following pages is a condensed list of Standard Reference Materials (SRMs) available from NIST that may be of interest to the semiconductor industry. A complete catalog of all available SRMs is called "NIST Special Publication 260" and is available from the NIST Standard Reference Materials Program office (301) 975-6776. NIST also offers calibration services that are summarized in the "Calibration Services User's Guide," NIST Special Publication SP-250 that is available from Calibration Services on (301) 975-2002.

In addition to these SRMs and calibration services, NIST has an ongoing program of research and development on new and improved metrological techniques and standards (see final section of the material to follow). This work is reported in the customary technical journals and conferences as well as in NIST's own journal entitled "Journal of Research of the National Institute of Standards and Technology." Finally, NIST has a growing grant program called the Advance Technology Program (ATP) for funding projects in industry (not academia). This funding is not for basic research nor for product development, but for the somewhat risky intermediate stage between these two extremes that NIST labels "precompetitive." For further information, call the NIST ATP program office on (301) 975-2636.

If there are any further questions about NIST, its activities or programs, call the author on (301) 975-2298; Mr. Robert Scace, Office of Microelectronic Programs, on (301) 975-2485; Mr. Frank F. Oettinger, Chief, Semiconductor Electronics Division on (301) 975-2054; or Dr. Dennis Swyt, Chief, Precision Engineering Division, on (301) 975-3463.

Semiconductor

U.S. DEPARTMENT
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Standard Reference Materials
Building 202, Room 204
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Gaithersburg, MD 20899
(301) 975-OSRM [6776]
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SRM

Standard Reference Materials for Semiconductor Manufacturing Metrology

The increasing sophistication of semiconductor technologies places increasingly stringent demands on the measurement techniques used to characterize semiconductor materials and fabrication processes. The advent of new measurement techniques and instruments has offered convenience to the user. The new techniques, however, have also introduced new sources of measurement error or have highlighted the problems with the existing measurement techniques. The Standard Reference Materials (SRM) program at the National Institute of Standards and Technology produces calibrated artifacts providing a convenient and cost-effective approach to improve measurement accuracy and compatibility.

This brochure features selected SRM's from the Catalog of Standard Reference Materials (see below) that are expected to be useful for various aspects of semiconductor manufacturing technology.

Standard Reference Materials

The Standard Reference Materials Program of the National Institute of Standard and Technology (NIST) provides science, industry, and government with a central source of well-characterized materials certified for chemical composition or for some chemical or physical property. These materials are designated Standard Reference Materials (SRM's) and are used to calibrate instruments and evaluate methods, and systems, or to produce scientific data that can be referred readily to a common base. Approximately 1,100 SRM's currently available from NIST are described in the Catalog of Standard Reference Materials, Special Publicaton 260. To obtain a copy of the catalog and price list, please write or call:

Standard Reference Materials Program
Building 202, Room 204
National Institute of Standards and Technology
Gaithersburg, MD 20899
(301) 975-OSRM (6776)

FAX: (301) 948-3730

Silicon Resistivity

SRM's 1521, 1522, and 1523 are for calibrating four-probe and eddy-current test equipment; SRM's 2526, 2527, 2528, and 2529 are mounted on beveled blocks for two-probe spreading resistance test equipment.

SRM	Type	Resistivity	Unit/Size
1521	111 p-Type Silicon	0.1 and 10 Ω·cm	2 wafers, 51 mm Dia, 0.625 mm thick
1522	111 n-Type Silicon	25, 75, and 180 Ω·cm	3 wafers, 51 mm Dia, 0.625 mm thick
1523	100 and 111 p-Type Silicon	0.01 and 1 Ω·cm	2 wafers, 51 mm Dia, 0.625 mm thick

SRM	Type	Resistivity	Unit/Size
2526	111 p-Type Silicon	0.001 to 200 Ω·cm	16 levels, 5×10×0.625 mm
2527	111 n-Type Silicon	0.001 to 200 Ω·cm	16 levels, 5×10×0.625 mm
2528	100 p-Type Silicon	0.001 to 200 Ω·cm	16 levels, 5×10×0.625 mm
2529	100 n-Type Silicon	0.001 to 200 Ω·cm	16 levels, 5×10×0.625 mm

Sizing

Optical Microscope Linewidth-Measurement

These SRM's are for use in calibrating optical microscopes used to measure the widths of opaque lines and clear spaces on integrated-circuit photomasks. They can also be used to calibrate line spacings and line-to-space ratios. The uncertainty of a measured linewidth or line spacing is ±0.05 µm or better. They are for photomasks only and are not for use with partially transmitting materials, with reflected light with opaque materials, or with the scanning electron microscope. SRM 475 is made with anti-reflective chromium on a borosilicate glass substrate. SRM 476 is made with bright chromium.

