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Review on Extreme Ultraviolet Lithography

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Abstract— ***The technology is a latest used technology in the field of printing on the silicon wafer. This topic covers the full details of the EUVL technology and the advantages of the same. The contribution given by the companies in the development of this technology, which are manufacturing the integrated circuits, is also discussed. It also includes the information regarding establishments of the laboratory for the research involving such technology till today. It also covers the comparison of other lithography technologies with the EUVL. The merits and demerits of the EUVL technology in comparison with other techniques are discussed justifying the use of EUVL technique. In this paper the application of this technology and the detail about the generation of the technology has also been discussed. In today's modern technologies, we are dealing with the electronics equipments and the best we get from these gadgets are requirements of compactness, life time, power and time saving. We are surrounded with the electronics utilities, so in this article the main emphasis on the working process of the technology has been given and the use of this technology in the electronics world is discussed.***

Keywords— ***EUVL(Extreme Ultraviolet Lithography),VNL(Virtual National Laboratory),ETS(Engineering Test Stand),HVM(High Volume Manufacturing),DPP(Discharged Produce Plasma),LPP(Laser Produced Plasma)...***

I. INTRODUCTION

Lithography originally used an image drawn (etched) into a coating of wax or an oily substance applied to a plate of lithographic stone as the medium to transfer ink to the blank paper sheet, and so produce a printed page. But in electronics technology we use to print a component on the silicon chip. And these lithography techniques are classified as below.[1][8]

1 Photolithography
1 E-beam lithography
2 X-ray lithography
3 Extreme ultraviolet lithography
4 Charged-particle lithography
5 Neutral Particle Lithography
6 Nanoimprint lithography
7 Atomic Force Microscopic Nanolithography
8 Magnetolithography

Next-generation lithography include: extreme ultraviolet lithography (EUV-lithography), X-ray lithography, electron beam lithography, focused ion beam lithography, and nanoimprint lithography. EUV as the most popular choice for next-generation lithography, due to its inherent simplicity and low cost of operation as well as its success in the LED, hard-disk and microfluidics sectors.[9]

Extreme ultraviolet lithography (also known as ***EUV*** **or** *EUVL) is a next-generation lithography technology using an* extreme ultraviolet (EUV) wavelength, currently expected to be 13.5 nm.[1]

Thirty years ago, the computing equivalent of today's laptop was a room full of computer hardware and a cartload of punch cards. Since then, computers have become much more compact and increasingly powerful largely because of lithography, a basically photographic process that allows more and more features to be crammed onto a computer chip. Light is directed onto a mask a sort of stencil of an integrated circuit pattern and the image of that pattern is then projected onto a semiconductor wafer covered with light-sensitive photo resist. Creating circuits with smaller and smaller features has required using shorter and shorter wavelengths of light. However, current lithography techniques have been pushed just about as far as they can go. They use light in the deep ultraviolet range at about 248-nanometer wavelengths to print 150- to 120-nanometersize features on a chip. (A nanometer is a billionth of a meter.) In the next half dozen years,

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manufacturers plan to make chips with features measuring from 100 to 70 nanometers, using deep ultraviolet light of 193- and 157-nanometer wavelengths. Beyond that point, smaller features require wavelengths in the extreme ultraviolet (EUV) range. Light at these wavelengths is absorbed instead of transmitted by conventional lenses. The result: no light, no image, no circuit. Semiconductor manufacturers are, therefore, at a critical juncture. Soon, they must decide which lithographic horse to back in the race to the next generation of microchip manufacturing. There are currently four possible alternatives: EUV, x-ray, electron beam, and ion-beam lithography

II. VIRTUAL LAB CONCEPT[4]

Few years ago, three Department of Energy national laboratories Lawrence Livermore, Lawrence Berkeley, and Sandia/California formed the Virtual National Laboratory (VNL) to research and develop extreme ultraviolet lithography (EUVL) technology. The VNL is funded by the Extreme Ultraviolet Limited Liability Company a consortium of Intel Corporation, Motorola Corporation, Advanced Micro Devices Corporation, and Micron Technology, Incorporated in one of the largest cooperative research and development agreements within the Department of Energy. The three year, $250-million venture is dedicated to developing the EUVL technology for commercial manufacturing of computer chips and to move this technology into production facilities in the first decade of the 21st century. Each national laboratory brings unique contributions to this effort. Lawrence Livermore supplies its expertise in optics, precision engineering, and multilayer coatings. Sandia provides systems engineering, the photoactive polymer thin film exposed by the light, and the light source. Berkeley contributes its Advanced Light Source capability to generate EUV light to characterize optics and resists at the nanometer scale. The VNL's lithography system uses mirrors to project the image of a reflective mask onto the photo resist coated semiconductor wafer. Ultimately, this system will enable a microchip to be manufactured with etched circuit lines smaller than 100 nanometers in width, extendable to below 30 nanometers.

