Micralign™ Projection Mask Alignment Systems

PERKIN-ELMER

Projection mask alignment

Projection mask alignment has become a standard production technique since the introduction of the Micralign™ Projection Mask Alignment System more than four years ago. During that time, this system has proven far superior to other photolithographic printers for integrated circuit manufacture.

Perkin-Elmer has established a position of leadership in the manufacture and sale of projection mask aligners. Today, more than 50 customers at 75 separate locations worldwide are using the Micralign system for their production of semiconductor devices.

Historically, the manufacture of integrated circuits involved placing the photomask directly in contact with the wafer during the exposure process. Repeated just a few times, this contact soon degraded the mask surface and the photoresist layer. Each defect that resulted was then propagated through the replication cycle. Consequently, masks were considered expendable, to be used between five and fifteen times and then discarded.

These problems led to several attempts at prolonging mask life. One was to make the photomask from harder materials that were more resistant to abrasion. Another was to reduce abrasion by reducing or even eliminating the contact force. These efforts did improve mask life to a limited extent, but neither was as effective as optically projecting the photomask image onto the wafer.

ECONOMICS OF PROJECTION MASK ALIGNMENT

There are three ways in which the Micralign system delivers substantial savings. It significantly reduces mask costs, substantially increases circuit yields, and markedly reduces rework.

With projection printing, a photomask is not subjected to any mechanical contact and therefore has an essentially infinite life. Compared to methods that involve contact or partial contact, this technique brings annual savings in photomask usage alone to as high as $40,000 per year, per shift.

Moreover, a major cause of yield loss with earlier methods of contact printing was photomask imperfections. Now, with essentially infinite mask life, the cost of making a "defect free" mask can be spread over a larger number of circuits. The resulting increase in yield can produce extremely large savings.

Projection printing can substantially reduce rework. Rework is typically caused by misalignment and poor mask-to-wafer contact. Rework often has a snowballing effect. Wafers are in process much longer than normal and are subject to more contamination. The utilization of equipment also deteriorates because there is no longer an orderly flow of materials. Ultimately, the wafer probe yield also deteriorates.

HOW THE METHOD DEVELOPED

The semiconductor industry has long been aware of the potentially large savings in using projection printing. For more than a decade, numerous attempts have been made to design and manufacture the extremely complex lens system required. Much of the initial development work was carried out by the large semiconductor manufacturers who had the mechanical expertise, but lacked the optical technology.

The design and manufacture of sophisticated lens systems are slow, complicated processes. Keeping lens aberrations within limits acceptable to the semiconductor industry is extremely difficult. Coupled with the rapid growth in wafer size, it usually is impossible to scale-up an existing lens design to cover a larger field. Each time wafers increased in size, companies had to develop a completely new lens design.

The history of one-to-one projection mask alignment began in the mid-1960's, with the ability to manufacture optical systems capable of limiting distortions to less than one micron over a two-inch diameter field.

This field size was possible so long as only one wavelength was used for exposure and one for alignment. All these systems were based on refracting optics, which suffer severely from chromatic aberrations. These refracting systems were difficult to use because of standing wave effects. In addition, oxygen effect and scattered light from the lens system severely limited the use of negative photoresist.

As wafer sizes increased to three inches, it was evident that entirely new concepts were needed to solve the optical design and fabrication problems. In July 1973, the Micralign Projection Mask Alignment System, utilizing reflecting optics, was introduced by Perkin-Elmer.