SRM	Type	Linewidths	Unit Size
475	Linewidth Measurement Standard	0.9 to 10.8 µm	6.35×6.35×0.15 cm
473	Linewidth Measurement Standard IN PREP	0.5 to 30 µm	12.7×12.7×0.23 cm
476	Linewidth Measurement Standard	0.9 to 10.8 µm	6.35×6.35×0.15 cm

Sizing (Continued)
Scanning Electron Microscope (SEM)

These SRM's are for calibrating the magnification scale and evaluating the performance of Scanning Electron Microscopes. SRM 484f has spacings of 0.5, 1, 2, 5, 10, 30, and 50 µm, and can be used to calibrate the magnification scale of an SEM from 1000 to 20,000 X to an uncertainty of 5 percent or better. SRM 2069a consists of graphitized natural fibers with smooth and uniform edges on an SEM specimen mount. Two new SRM's are in preparation; one, on a silicon wafer or on a silicon chip, has pitch patterns ranging over the dimensions shown. The other is a silicon wafer with an ellipsometrically calibrated oxide layer which can be viewed in cross section.

SRM	Type	Unit/Size
484f	SEM Magnification Standard	11 mm Dia, 6.5 mm high
2069a	SEM Performance Standard	12 mm Dia, 3 mm peg (supporting stub)
TBA	SEM Magnification Standard IN PREP	0.2 µm to 1000 µm pitch features
TBA	SEM Magnification Standard IN PREP	0.1 µm to 1 µm oxide thickness

Particle Size

SRM's 1003a, 1690, 1691, 1960, 1961, 1962, and 1965 are intended for use as primary particle size reference standards for the calibration of particle size measuring instruments including electron microscopes.

SRM	Type	Size (µm)	Unit
1003a	Glass Spheres	8-58	5 mL vial
1690	Polystyrene Spheres (0.5% wt. conc. in water)	0.895	5 mL vial
1691	Polystyrene Spheres (0.5% wt. conc. in water)	0.269	5 mL vial
1960	Polystyrene Spheres (0.4% wt. conc. in water)	9.89	5 mL vial
1961	Polystyrene Spheres (0.5% wt. conc. in water)	29.64	5 mL vial
1962	Polystyrene Spheres (0.5% wt. conc. in water)	2.978	5 mL vial
1965	Polystyrene Spheres (0.5% wt. conc. in water)	9.94	1 slide

Depth Profiling

These SRM's are for calibrating equipment used to measure sputtered depth and erosion rates in surface analysis. SRM 2135b consists of nine alternating metal thin-film layers—five layers of pure chromium and four of pure nickel on a polished silicon (100) substrate. It is certified for total chromium and total nickel thickness, for individual layer uniformity, for Ni/Cr bi-layer uniformity, and for individual layer thickness. The nominal thicknesses for Cr and Ni are 53 and 66 nm, respectively. SRM 2136 will consist of layers of chrome separated by thin layers of chrome-oxide. SRM 2137 will consist of boron implanted in silicon with the boron concentration characterized as a function of depth from the surface.

SRM	Type	Unit/Size
2135b	Ni-Cr Thin-Film Depth Profile Standard	1×2.54×0.04 cm
2136	Cr/CrO Thin-Film Depth Profile Standard	1×2.54×0.04 cm
2137	Boron Implant in Silicon Depth Profile (unannealed)	IN PREP

Mechanical Testing
Microhardness

These SRM's are for use in calibrating and checking the performance of microhardness testers. These test blocks were made by electroforming the test metal on a steel substrate. The hardness numbers for 1893 through 1896 are each certified at loads of 25, 50, and 100 gram force, while 1905, 1906, and 1907 are certified for 300, 500, and 1000 gram force, respectively.

SRM	Type	Hardness	Unit/Size
1893	Bright Copper (Knoop)	125 kg/mm^2	12.5 mm square
1894	Bright Copper (Vickers)	125 kg/mm^2	12.5 mm square
1895	Bright Nickel (Knoop)	600 kg/mm^2	12.5 mm square
1896	Bright Nickel (Vickers)	600 kg/mm^2	12.5 mm square
1905	Bright Nickel (Knoop)	600 kg/mm^2	12.5 mm square
1906	Bright Nickel (Knoop)	600 kg/mm^2	12.5 mm square
1907	Bright Nickel (Knoop)	600 kg/mm^2	12.5 mm square

Mechanical Testing (Continued)

Dye Penetrant Test Blocks

This SRM is for checking the performance of liquid dye penetrants and dye penetrant crack detection techniques. This test block has four synthetic cracks, approximately 0.2, 0.5, 1, and 2 µm wide.

