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(54) MULTI-POLE DEFLECTOR FOR CHARGED (56) References Cited PARTICLE BEAM AND CHARGED PARTICLE BEAM IMAGING APPARATUS U.S. PATENT DOCUMENTS

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(57) **ABSTRACT**
The invention provides a multi-pole deflector for a charged particle beam, and a charged particle beam imaging apparatus. The deflector includes a plurality of poles, including at least two pairs of poles, each pole in each pair of poles including a main body constructed in the for inner side of the main body. respective two main bodies of each pair of poles are arranged concentrically and diametrically opposite, and the at least two pairs of poles at least partially encompass and delimit a through-hole thereamong,
which opens axially and is configured to receive and to pass
therethrough the charged particle beam; and the at least two
pairs of poles cooperate to generate resp respectively, and the secondary deflection fields are synthesized by combination of vectors into a resultant deflection field of the deflector which is distributed within and across
the through-hole and is configured to deflect the charged particle beam passing therethrough.

16 Claims, 7 Drawing Sheets

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 $H0IJ 37/244$ (2006.01) $H01J$ 37/244
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- CPC H01J 2237/0492 (2013.01); H01J 2237/2448 (2013.01)
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FIG₃

 $FIG.4(a)$

FIG5

 $FIG. 6(a)$

 $\bf{F1}$ C \bf{U} \bf{U}

 $FIG.6(c)$

FIG.7

15

PARTICLE BEAM AND CHARGED deflection field in a paraxial region of an optical axis Z).
PARTICLE BEAM IMAGING APPARATUS

CROSS-REFERENCE TO RELATED
APPLICATION

Aug. 28, 2019 in the State Intellectual Property Office of 10 particle beam and a charged particle beam imaging appara-
China, the whole disclosure of which is incorporated herein tus.
In order to achieve above objectives,

the technical field of scan imaging technology with charged pole in each pair of poles comprising:

particle beam, and more particularly to a device configured a main body constructed in the form of a circular particle beam, and more particularly to a device configured a main body construction and the generate a deflection field (such as an electric field, a 20 shaped section; and to generate a deflection field (such as an electric field, a 20 shaped section; and
magnetic field, or the like) for deflection of a charged a protrusion projecting from an radial inner side of the
particle beam and furthe

apparatuses have been more and more widely used in and
semiconductor industry, for example, a critical dimension 30 wherein respective two poles in pairs of the at least two scanning electron microscope (CD-SEM), which is often pairs of poles cooperate to generate respective secondary
used to measure critical dimension(s) of patterns on one and deflection fields distributed within the throughused to measure critical dimension(s) of patterns on one and deflection fields distributed within the through-hole and
the same production object during manufacturing of the across an internal space defined within the thro chip, such as a semiconductor wafer, a mask, or the like, so respectively, and the secondary deflection fields are synthe-
as to implement an online monitoring of production pro- 35 sized by combination of vectors into a r as to implement an online monitoring of production pro- 35 cesses. Electron beam defect detection apparatus is configcesses. Electron beam defect detection apparatus is config-
ield of the deflector which is distributed within and across
ured to perform an imaging detection of defects in micro-
the through-hole and is configured to defle red to perform an imaging detection of defects in micro-
scopic patterns on a semiconductor silicon wafer and in turn
to feed back the yield in processes of production and process
development. A main principle of the imagi apparatuses with the charged particle beam is to use the tor, the at least two pairs of poles are at least two pairs of charged particle beam (such as high-energy electron beam, electrodes formed by a conductive material a and the like) to bombard a bombardment region on a surface to generate respective electric fields cooperatively when bias
of an object to be detected or tested (e.g., a chip to be tested), voltages are applied thereon resp so as to excite charged particles which may contain or carry 45 electric fields are synthesized by combination of vectors into a variety of physical and chemical information of a sample a resultant deflection electric fiel a variety of physical and chemical information of a sample a resultant deflection electric field of the multi-pole electro-
itself which is to be tested within in the bombardment static deflector; or the deflector is a mul region, such as secondary charged particles, back-scattered deflector, the at least two pairs of poles comprise at least two particles and the like; and then, these charged particles are pairs of magnetic poles formed by a collected, processed and imaged, and in turn to obtain a 50 material and having respective excitation coils which are variety of information of the sample to be tested, such as attached onto respective radial sides of the and the like) to bombard a bombardment region on a surface

primary functionality of deflecting charged particle beam to 55 netic fields are synthesized by combination of vectors into a
perform a scanning. Specifically, a reflector may for resultant deflection magnetic field of the example be an electric deflector or a magnetic deflector,
which deflects charged particles entering a deflection field
generated by the deflector itself, depending on respective
disclosure, the respective two main bodies o

obtain an improved multi-pole deflector which may achieve and have a same inner radius at respective radial inner sides a compromise between a simplification in structural design and a same outer radius at respective radia (e.g. , a minimum number of poles and a minimum number 65 respective main bodies of the at least two pairs of poles are a

MULTI-POLE DEFLECTOR FOR CHARGED obtained (especially a uniformity of field distribution of the **PARTICLE BEAM AND CHARGED** deflection field in a paraxial region of an optical axis Z).