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The Micralign™ System . . . all-reflecting, one-to-one

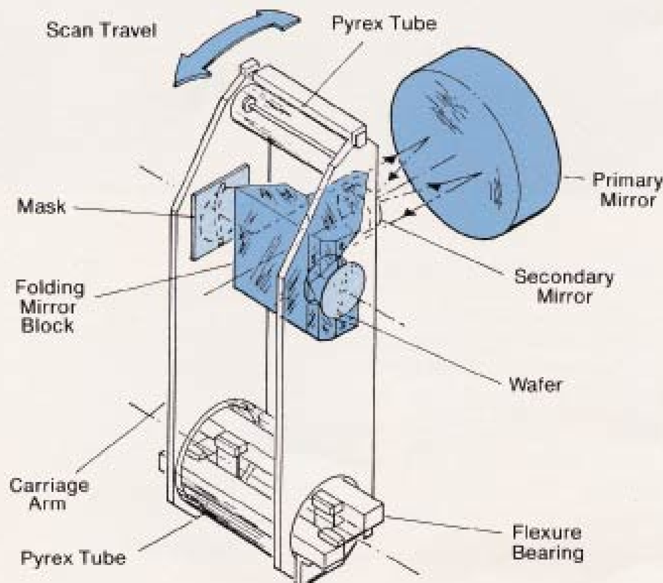
THE 1:1 SYSTEM

The one-to-one projection optical system is basically two concentric, spherical reflective surfaces. The object and image focal planes are nominally in the same plane on opposite sides of the optical axis. A narrow annular ring of good correction is obtained. The image is inverted and reversed.

To correct the image, a folding mirror block is added. The folding mirror on the left is at 45°. On the right are two mirrors configured as a 90° roof mirror. The three mirrors are manufactured as a single piece so that no adjustment is ever required. This folding mirror configuration, in conjunction with the primary and secondary mirrors, produces the same image orientation as a contact printer; i.e., the image on the wafer is a mirror image of the mask. The folding mirror permits use of the same masks as those used on a conventional contact printer.

In the projection system, the mask and wafer are maintained vertically, minimizing the possibility of dust settling on them. A scanning mechanism moves both mask and wafer simultaneously to provide the desired total field exposure. Scanning is accomplished in a single pass.

The scanning carriage consists of two sturdy arms spaced and rigidly connected by two strong Pyrex tubes. The carriage rotates as a unit around a single axis defined by a crossed flexure blade bearing. This type of bearing requires no lubrication and is immune to dust, dirt, and wear. The mask and wafer are carried on their respective arms during the scan. The projection optics (primary mirror, secondary mirror, and folding mirror block) are stationary.

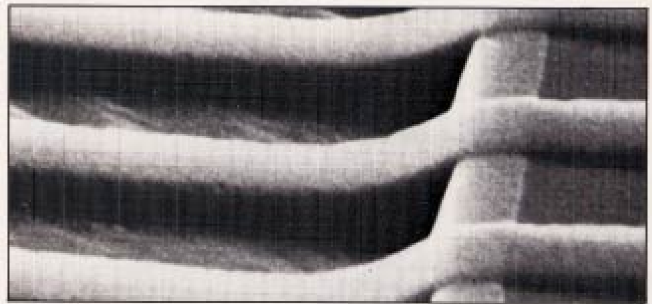


Optical system with scanning mechanism

OPTICAL PERFORMANCE

The Micralign instrument's all-reflecting 1:1 projection system and unique condenser system are the keys to these outstanding performance features:

High Resolution. High resolution is combined with a large depth of focus. Two micron lines and spaces in the photoresist can be printed over the entire field. The use of partial coherence provides resolution equivalent to f/2.4 but with a depth of focus equivalent to f/3.0. Therefore, both resolution and depth of focus are enhanced to meet the specific need of the semiconductor industry. The large depth of focus provides precise focus and patterning over thick oxide steps or warped wafers.



SEM photomicrograph of unetched 3-micron lines over 2.8-micron steps (1.25 micron thick positive photoresist).

Broadband Illumination. The entire output of the mercury lamp is utilized for photoresist exposure. Full advantage is taken of the 3650Å, 4047Å, 4358Å peaks, resulting in shorter exposure time and reduction of standing wave effects in photoresist exposure.

No Chromatic Aberrations. The 1:1 projection optical system is not affected by color. There is no change in focus or in magnification as a function of exposure wavelength.