SRM	Type	Surface	Unit Size
1851	NDE Penetrant Test Block	Matte Finish	5 cm Dia, 1 cm thick

Coating Thickness (Mass Per Unit Area)

SRM	Type	Nominal Coating Weight (mg/cm^2)	Nominal Coating µm	Thickness µin
1379	Ultra Thin Au/Ni	0.35	0.175	7
1380	Ultra Thin Au/Ni	0.55	0.275	11
1387	Ultra Thin Au/Ni	2.2	1.4	45
1389b	Ultra Thin Au/Ni (set 4)	1.5, 3.0, 6.0, 14.0	0.8, 1.5, 3, 7	30, 60 120, 280

Radiographic Image Quality

This SRM is for determining the radiographic image quality of x-ray radiographic systems, or x-ray system components such as film.

SRM	Type	Unit of Issue
1844	Radiographic Quality Image Indicator	Set of 4 plates

Surface Roughness

These SRM's are for calibrating stylus instruments that measure surface roughness. These electroless-nickel coated steel blocks have a sinusoidal roughness profile machined on the top surface.

SRM	Type	Roughness	Wavelength	Unit of Issue
2071	Sinusoidal Roughness	0.3 µm	100 µm	Block, 24×33 mm
2072	Sinusoidal Roughness	1.0 µm	100 µm	Block, 24×33 mm
2073	Sinusoidal Roughness	3.0 µm	100 µm	Block, 24×33 mm
2074	Sinusoidal Roughness	1.0 µm	40 µm	IN PREP
2075	Sinusoidal Roughness	1.0 µm	800 µm	IN PREP

Optical Methods

Ellipsometry

Each of these SRM's is certified for the ellipsometric parameters of delta (Δ) and psi (ψ) and derived thickness and refractive index of the silicon dioxide layer on the silicon wafer.

SRM	Type	Nominal Thickness (nm)	Unit Size
2531	SiO_2 on Si Wafer	50	76-mm Dia Wafer
2532	SiO_2 on Si Wafer	100	76-mm Dia Wafer
2533	SiO_2 on Si Wafer	200	76-mm Dia Wafer
2534 •	SiO_2 on Si Wafer	25	76-mm Dia Wafer

Infrared Reflectance

This SRM is for use in establishing the accuracy of the wavelength scale of reflectance spectrophotometers. It consists of rare earth oxides mounted sealed behind an infrared transmitting window in a cylindrical holder.

SRM	Type	Wavelength Range (nm)	Unit/Size
1920	Near IR Wavelength	740-2000	51 mm Dia×12 mm

Reflectance

These SRM's are for calibrating the reflectance scale of integrating sphere reflectometers used to evaluate materials for solar energy collectors and to calibrate reflectometers used in evaluating the appearance of polished metals and metal plated objects.

Specular Spectral Reflectance

SRM	Type	Wavelength Range (nm)	Unit/Size
2003	First Surface, Aluminum on Glass	250-2500	5.1 cm Dia
2025	Second Surface, Aluminum on Fused Quartz with Wedge	250-2500	2.5×10.2 cm

X-Ray and Photographic Films

SRM 1001 is a calibrated x-ray film step tablet of 17 steps that cover the optical density range from 0 to 4; it has a blue tint and emulsion on both sides. SRM 1008 is a calibrated photographic step tablet of 21 steps that cover the optical density range from 0 to 4; it has a black tint and emulsion on a single side.

SRM	Type	Unit of Issue
1001	X-Ray Film Step Tablet (0-4)	1 tablet, 17 steps
1008	Photographic Step Tablet (0-4)	1 tablet, 21 steps

X-Ray Diffraction

These SRM's are powdered materials to be used as internal or external standards for powder diffraction measurements.

SRM	Type	Lattice Parameter (25.0 °C)	Unit Size
640b	Silicon Powder	5.430940 Å	10 g
660	Lanthanum Hexaboride Powder	4.15695 Å	3 g
674a	Powder Diffraction Intensity Set ($06{\cdot}Al_2O_3$, ZnO, TiO_2,Cr_2O_3 and CeO_2)	Absorptivities μ, 126 to 2203 cm^{-1} for CuKα radiation	10 g

Chemical Analysis

High Purity Gold

These SRM's are for determining impurity elements in high-purity metals.

SRM	685W* (Wire)	685R* (Rod)
Wt./Unit		
Constituents	µg/g	µg/g
Ag	[0.1]	[0.1]
Cu	0.1	0.1
Fe	0.3	0.2
In	0.007	0.007
Mg	(<0.2)	(<0.2)
Ni	(<10.05)	(<10.05)
O	[2]	[<2]
Sn	(<10.07)	(<10.07)

*Certificate gives upper limits for other elements found to be present.

