US005815310A

United States Patent [19]

Williamson

[11] **Patent Number: 5,815,310**

[45] **Date of Patent: Sep. 29, 1998**

[54] **HIGH NUMERICAL APERTURE RING FIELD OPTICAL REDUCTION SYSTEM**

[75] Inventor: **David M. Williamson**, West Malvern, United Kingdom

[73] Assignee: **SVG Lithography Systems, Inc.**, Wilton, Conn.

[21] Appl. No.: **571,081**

[22] Filed: **Dec. 12, 1995**

[51] **Int. Cl.**[6] **G02B 17/00**; G02B 21/00; G02B 23/00; G02B 5/10

[52] **U.S. Cl.** **359/365**; 359/730; 359/858

[58] **Field of Search** 359/365, 366, 359/729, 858, 859, 730, 731

[56] **References Cited**

U.S. PATENT DOCUMENTS

4,226,501	10/1980	Shafer	359/366
4,241,390	12/1980	Markle et al.	362/299
4,701,035	10/1987	Hirose	359/366
4,747,678	5/1988	Shafer et al.	359/366
5,063,586	11/1991	Jewell et al.	378/34
5,153,898	10/1992	Suzuki et al.	378/34
5,315,629	5/1994	Jewell et al.	378/34

OTHER PUBLICATIONS

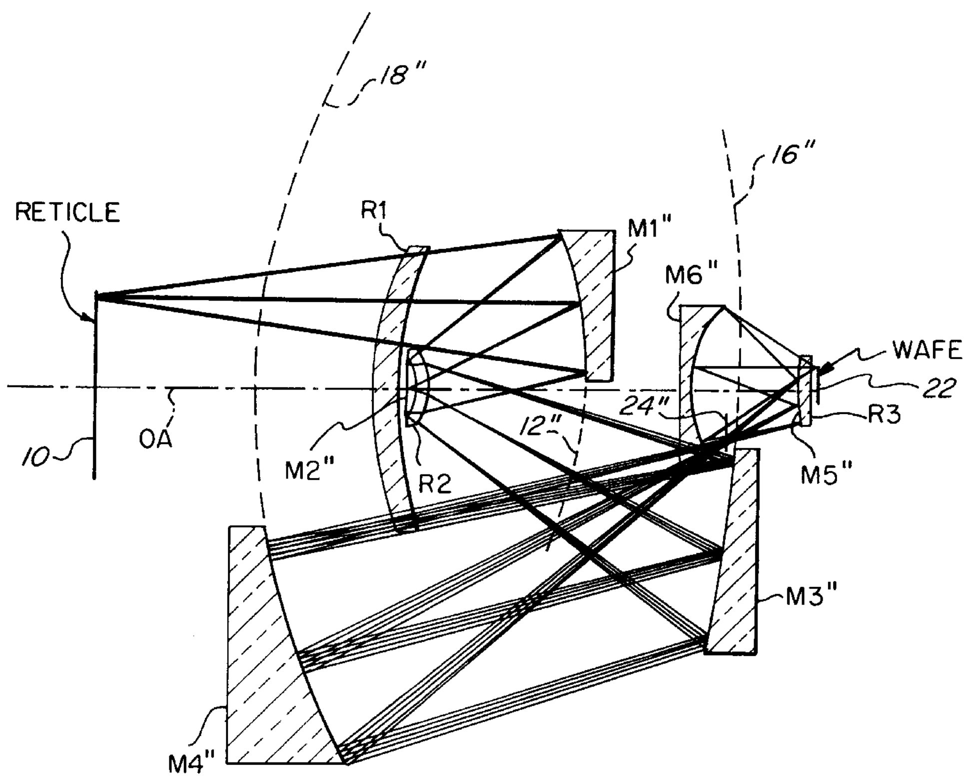
Jewell et al, Reflective Systems Design Study For Soft X–Ray Projection Lithography, Aug. 3, 1990, J. Vac. Sci. Technol B8(6), Nov./Dec. 1990;1990 American Vaccum Society; pp. 1519 to 1523.