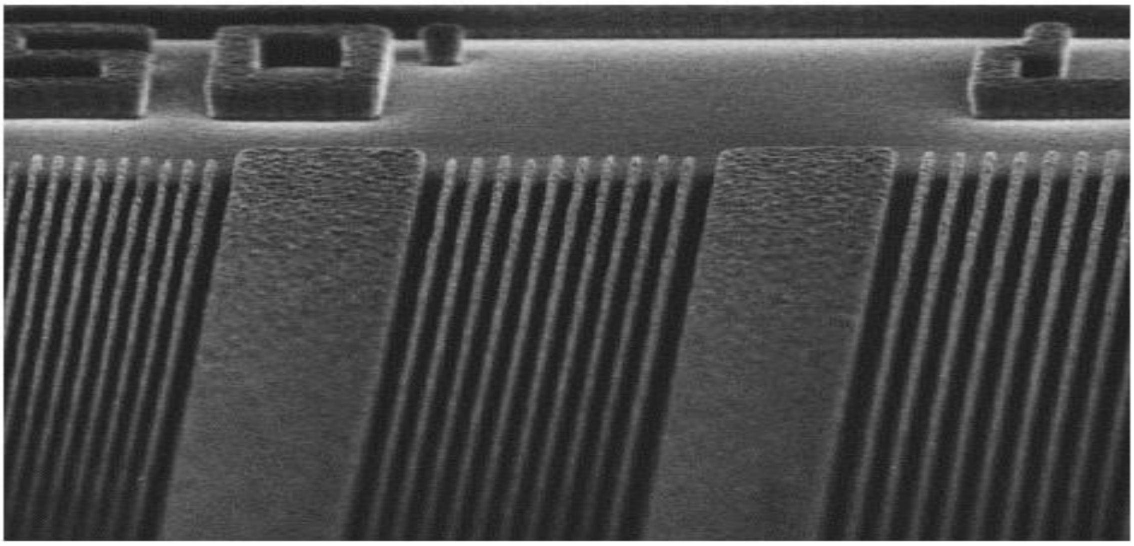


Fig-1: Using a prototype system, the Virtual National Laboratory has successfully printed lines as small as 50 nanometers (billionths of a meter) wide in photo resist[4]

The resulting microprocessors would be a hundred times more powerful than those made today. Memory chips would be able to store a thousand times more information than at present. Lithography is generally viewed as the enabling technology for each new generation of semiconductor devices, says Don Sweeney, Lawrence Livermore's program manager for EUVL. To put this technology into production facilities in 10 years, we need to show that the technology can work under real manufacturing conditions. The VNL's current focus is on building and integrating the necessary technologies into an engineering test stand (ETS). Each national laboratory spearheads specific development areas for the ETS and for the systems beyond. Lawrence Livermore is leading the efforts to develop the optical systems and components, thin films, masks, and sub micrometer metrology required for EUVL.

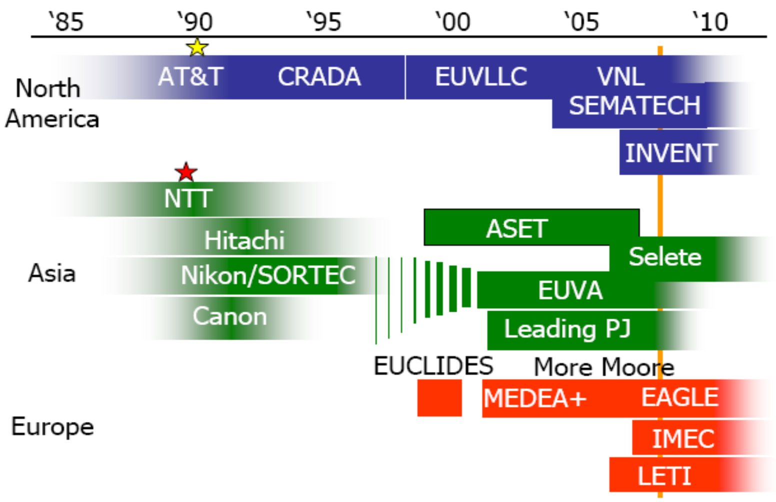
III. EUVL TECHNOLOGY[3]