Copper "Benchmark"

SRM	393 Copper "O"	394 Copper I	395 Copper II
Wt./Unit	50 g	50 g	50 g
Constituents	µg/g	µg/g	µg/g
Ag	0.10	50.5	12.2
Al	<0.1	(<2)	(<2)
As	0.41	2.6	1.6
Au	<0.05	(0.07)	(0.13)
B	<0.01		
Be	<0.01		
Bi	<0.1	0.35	0.50
Ca	<0.05		
Cd	<0.1	(0.5)	(0.4)
Co	0.02	0.5	
Cr	<0.5	2.0	6.0
Fe	<1	147	96
Li	<0.01		

Chemical Analysis (Continued)
Copper "Benchmark" (Continued)

SRM	393 Copper "O"	394 Copper I	395 Copper II
Wt./Unit	50 g	50 g	50 g
Constituents	µg/g	µg/g	µg/g
Mg	<0.1	(<1)	(<1)
Mn	<0.01	3.7	5.3
Ni	0.05	11.7	5.4
P	<0.05		
Pb	0.039	26.5	3.25
Pd	<0.05		
S	<1	15	13
Sb	0.25	4.5	8.0
Se	<0.05	2.00	0.63
Si	<0.5	(<2)	(<2)
Sn	<0.1	70	1.5
Te	<0.5	0.58	0.32
Tl	<0.5		
Zn	<0.1	405	12.2
Zr	<0.5		

Metals for Microanalysis

These SRM's provide highly homogeneous materials at microscopic spatial resolution. They are intended primarily for use in calibration of quantitative electron probe, secondary ion mass spectrometry, spark source mass spectrometry, and laser probe microanalytical techniques.

SRM	Type	Form	Unit Size
470	Mineral Glasses for Microanalysis	Slices	Two glasses containing SiO_2, FeO, MgO, CaO, and Al_2O_3

SRM	Type	Form	Elements (Nominal wt%)
480	Tungsten-20% Molybdenum	Wafer	W-78;Mo-22
481	Gold-Silver	Six Wires	Au-100;80;60;40;20;0 Ag-0;20;40;60;80;100
482	Gold-Copper	Six Wires	Au-100;80;60;40;20;0 Cu-0;20;40;60;80;100
483	Iron-3% Silicon	Small Sheet	Fe-97;Si-3
2063	Thin Film Mg-Si-Ca-Fe	3 mm Dia film	

Ordering Instructions

Address purchase orders and quotation requests to:

Standard Reference Materials Program
Building 202, Room 204
National Institute of Standards and Technology
Gaithersburg, MD 20899
(301) 975-OSRM (6776)

FAX: (301) 948-3730

The request or order should give the number of units, the SRM number, and type of standard requested, for example: 2 each, SRM 475, Linewidth Measurement Standard.

SRM's are distributed only in the units listed. Acceptance of an order does not imply acceptance of any provision in the order contrary to the policy, practice, or regulations of the National Institute of Standards and Technology or the U.S. Government.

Prices are subject to change without notice. Prices in effect at time of shipment will be billed to the purchaser. No discounts are given on Standard Reference Materials. Payments not accompanying purchase orders are expected within 30 days after receipt of invoices.

Development of New SRM's

The National Institute of Standards and Technology has the function to develop, produce, and distribute Standard Reference Materials (SRM's) that provide a basis for comparison of measurements on materials, and that aid in the control of production processes.

To be an SRM, a candidate material must meet one or more of these criteria:

1. It would permit users to attain more accurate measurements.
2. Its production elsewhere would not be economically or technically feasible.
3. It would be an industry-wide standard for commerce from a neutral source not otherwise available.
4. Its production by NIST would provide continued availability of a well-characterized material important to science, industry, or government.

To determine which requests receive top priority, NIST needs and uses information supplied by industry and such interested organizations as the American National Standards Institute, American Society for Testing and Materials, Electronic Industries Association, Semiconductor Equipment and Materials International, etc.

Requests for the development of new Standards Reference Materials should provide information such as listed below:

1. Short title of the proposed SRM.
2. Purpose for which the SRM would be used.
3. Reasons why the SRM is needed.
4. Special characteristics and requirements for the materials. Include additional requirements and reasons if more than one SRM is necessary for standardization in this area.
5. An estimate of the probable present and future (6–10 year) demand for such an SRM in your operations and elsewhere. (National and International estimates are useful.)
6. Whether such an SRM, or a similar one, could be produced or obtained from a source other than NIST; and if so, justify its preparation by NIST.
7. Miscellaneous pertinent information to aid justification for the SRM, such as: (a) an estimate of the potential range of application, monetary significance of the measurement affected, scientific and technological significance including, when feasible, estimates of the impact upon industrial productivity, growth, quality assurance or control, and (b) supporting letters from industry leaders, trade organizations, interested committees, and others.

All such requests should be addressed to:

Standard Reference Materials Program
ATTN: SRM Development
Building 202, Room 204
National Institute of Standards and Technology
Gaithersburg, MD 20899