Primary Examiner—Thong Nguyen
Assistant Examiner—Mark A. Robinson
Attorney, Agent, or Firm—Paul A. Fattibene; Arthur T. Fattibene; Fattibene & Fattibene

[57] **ABSTRACT**

An optical projection reduction system used in photolithography for the manufacture of semiconductor devices having a first mirror pair, a second field mirror pair, and a third mirror pair. Electromagnetic radiation from a reticle or mask is reflected by a first mirror pair to a second field mirror pair forming an intermediate image. A third mirror pair re-images the intermediate image to an image plane at a wafer. All six mirrors are spherical or aspheric and rotationally symmetrical about an optical axis. An annular ring field is obtained, a portion of which may be used in a step and scan photolithography system. In another embodiment, weak refracting elements are introduced to further reduce residual aberrations allowing a higher numerical aperture. In the catoptric embodiment of the present invention, a numerical aperture of 0.25 is obtained resulting in a working resolution of 0.03 microns with electromagnetic radiation having a wavelength of 13 nanometers. The optical projection reduction systems are intended for use at extreme ultraviolet to the soft X-ray wavelength range. The present invention, provides a relatively high numerical aperture and uses substantially all reflective elements, greatly facilitating the manufacture of semiconductor devices having feature sizes below 0.25 microns.