Negative and Positive Photoresist/Chrome Masks. The superior image quality of the projection optical system, near-zero scatter, and the elimination of flare problems permit the use of either negative or positive photoresist with chrome masks.

Temperature Stability. The projection optics are made of low-coefficient material and are self-compensating for nominal temperature changes. Focus is thereby retained when thermal stability is reached.

Direct Wafer Viewing. A split field binocular microscope provides a high contrast, full color view of the mask imaged on the wafer. The microscope permits viewing at low power for row and column alignment and at high power for precise circuit alignment.

The third generation Micralign™ Systems

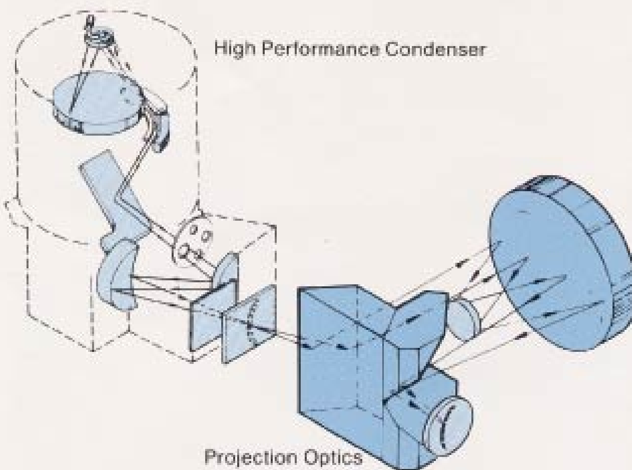
The new Micralign Systems include third generation refinements that produce even better image quality and shorter exposures than do the previous models 100 and 110. The full capabilities of the all-reflecting 1:1 projection optical system are more fully exploited by a high performance condenser which provides a greater range of energy output plus improved imaging characteristics.

The new models offer a choice of wafer loading methods (conventional cassettes, optional thru-track, or manual). They retain the design features that have proven effective in previous models, such as modular electronics, self-checking electronics system, controlled air flow for clean operation, pre-focused light source, convenient operator controls, and ease of serviceability.

