To search page

Late 1970's
Reduction Projection Exposure System (Stepper)

~ Equipment & Materials Table of Contents ~

In 1978, a reduction projection exposure apparatus (hereinafter referred to as a stepper) appeared. This is a method of reduction exposure which directly projects the reticle pattern onto the wafer without using a photomask. In the same year, GCA (Geography Corporation of America) started selling 10:1 stepper (4800 DSW). In the same year, Nikon also delivered a 10:1 stepper (VL-SR 2) to ULSI Research Association. This is the beginning of the wafer exposure of the reduction projection type.
The basic method of reduction projection exposure is the same as lithography by a step and repeat camera used by Fairchild's Jay Last and Robert Noyce in the planar process development in 1959, and the one used for photo-repeater for photomask fabrication by GCA. Nikon had delivered a projection lenses for the photo repeaters in the 1960 's, and there was a history that Nikon had made a proposal to GCA to apply its photo-repeater to the wafer exposure method.
In 1973, Canon also developed a 2:1 reduction projection exposure apparatus (FPA - 120) with a resolution of 1.5 μm. and then a 4:1 reduction manual projection exposure apparatus (FPA - 141) using a lens with the resolution of 0.8 μm. However, in the reduction projection exposure method, productivity is low due to wafer-exposure by step-and-repeat for each chip, and in the 1960's and 1970's, whole-wafer exposure using a photomask (contact exposure / projection exposure systems) were mainstream. In the latter half of the 1970s, when the miniaturization below 1μm was expected in the 1980s, interest in the reduction projection exposure method increased once again, and research and development was advanced at ULSI Research Association, IBM and so on. GCA's stepper was developed based on IBM's empirical verification results. It was called a stepper, since it exposed several chips at a time by step-and-repeat. The major difference from the photo repeater was that alignment between the wafer and the mask (reticle) was necessary, and an off-axis alignment mechanism was mounted. In addition, 436 nm g-line of the mercury lamp was used as the light source and g-line projection lens of Zeiss with NA (numerical apertures) of 0.28 were used. They were delivered to major manufacturers of semiconductor devices worldwide, and semiconductor manufacturing by reduction projection exposure method began.
The resolution of this stepper was not much different from the advanced projection aligners at the time, and the productivity was inferior. What was overwhelmingly superior to the projection exposure method was the ability to reduce the defect density. For example, in the one-shot exposure method, dust of 1 μm on a photomask is resolved on a wafer to be a defect of 1 μm, but 1 μm dust on the reticle of 10:1 reduction exposure becomes 0.1μm on the wafer and is not resolved as a defect. For this reason, the stepper began to spread as a promising exposure method for reducing defects together with the expectation for future miniaturization, and the stepper era came after the 1980s.

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