18 Claims, 3 Drawing Sheets



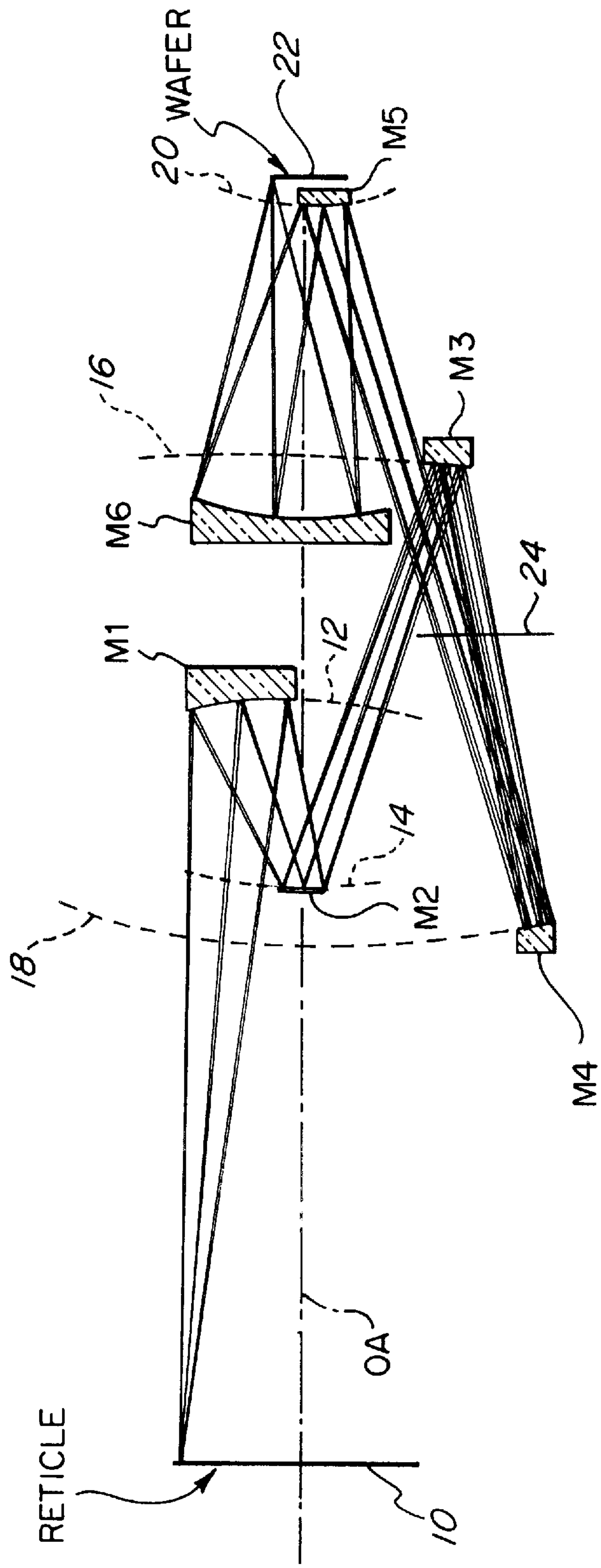


FIG. 1

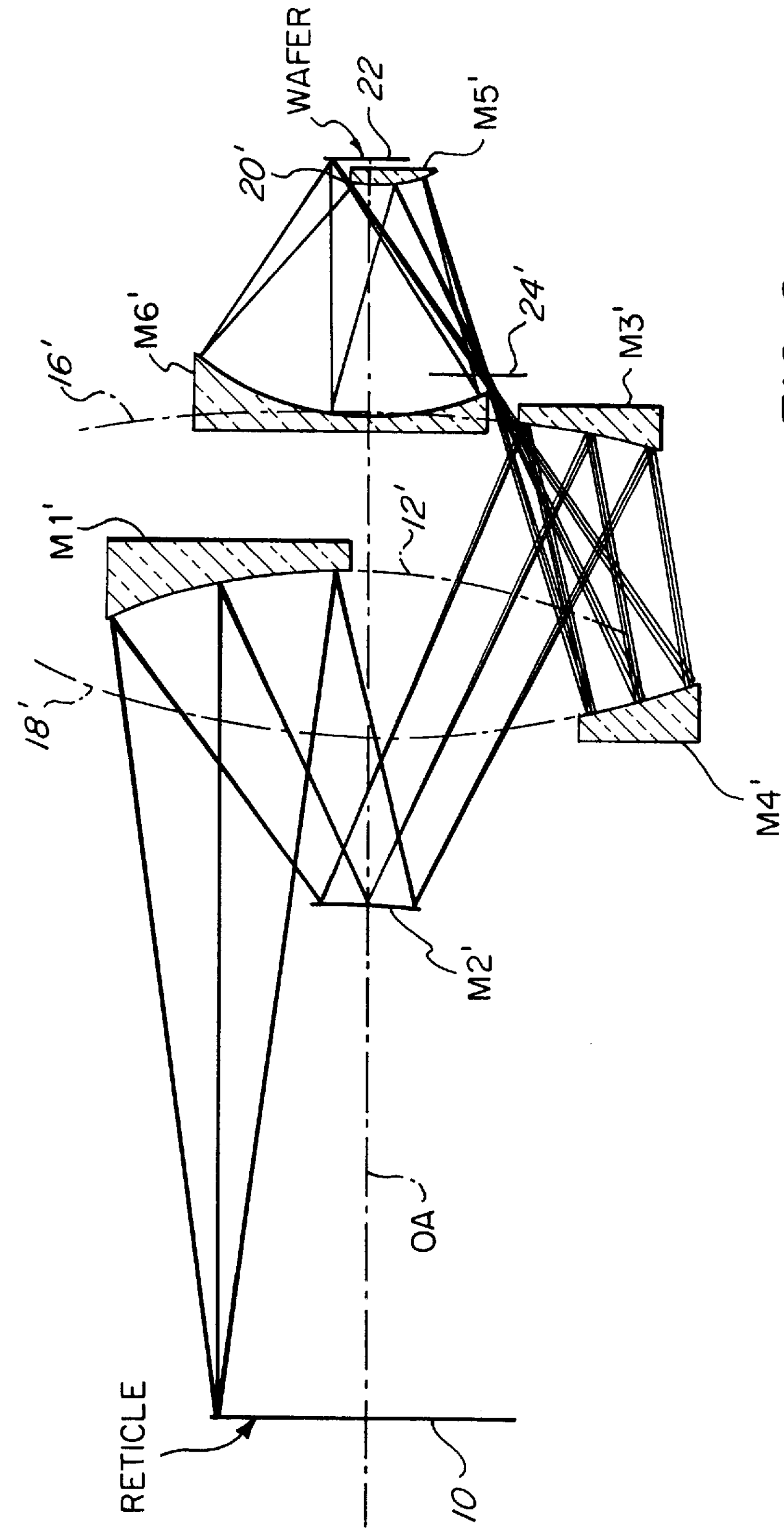


FIG. 2

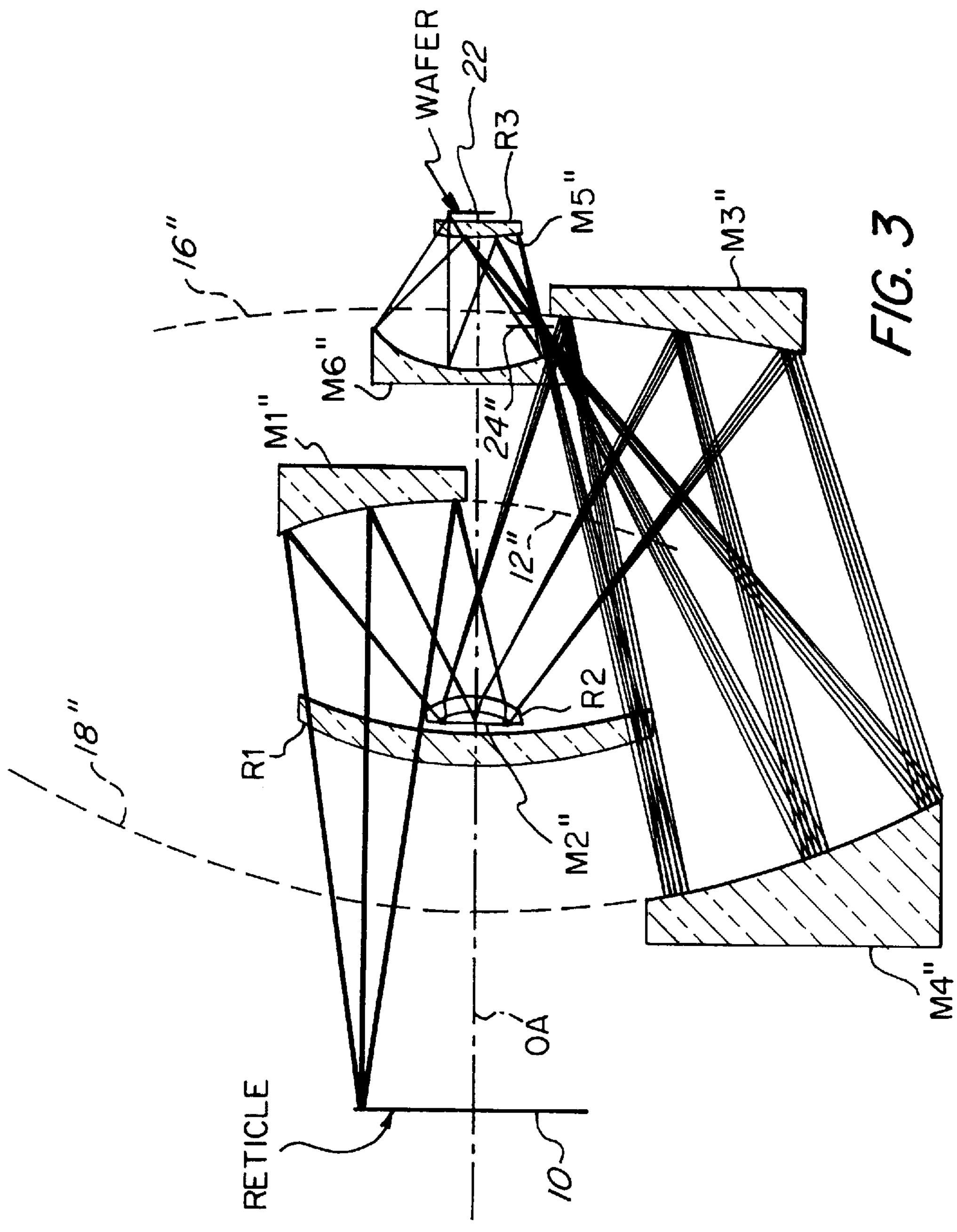


FIG. 3

HIGH NUMERICAL APERTURE RING FIELD OPTICAL REDUCTION SYSTEM

FIELD OF THE INVENTION

This invention relates generally to projection lithography, and more particularly to a catoptric and catadioptric optical system for use with short wavelengths in the near and extreme ultraviolet or soft X-ray region.

BACKGROUND OF THE INVENTION

In the manufacture of semiconductor devices, photolithography is often used. Projection optics are used to image a mask or reticle onto a wafer. Optical systems using refractive elements have achieved resolutions approaching 0.25 micrometers operating with illumination sources having wavelengths of 248 or 193 nanometers. As the element or feature size of semiconductor devices become smaller, the need for optical projection systems capable of providing a resolution less than 0.25 micrometers are needed. In order to decrease the feature size which the optical projection systems used in photolithography can resolve, shorter wavelengths of electromagnetic radiation must be used to project the image of a reticle or mask onto a photosensitive substrate, such as a semiconductor wafer. Because very few refractive optical materials are able to transmit significant electromagnetic radiation below a