Extreme ultraviolet lithography (EUVL) is the leading technology being considered for printing circuits at the 32-nm node1 and below in a high-volume manufacturing (HVM) environment fab. In EUVL, a 13.5-nm-radiation wavelength generated by an EUV source is used to print circuits. Because light radiation is strongly absorbed at this wavelength, the entire EUVL scanner system must be in a vacuum environment, and all optics must be reflective, not refractive. Based on the HVM requirements of 100-wafer/h throughput and other system requirements for optics, resist sensitivity, and overhead, a power requirement of 115W has been specified for HVM EUVL scanners. Besides power, EUV sources must meet additional specifications. The production-level requirements in Table I, have been jointly agreed upon by major scanner manufacturers

Discharge-produced plasma (DPP) and laser-produced plasma (LPP) are the leading technologies for generating high-power EUV radiation at 13.5 nm. In both technologies, hot plasma of ≈20–50 eV of the chosen fuel material is generated, which produces EUV radiation. In DPP, magnetic pinching of low temperature plasma generates the high-temperature plasma. In LPP, the target material is heated by a laser pulse to generate high-temperature plasma. Xenon, tin, and lithium are the fuel materials of choice for EUV sources.

TABLE I

DEVELOPMENT OF THE EUVL TECHNOLOGY[5]



The cost-effective implementation of EUVL in HVM presents many technical challenges, of which the EUV source power has remained the greatest one until recently. In the fall of 2004, significant progress in EUV source power was reported at the EUVL Symposium in Miyazaki, Japan, making source power a lesser concern.

Today worldwide, more than eight suppliers and consortia are working to develop high-power EUV sources for EUVL. In addition, some suppliers are working to develop low-power EUV sources that are finding applications in metrology to support EUVL. This chapter presents the status of high-power EUV source technology and summarizes the technical challenges that must be overcome to meet the specifications for high-power EUV sources in HVM.

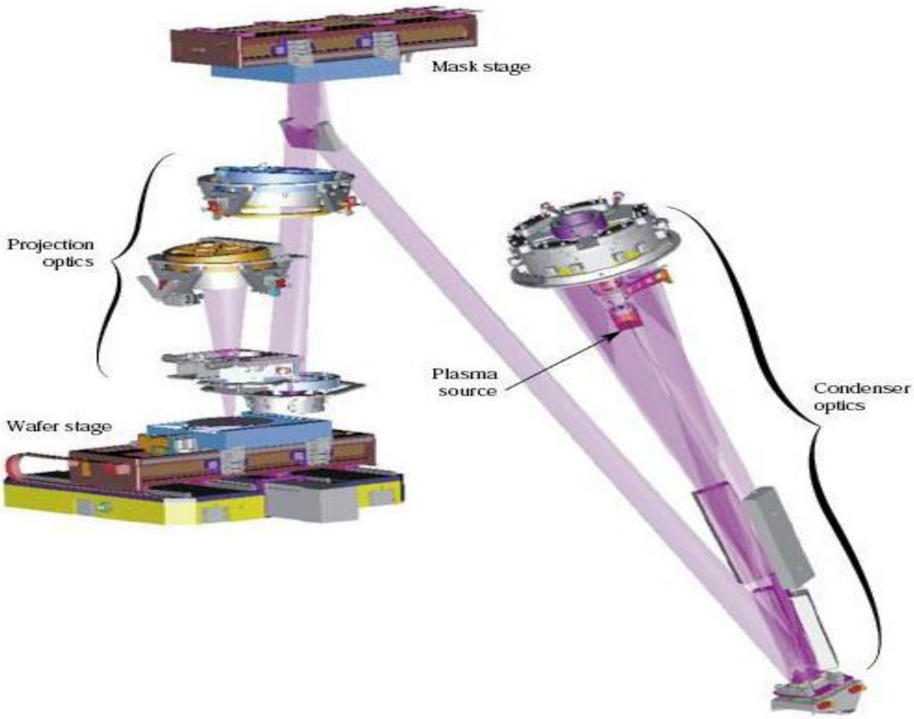


Fig-2: Basic diagram of the EUVL setup [5]

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Minimum lithographic feature size = $\frac{k1\lambda}{NA}$.......... (1)

- **k1**: “Process complexity factor” – includes “tricks” like phase-shift masks
- **λ**: Exposure wavelength
- **NA**: Numerical aperture of the lens – maximum of 1 in air, a little higher in immersion lithography (Higher NA means smaller depth of focus, though)