HIGH PERFORMANCE CONDENSER

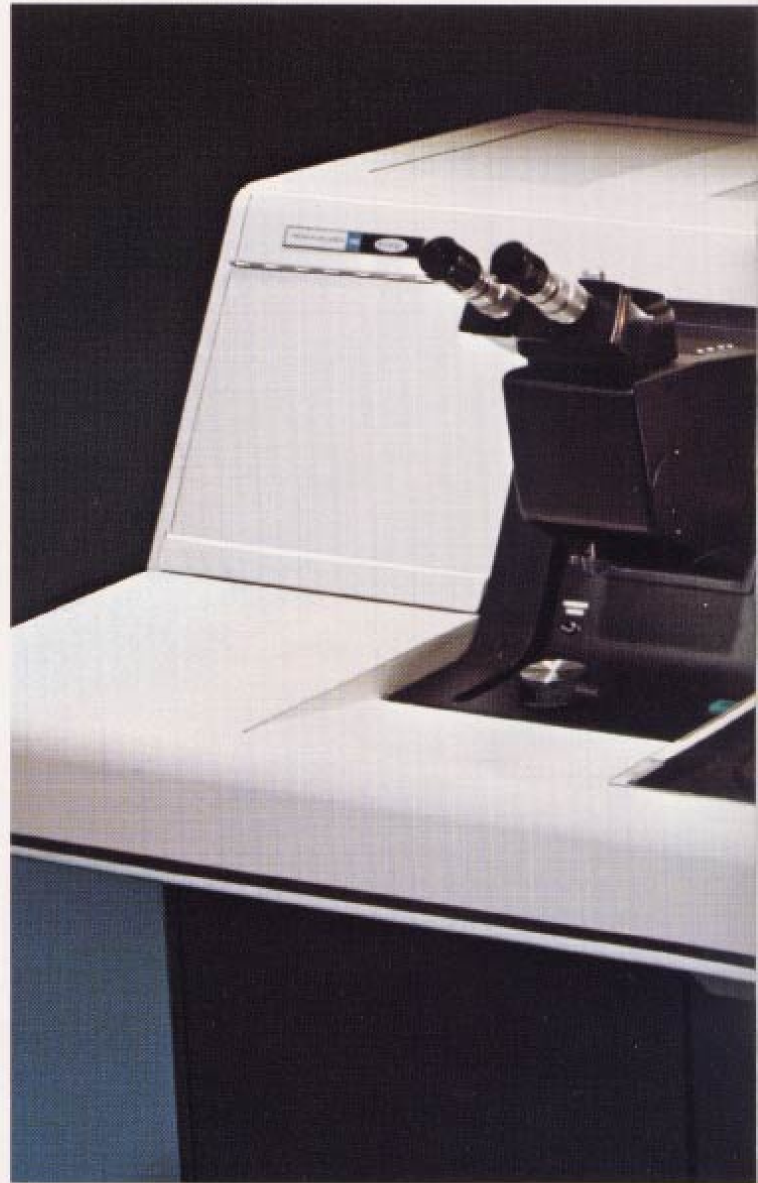
The High Performance Condenser produces twice the light output of previous models for the same specified resolution, or as much as three times the output if edge gradient requirements and process optimization permit. Uniformity of illumination is improved and alignment stability is enhanced by a one-piece condenser structure. Selectability of field stops and aperture stops in the High Performance Condenser permits various combinations of illumination levels and resolution of the image projected on the wafer.

The new design results in better uniformity of illumination and takes advantage of the full capabilities of the projection optics system. The chordal length of the slit image has been increased to 3¼ inches, permitting correspondingly increased wafer coverage in appropriately equipped Micralign instruments.



Structure of high performance condenser

Model 140



100-mm WAFER CAPABILITY

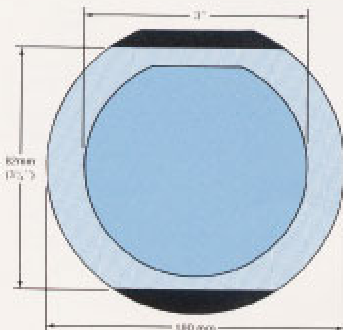
The 100-mm wafer capability is provided by increasing the chordal length of the slit image (right) from 3 to 3¼ inches with the High Performance Condenser, and extending the carriage scan to four inches, producing a zone of high quality imagery that covers more than 90% of the area of the 100-mm diameter wafer. This represents a 60% area increase over three-inch wafers with no sacrifice in optical performance.

AUTOMATIC WAFER LOADING

Automatic wafer loading increases yield by eliminating wafer-handling damage and increases throughput by reducing the already short alignment time. Wafers are loaded in cassettes or by a thru-track option for easy adaption to in-line processing. Most commonly used cassettes can be accommodated and adjustments made for prealignment of various primary and secondary flat combinations. Positioning repeatibility of the prealigner for any point on the wafer is within 0.005 of an inch.

The automatic wafer loading system includes air tracks and pneumatically actuated wafer handling mechanisms. The system has extensive programming features that provide a smooth operator interface to maximize productivity.

Automatic wafer loading system



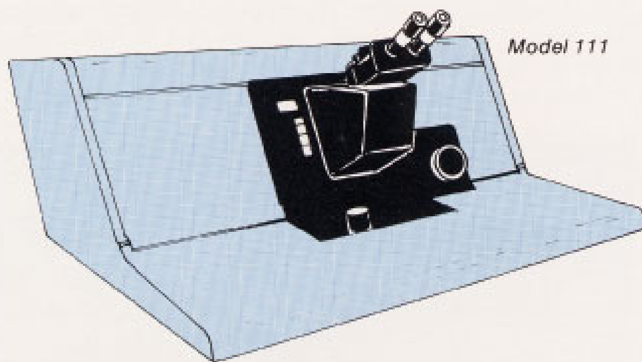
More than 90% of the area of a 100-mm wafer (light blue) may be exposed by Micralign systems. This is a 60% increase in area over a 3-inch wafer (dark blue). The unexposed areas are shown in black.