wavelength of 193 nanometers, it is necessary to reduce to a minimum or eliminate refractive elements in optical projection systems operating at wavelengths below 193 nanometers. An optical system that is usable in the deep ultraviolet portion of the spectrum is disclosed in U.S. Pat. No. 4,747,678 entitled "Optical Relay System With Magnification" issuing to Shafer, et al, on May 31, 1988, which is herein incorporated by reference. However, the desire to resolve ever smaller features makes necessary optical projection systems that operate at the extreme ultraviolet wavelengths, below 200 nanometers, to the soft X-ray wavelengths, around 13 nanometers. While there are several optical projection systems that operate within this wavelength region, they are limited to a relatively low numerical aperture of less than 0.1 at the image or wafer. Increasing the numerical aperture of these designs will result in unacceptably large residual aberrations and obscuration of the light beams by the edges of the mirrors. While these projection optical systems perform adequately for their intended purpose, there is a need for optical projection systems having a higher numerical aperture for use at wavelengths in the extreme ultraviolet or soft x-ray wavelengths, or for resolutions substantially less than 0.1 micrometers or microns.

SUMMARY OF THE INVENTION

The present invention comprises three mirror pairs. The first mirror pair includes a positive power mirror imaging an entrance pupil onto a second mirror of the first mirror pair providing an accessible, real aperture stop. A second mirror pair receives electromagnetic radiation from the first mirror pair and includes a positive power mirror relaying the aperture stop to a second real pupil and forming an intermediate image. A third mirror pair receives electromagnetic radiation from the second mirror pair, and includes a positive power mirror relaying the second real pupil to an exit pupil at infinity and imaging the intermediate image to a real final image. A six mirror reduction system of relatively high numerical aperture is thereby obtained that provides a reduced image of an object, such as a reticle or mask, onto a photosensitive substrate, such as a semiconductor wafer. The second mirror pair acts as a field mirror element providing a relatively high numerical aperture with good or acceptable image quality. All six mirrors may be aspheric to obtain the smallest possible residual aberrations.

Accordingly, it is an object of the present invention to provide a projection optical system for use with wavelengths lower than approximately 200 nanometers and having a relatively high numerical aperture.

It is a further object of the present invention to increase resolution permitting imaging of small element features as required in semiconductor manufacture.

