Specification

~~LIQUID RECOVERY APPARATUS, EXPOSURE APPARATUS, EXPOSURE METHOD, AND DEVICE MANUFACTURING METHOD~~

EXPOSURE APPARATUS, EXPOSURE METHOD AND DEVICE MANUFACTURING METHOD

Technical Field

This invention relates to liquid recovery apparatus, exposure apparatus, exposure methods, and device manufacturing methods, and particularly to exposure apparatus that fill a space between a projection optical system and a substrate with liquid and expose a pattern onto a substrate via the projection optical system and the liquid, and device manufacturing methods using the exposure apparatus.

Priority of the following applications is claimed, and the disclosures of these applications are herein incorporated by reference in their entireties: Japanese Patent Application 2003-307771 filed August 29, 2003 and Japanese Patent Application 2004-150353 filed May 20, 2004.

Technical Background

Semiconductor devices and liquid crystal display devices are manufactured by a so-called photolithographic method that transfers a pattern formed on a mask onto a photosensitive substrate. An exposure apparatus that is used in this photolithographic method is provided with a mask stage that supports a mask, and a substrate stage that supports a substrate. The exposure apparatus transfers a mask pattern onto a substrate via a projection optical system while synchronously moving the mask stage and the substrate stage. Recently, higher resolution of the projection optical system is demanded to obtain higher integration of a device pattern. The resolution of the projection optical system increases as an exposure wavelength that is used becomes shorter and a numerical aperture of the projection optical system becomes larger. Because of this, the exposure wavelength that is used in exposure apparatus has become shortened over the years, and the numerical aperture of projection optical systems has increased. Furthermore, although an exposure wavelength of 248 nm of a KrF excimer laser is currently the mainstream, an exposure wavelength of 193 nm of an ArF excimer laser also has been put into practice. When performing exposure, a depth of focus (DOF) also becomes important in addition to the resolution. The resolution R and the depth of focus δ can be expressed by the following equations.

$$R = k_1 \cdot \lambda / NA \quad \ldots \quad (1)$$

$$\delta = \pm k_2 \cdot \lambda / NA^2 \quad \ldots \quad (2)$$