Model selection

The Perkin-Elmer policy of planned growth lets you select the correct Micralign instrument for your present application, and expand it as your requirements change.

MODEL 111

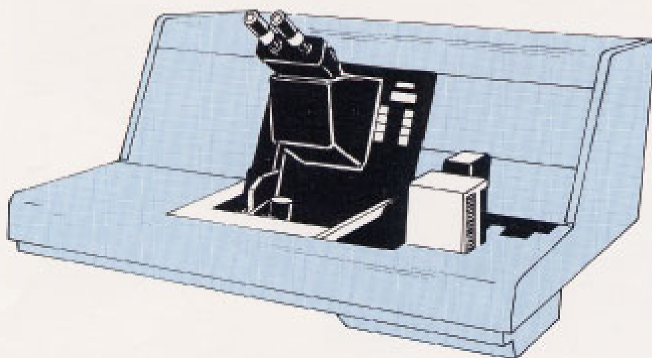
The Model 111 is the basic Micralign instrument. It is manually loaded and can be ordered for 2, $2\frac{1}{4}$, or 3-inch wafers. The Model 111 normally uses 4-inch by 4-inch photomasks, however, 3-inch × 3-inch or 3.5-inch × 3.5-inch photomasks may be used if specified at time of order.



Model 111

MODEL 120

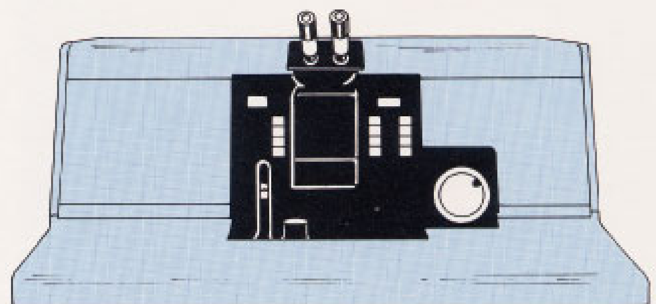
The Model 120 includes the optical performance features of the Model 111 plus three-inch automatic wafer loading capability. The automatic wafer loading system is available for cassette load or optional thru-track operation.



Model 120

MODEL 130

The Model 130 includes the optical performance features of the Model 111 plus a 100-mm wafer capability. The Model 130 is manually loaded and uses 5-inch × 5-inch photomasks.

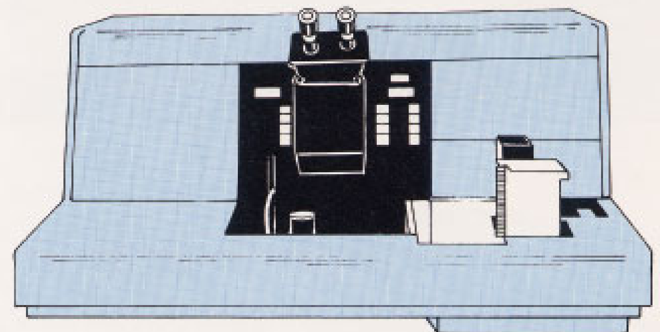


Model 130

MODEL 140

The Model 140 Micralign combines all the latest features of the Micralign System and includes 100-mm wafer capability and wafer loading — either cassette load or optional thru-track operation.

All of the current Micralign System models may be modified by conversion kits to produce the results of the Model 140.