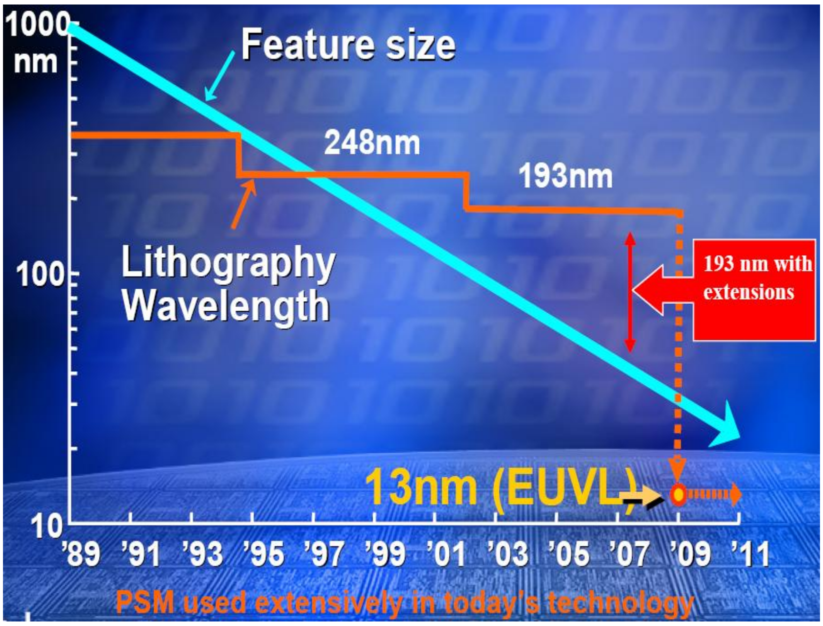

Fig 3 : The feature size minimization update[6]

IV. EUV SOURCES REQUIREMENTS[3]

Joint specifications for EUV sources were first presented by ASML, Canon, and Nikon in February 2002 to accelerate source development by source suppliers, and the joint specifications have been updated periodically. The latest requirements, which was presented at the EUV Source Workshop in Miyazaki (Japan) on November 5, 2004.1 These specifications are defined at/after the intermediate focus (IF), which is explained in the next subsection. Requirements for wavelength, EUV inband power, and etendue of source output were agreed on at the workshop, but requirements for repetition frequency and maximum solid angle input to illuminator are not yet agreed on, because they depend on the tool design.

Two kinds of plasmas emit EUV light: laser-produced plasma (LPP) and gas discharge plasma (GDP). There are various types of GDPs according to the arrangement of the electrodes. Furthermore, several materials (Xe, Sn, etc.) are used for the plasma. Thus, even if only the plasma is considered, there are many potential candidates for the EUV source to be used for high-volume manufacturing (HVM). Collector optics is used to collect EUV light that radiates from the plasma and to focus the light at the IF. There are two kinds of mirror for the collector: the normal-incidence multilayer mirror and the grazing-incidence total-reflection mirror. Furthermore, there are many types of collector that are being developed.

The EUV source is defined as the IF where the EUV light is focused, so that the appropriate exposure tool, and particularly its illuminator, does not depend on the variety of EUV source as described above. The IF is the illuminator entrance. The characteristics of EUV light at the IF should not depend on the method of generating the plasma or on its material, but must satisfy the overall joint requirements. The lifetime of the source components, including the collector optics, is an important factor in the cost of ownership (CoO) of the EUV source. Debris shortens the lifetime of the collector. The material, size, energy, and state of the debris depend on the method of generating the plasma and on its material. Therefore, a debris mitigation system is an indispensable component, and its structure must be optimized for each EUV source. Light emitted from plasma has a wide-ranging spectrum, from EUV to IR. A spectral filter may be needed for the EUV source to satisfy the requirement of spectral purity for its application. It is known that the spectra of light from LPPs and GDPs are different. The spectral filters for LPP and GDP may therefore differ because they must be optimized.

Depending on the type of light source, it is possible to achieve only a 5%– 10% increase in the optical throughput of a system by accurate spectral matching for emitters other than Li. The same shift for a Li-based source would make its use in EUVL impossible. That is not desirable at this early stage of development of EUVL. Currently, therefore, 13.5 nm is the wavelength of choice for EUVL.

