PARTICLE-OPTICAL APPARATUS AND METHOD FOR OPERATING THE SAME

BACKGROUND OF THE INVENTION

[0001] 1) Field of the Invention

[0002] The present invention relates to a particle-optical apparatus for manipulating a beam of charged particles, a method for operating such a particle-optical apparatus, a microscopy system and a lithography system.

[0003] 2) Brief Description of Related Art

[0004] The particle-optical apparatus provides a magnetic field which the beam to be manipulated traverses. This manipulation may include a focusing, a deflection, a conversion of the beam or the like.

[0005] Magnetic field configurations are known from the prior art which have a focusing, deflecting or converting effect on a beam of charged particles.

[0006] For example, a beam deflector is known from U.S. Pat. No. 6,188,071 B1 for use in a lithography system. Here, a beam traversing the apparatus is an electron beam which is used as writing beam of the lithography system. A resolution of the lithography method performed therewith is thus determined also by the accuracy with which the deflection or/and focusing of the writing beam is performed in the apparatus. The apparatus comprises ferrite bodies for carrying the magnetic fields produced by current conductor windings. It is a property of ferrite materials that their magnetic permeability is temperature-dependent. Accordingly, if the temperature of the ferrite body changes, its magnetic property will also change and, correspondingly, the effects which the apparatus exerts on the writing beam traversing the same will change with temperature variations. According to U.S. Pat. No. 6,188,071 B1, a temperature control is provided to stabilize the temperature of the ferrite body in order to reduce influences of temperature on the quality of the lithographic process. It is also recognized in the document that the temperature regulation might, under certain circumstances, be too slow to sufficiently suppress temperature changes in the ferrite body. Therefore, the conventional apparatus comprises an additional correcting coil with low inductivity to actively compensate for the influences of the temperature dependence of the permeability of the ferrite material on the beam which are not completely suppressed by the temperature control.

SUMMARY OF THE INVENTION

[0007] It has been found that it is not easy to suppress temperature influences on the ferrite material. Accordingly, it is an object of the present invention to provide a particle-optical apparatus with a magnetic-flux-carrying body, such as a ferrite, wherein temperature changes in the magnetic-flux-carrying body have less influence on a beam of charged particles to be manipulated by the apparatus. Moreover, it is an object of the invention to provide a method for operating such apparatus. A further object. of the invention is to provide an electron microscopy system and/or a lithography system wherein relatively good imaging properties are achievable.

[0008] The invention proceeds from a particle-optical apparatus for providing a magnetic field for manipulating a beam of charged particles which comprises: a magnetic-flux-carrying body made of a material having a high permeability number, at least one current conductor engaging at least partially around the magnetic-flux-carrying body and a temperature-adjusting unit for adjusting a temperature of the magnetic-flux-carrying body substantially to a nominal or target temperature.

[0009] The invention takes into account the fact that the permeability number of the magnetic-flux-carrying body always depends on temperature. In order to reduce influences exerted by temperature changes in the magnetic-flux-carrying body on the manipulation of the beam, the temperature-adjusting unit is accordingly provided for stabilizing the magnetic-flux-carrying body substantially to the nominal or target temperature. Here, too, the invention takes further into account the fact that such a temperature-adjusting unit, be it a temperature-adjusting-unit with or without feed-back control, will not be able to perfectly prevent temperature variations in the magnetic flux-carrying body. At this point, the concept which the invention is based upon sets in, namely to select the nominal or target temperature of the magnetic-flux-carrying body such that it is in a temperature range in which the permeability number of the material of the magnetic-flux-carrying body has relatively low temperature dependent changes.

[0010] If temperature changes occur in such a range, they have thus a relatively small influence on the permeability number and thus on the effect exerted by the particle-optical apparatus on the beam traversing the same.

[0011] A temperature range in which the permeability number has relatively low changes is a range in which a graph which represents the dependence of the permeability number on the temperature exhibits a relatively flat slope. Accordingly, such a range can be characterized by the following formula:

$$\frac{\mu_{\max} - \mu\min}{\mu_{\max} \cdot \Delta T} = c,$$

[0012] wherein $c<3 \cdot 10^{-3}$ K^{-1}.

[0013] Here,

[0014] $\mu_{\max}$ is a maximum value of the permeability number in the temperature range,

[0015] $\mu_{\min}$ is a minimum value of the permeability number in the temperature range and

[0016] ΔT is a width of the temperature range.

[0017] In order to achieve a particularly small temperature dependence of the permeability within the temperature range in which the nominal temperature is under practical conditions, c is preferably selected to be $c<9 \cdot 10^{4}$ $K^{31\ 1}$, preferably, $c<3 \cdot 10^{-4}$ $K^{31\ 1}$, more preferred, $c<9 \cdot 10^{-5}$ $K^{31\ 1}$, even more preferred, $c<3 \cdot 10^{-5}$ $K^{31\ 1}$. Further preferred are even smaller values of c, namely $c<9 \cdot 10^{-6}$ $K^{31\ 1}$, in particular, $c<3 \cdot 10^{-6}$ K^{-1} and, even more preferred, $c<1 \cdot 10^{-6}$ K^{-1}.

[0018] A particularly favorable independence of temperature variations is achieved if the nominal or target temperature is adjusted such that the temperature dependence of the permeability number of the material of the magnetic-flux-