Model 140

Conversion kits and accessories

One of the advantages of owning a Micralign System is that, while we continually make improvements, we also protect your investment. Most new developments in our latest models are available as conversion kits for earlier models.

100-mm CONVERSION KIT

The Extended Scan Conversion Kit permits exposure of an 82.5-mm by 100-mm area on a 100-mm wafer, making it possible to expose more than 90% of the area of the wafer with the quality imagery of a Micralign projection optics system. The conversion kit will vary, depending on the specific model. However, all kits include new mechanical components associated with mask and wafer focal surfaces, a modification of the scan arrangement, and the High Performance Condenser if one is not already installed.

AUTOMATIC WAFER LOADING CONVERSION

Automatic Wafer Loading Conversion Kits, available for Micralign Models 110, 111, and 130 can accommodate either three-inch or 100-mm wafers and are available with either a cassette load or a thru-track configuration. The new automatic wafer loading system prevents tweezer damage, provides precise wafer prealignment, and speeds up the already short alignment time. Therefore, profitability of existing Micralign Projection Mask Aligners can be increased with a minimal investment.

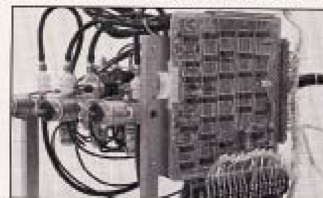
HIGH PERFORMANCE CONDENSER

The Micralign High Performance Condenser is a completely redesigned and substantially improved single-module successor to the two-module condenser system used in the Model 100 and Model 110 Micralign instruments.

In addition to the option for different slit widths, the new system provides an aperture selection capability. These two features permit various combinations of energy output (as much as three times that previously available), resolution, and degree of partial coherence. The High Performance Condenser thus provides a substantial degree of flexibility to permit process optimization.

MODEL 100 HIGH-SPEED ELECTRONIC SEQUENCER

The High-Speed Electronic Sequencer offers users of the Micralign Model 100 instrument a replacement package for the standard mechanical cam-actuated sequencer. The high-speed sequencer reduces cycle time by approximately ten seconds and provides cleaner and quieter operation of the entire system.



UNIFORMITY/CALIBRATION TEST INSTRUMENT

The Uniformity/Calibration Test Instrument provides the most accurate way to calibrate the Micralign instrument.

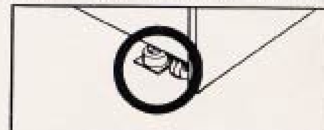
This test instrument can measure either the intensity of illumination or the exposure during scan at any point along the projected slit image. The spectral response of the test instrument is approximately that of typical photoresists so that exposure measurements may be readily correlated with photoresist behavior.

PRECISION FOCUS TEST WEDGE

The Precision Focus Test Wedge is the most accurate and reliable device for determining the best focus of the Micralign instrument. The test wedge is used to project precision test patterns over a two-mil range of focus onto the wafer. The test wedge permits the focal plane to be adjusted to the position of best focus.

VIBRATION ISOLATION KIT

The external Vibration Isolation Kit is recommended for installations subject to abnormal vibration. Four high stability air-spring mounts, especially selected for use with the Micralign instrument, eliminate vibratory forces above 30 Hz and substantially reduce others.



PERKIN-ELMER SALES OFFICES

UNITED STATES OF AMERICA EASTERN REGION

The Perkin-Elmer Corporation
Electro-Optical Division
50 Danbury Road
Wilton, CT 06897
(203) 762-6341

UNITED STATES OF AMERICA WESTERN REGION

The Perkin-Elmer Corporation
3255 — 3A Scott Boulevard
Santa Clara, CA 95051
(408) 249-5540

JAPAN

Kanematsu Semiconductor Corporation
8-5, 2-Chome, Hatchobori
Chuo-ku, Tokyo 104
(03) 552-6091

EUROPE

Perkin-Elmer Nederland B.V.
Zandweg 88
De Meern, Holland
(03) 406 3646

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