It is an advantage of the present invention that the object and image are accessible for parallel scanning of a reticle and wafer stage as used in step and scan photolithography.

It is another advantage of the present invention that a relatively large field is obtained.

It is a feature of the present invention that an aperture stop is accessible.

It is a further feature of the present invention that a field mirror element is used.

These and other objects, advantages, and features will become readily apparent in view of the following detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic illustration of one embodiment of the present invention.

FIG. **2** is a schematic illustration of a second embodiment of the present invention.

FIG. **3** is a schematic illustration of a third embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. **1** schematically illustrates a first embodiment of the present invention. The light from a reticle or mask **10** is collected by concave mirror **M1**. Dashed line **12** represents the extended curvature of mirror **M1**. Mirror **M1** reflects electromagnetic radiation to concave mirror **M2**. An aperture stop **14** is positioned at or near mirror **M2**. An entrance pupil is positioned a finite distance from the reticle or mask **10** and imaged at mirror **M2** by mirror **M1**. Electromagnetic radiation is reflected from mirror **M2** to concave mirror **M3**. Dashed line **16** illustrates the extended curvature of concave mirror **M3**. Electromagnetic radiation from mirror **M3** is received and reflected by concave mirror **M4**. Dashed line **18** illustrates the extended curvature of concave mirror **M4**. Electromagnetic radiation is reflected from mirror **M4** and received by convex mirror **M5**. Dashed line **20** illustrates the extended curvature of convex mirror **M5**. Electromagnetic radiation is reflected from mirror **M5** and received by concave mirror **M6**, and reflected by concave mirror **M6** to an image location at a wafer **22**. All of the mirrors **M1**–**M6** are substantially rotationally symmetric about the optical axis OA. An intermediate image **24** is formed between the mirrors **M4** and **M3** or at an off-axis location between the first mirror pair, **M1** and **M2**, and the third mirror pair, **M5** and **M6**. This intermediate image is re-imaged at the wafer **22** by mirrors **M4**, **M5**, and **M6**. The first mirror pair, **M1** and **M2**, reflects electromagnetic radiation to a second mirror pair, **M3** and **M4**. The second mirror pair, **M3** and **M4**, functions as a field mirror element and takes the chief ray leaving mirror **M2** diverging away from the optical axis OA, and converts it to a chief ray converging toward the optical axis OA for acceptance by a third mirror pair, **M5** and **M6**.

DOCKET ALARM

Explore Litigation Insights

Docket Alarm provides insights to develop a more informed litigation strategy and the peace of mind of knowing you're on top of things.

Real-Time Litigation Alerts

Keep your litigation team up-to-date with **real-time alerts** and advanced team management tools built for the enterprise, all while greatly reducing PACER spend.

Our comprehensive service means we can handle Federal, State, and Administrative courts across the country.

Advanced Docket Research

With over 230 million records, Docket Alarm's cloud-native docket research platform finds what other services can't. Coverage includes Federal, State, plus PTAB, TTAB, ITC and NLRB decisions, all in one place.

Identify arguments that have been successful in the past with full text, pinpoint searching. Link to case law cited within any court document via Fastcase.

Analytics At Your Fingertips

Learn what happened the last time a particular judge, opposing counsel or company faced cases similar to yours.

Advanced out-of-the-box PTAB and TTAB analytics are always at your fingertips.

API

Docket Alarm offers a powerful API (application programming interface) to developers that want to integrate case filings into their apps.

LAW FIRMS

Build custom dashboards for your attorneys and clients with live data direct from the court.

Automate many repetitive legal tasks like conflict checks, document management, and marketing.

FINANCIAL INSTITUTIONS

Litigation and bankruptcy checks for companies and debtors.

E-DISCOVERY AND LEGAL VENDORS

Sync your system to PACER to automate legal marketing.

WHAT WILL YOU BUILD? | **sales@docketalarm.com** | **1-866-77-FASTCASE**

fastcase® Smarter legal research.