Method and Device for Embossing of a Nanostructure

This invention relates to a method for embossing of a nanostructure to a stamp surface of a substrate and to a corresponding device.

Nanoimprint lithography (NIL) is a forming method in which nanostructures are formed by a stamp in curable materials, for example resist. In doing so not only is forming of a large number of nanostructure systems possible, but also the production of high-precision nanostructures on large areas by a step-and-repeat or a roll method. High-resolution surface structuring can be carried out with it. Fundamentally it is distinguished between thermal NIL (hot-embossing NIL) and UV-based NIL methods.

Based on the viscosity of the photoresist, capillary action can completely fill the intermediate spaces of the stamp with it. In UV-NIL the stamp at room temperature is pressed into the flowable resist, while in thermal NIL methods the thermoplastic resist must be pressed into the resist at elevated temperature (above the glass transition temperature). The stamp is removed only after the cooling. In UV-NIL lower contact pressures can be used and the process can take place at room temperature. The UV resist cross-links when exposed to UV radiation into a stable polymer (curing). Therefore structuring can be carried out with "soft" polymer stamps and with hard stamps. The soft UV-NIL with polymers as the stamp materials, depending on the application, is an often economical alternative to structuring with hard stamps. Soft UV-NIL (therefore with polymer stamps) is also carried out with hard polymer stamps. The modulus of elasticity of quartz is roughly 100 GPa. In comparison, the moduli of elasticity of polymers (hard and soft polymers) are up to several orders of magnitude smaller, therefore they are called "soft" compared to quartz (soft lithography).

The most important parameters in the NIL methods are the temperature (mainly in hot-embossing NIL), the contact pressure and the adhesion between the resist and stamp. In order to

reduce high adhesion between the resist and stamp, the stamp surface should have a surface energy as low as possible - in interplay with the resist.

Depending on the application, the 3-D structured resist itself can be used as a functional unit or is used as a mask for following etching steps.

For large areas it is difficult to distribute the pressure uniformly over the entire contact surface and to compensate for irregularities. Therefore nonuniform structuring can occur. In order to carry out the structuring of larger areas, embossing is done with a roller or alternatively the entire surface is gradually structured with a smaller stamp by shifting the stamp (step-and-repeat method).

Nanoimprint is used to produce multilayer structures and (cost-efficient) nanostructures (for example integrated circuits in silicon technology) with a resolution below the diffraction limit of light. A large-area nano-embossing process on the entire wafer allows costs, effort and time consumption to be kept low.

Embossing defects which can occur in NIL are for example cracks, nonuniformly filled stamp structures (therefore for example air inclusions) and a nonuniform resist layer thickness. The adhesion between the resist and stamp is critical. Otherwise distortions or cracks occur. Soft and also hard stamps can deform by the applied pressure during the NIL process. Furthermore (dirt) particles are very critical. Particles which are located between for example the resist and stamp lead to defects in the entire periphery of the particle.

High-resolution structuring in the low nm range ($\leq$ 50 nm) is one of the most important advantages of NIL. The replication of structures in the sub 20 nm range is however still a challenge.

Often, for larger wafers, several embossing steps in succession must be carried out to achieve the desired dimensional accuracy. The problem with these embodiments is however ensuring an exact alignment of the many embossing steps with the stamp. Generally alignment marks which are located on the substrate and/or on the stamp are used. High-precision, aligned embossing of different layers on top of one another is not possible or is possible only with great

effort.

Embodiments of this invention disclose a method and a device for embossing of a nanostructure with which large-area substrates can be embossed as much as possible without repeating process steps with structures which are as small as possible.

According to a first aspect of the present invention, there is provided a method for embossing of a nanostructure to a stamp surface of a substrate, including: applying a resist onto the stamp surface of the substrate prior to an imprint operation; and embossing the nanostructure of a nanostructure stamp to the substrate in vacuum or at ambient pressure under inert gas during the imprint operation.

According to a second aspect of the present invention, there is provided a device for embossing of a nanostructure from a nanostructure stamp into a stamp surface of a substrate, including: a deformation means for prestressing of the nanostructure stamp, wherein the deformation means is exposed to a fluid or a gas, and contact-making means for making contact of a partial area of the stamp surface of the substrate with the nanostructure stamp.

All combinations of at least two of the features given in the specification, the claims and/or the figures also fall within the scope of the invention. At the given value ranges, values which lie within the indicated limits will also be considered to be disclosed as boundary values and will be claimed in any combination. To the extent features disclosed for the device can also be interpreted as features of the method, they should also be considered as according to the method and vice versa.

The basic idea according to embodiments of this invention is to make contact first with only a partial area of a stamp surface with the nanostructure stamp by prestressing a nanostructure stamp and/or a substrate and then to effect automatic contact-making with the contact surface by releasing the nanostructure