V. EUVL OPTICS AND PHOTO RESISTS

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EUVL is a significant departure from the deep ultraviolet lithography used today. All matter absorbs EUV radiation. Hence, EUV lithography needs to take place in a vacuum. All the optical elements, including the photomask, must make use of defect-free Mo/Si multilayers which act to reflect light by means of interlayer interference; any one of these mirrors will absorb around 30% of the incident light. This limitation can be avoided in maskless interference lithography systems. However, the latter tools are restricted to producing periodic patterns only.[1]

The pre-production EUVL systems built to date contain at least two condenser multilayer mirrors, six projection multilayer mirrors, and a multilayer object (mask). Since the optics already absorbs 96% of the available EUV light, the ideal EUV source will need to be sufficiently bright. EUV source development has focused on plasmas generated by laser or discharge pulses. The mirror responsible for collecting the light is directly exposed to the plasma and is therefore vulnerable to damage from the high-energy ions and other debris. This damage associated with the high-energy process of generating EUV radiation has precluded the successful implementation of practical EUV light sources for lithography.

There are two technical issues regarding EUV masks: lowering the defect density of multilayer mask blanks and the delineation of absorber patterns without defects. The development of defect-free multilayer coatings is one of the most crucial issues in the development of EUV mask blanks. A new actinic defect inspection system was developed in Selete. Mask suppliers are working on the selection of a suitable absorber material, absorber etching, and defect repair technology for multi layers.[7]

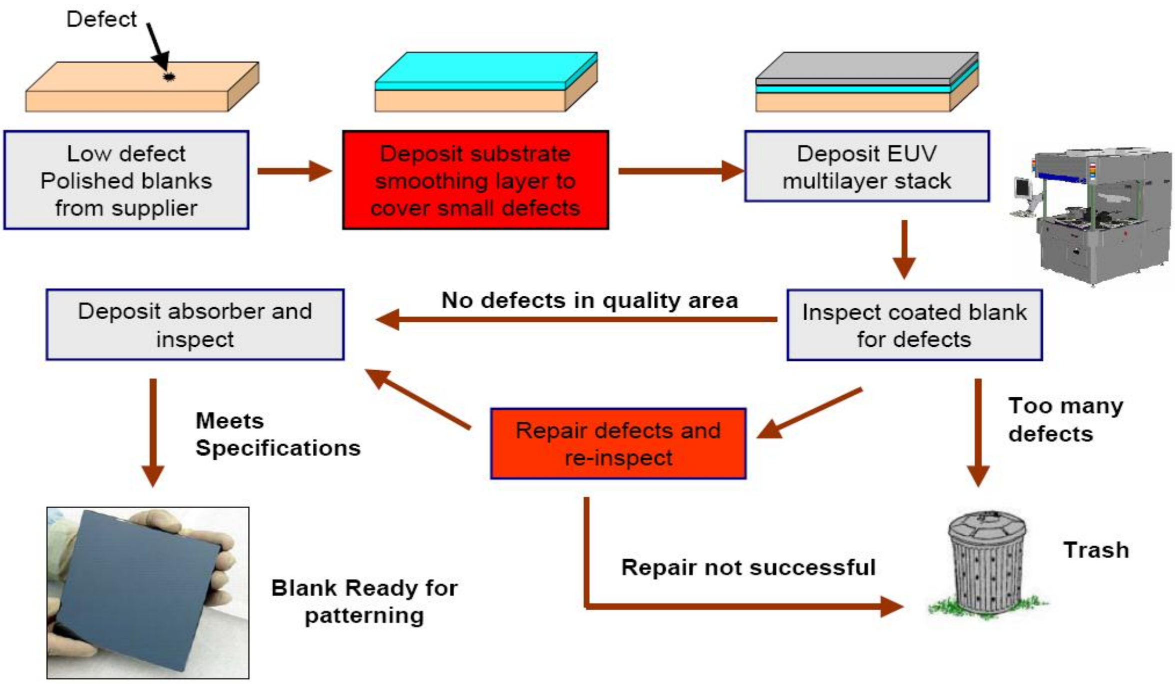

Fig 4 : EVU mask development process[7].

- Extremely flat and defect-free substrate, perfected by smoothing layer
- All defects in multilayer reflecting stack must be completely repaired
- No defects allowed in absorber layer
- All defects in final absorber pattern must be completely repaired

VI. Conclusions

The extreme ultra violet lithography is the most popular and efficient technology that meets every requirements of the silicon wafer printing technology. By using this nanotechnology we can be able to get more and more compact and electronics chips with less power requirements. The technology is cost-effective and much more advantageous than the other nanotechnology in silicon wafer printing.

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