SUMMARY

The embodiments of the present disclosure have been made to overcome or alleviate at least one aspect of the above mentioned disadvantages and/or shortcomings in the The present disclosure claims the benefit of Chinese above mentioned disadvantages and/or shortcomings in the Patent Application Invention No. 201910803416.X filed on prior art, by providing a multi-pole deflector for a ch

solutions are adopted in exemplary embodiments of the

BACKGROUND invention.

15 According to one aspect of embodiments of the disclosure, there is provided a multi-pole deflector for a charged Field sure, there is provided a multi-pole deflector for a charged Embodiments of the present disclosure generally relate to particle beam, comprising at least two pairs of poles, each e technical field of scan imaging tec

for a charged particle beam and a charged particle beam 25 cally opposite to each other, and the at least two pairs of imaging apparatus.
poles at least partially encompass and delimit a through-hole
bescription of the Rel Description of the Related Art thereamong, which opens axially and is configured to In recent years, charged particle beam scanning imaging receive and to pass therethrough the charged particle beam; receive and to pass therethrough the charged particle beam; and

topography, composition, feature distribution and the like. of magnetic poles, and is configured to generate respective
In a charged-particle detection and imaging apparatus, magnetic fields cooperatively when an excitatio

charged particles.
In a relevant technical field, it is required urgently to eircumferential direction of the respective two main bodies, and a same outer radius at respective radial outer sides; and respective main bodies of the at least two pairs of poles are of feed ports or feed terminals required by the poles) and a spaced apart from one another angularly and circumferen-
uniformity of field distribution of a deflection field as tially, and are arranged to be in rotational s tially, and are arranged to be in rotational symmetry with

pairs of poles extend across an equivalent radian and have a 5 poies have central symmetry with reference to each other.

According to an exemplary embodiment of the present

disclosure, the respective protrusions.

pairs of poles extend across an equivalent radian and have a 5

pairs

disclosure, the respective main bodies of the at least two second charged particles therefrom for imaging, further pairs of poles are arranged to space apart from one another 15 comprising:
at a same angle circumferentiall

According to an exemplary embodiment of the present particle beam; and
disclosure, the at least two pairs of poles comprise just two a secondary charged particle detector, which is located to

disclosure, respective protrusions of the at least two pairs of ary charged particles generated by the charged particle beam
poles are shaped and dimensioned to minimize an off-axis projected to the sample to be tested; poles are shaped and dimensioned to minimize an off-axis projected to the sample to be tested;
aberration of the charged particle beam being incident on the wherein, the at least one pair of the deflectors are sym-

between the sample to be tested in response to a scanning signal applied
poles extends circumferentially across an angle not exceed-
ing a threshold angle range, and projects from respective 30 According to an exemplary em

disclosure, the threshold angle range is 5° to 40° and the upstream of the at least one pair of the deflectors, and is threshold radial distance is between 0.1 and 0.9 times of the 35 configured to focus the charged

poles is shaped to be in the form of a boss which projects 40 at least one focusing lens, which is arranged coaxially
from the respective radial inner side of the respective main with the optical axis and between the charg

a partial cone and a partial pyramid projecting from the charged particle beam.

respective radial inner side of the respective main body of

the respective pole and is provided with a convex top BRIEF DESCRIPTION OF THE D the respective pole and is provided with a convex top portion. 50

poles is shaped to be in the form of one of a truncated required to be used with the description of the embodiments frustum of a cone, a truncated spherical segment, a frustum, of the present disclosure will be briefly des frustum of a cone, a truncated spherical segment, a frustum, of the present disclosure will be briefly described by way of and a multi-stage stepped boss projecting from the respec- 55 example as below in which correspondi

disclosure, the threshold angle range for respective protru-
sions of each pair of poles is equal to a radian angle range 60 drawings without paying any creative efforts. The accomoccupied by each of a pair of imaginary protrusions used panying drawings are used to provide a further understand-
instead of the respective protrusions in the pair of poles, ing of the technical solution of embodiments o such that a pair of poles alternatively having the pair of sure, and constitute a part of the specification, for imaginary protrusions, each of which is in the form of a boss cooperating with embodiments of the disclosure projecting from the respective radial inner side of the 65 the technical solution of the embodiments of the disclosure, respective main body and is provided with an arc-shaped rather than forming any restriction on the tec concave top portion, generate an imaginary secondary

reference to one another, and respective poles in each pair of deflection field equivalent to the secondary deflection field poles have central symmetry with reference to each other. as generated practically by the pair of

from one another angularly in the same circumference
defined collectively by the respective main bodies.
According to an exemplary embodiment of the present of a sample to be tested and in turn to excite and collect

pairs of poles alternately spaced apart from one another at an the offset from an optical axis of the charged particle beam angle of 90°.

²⁰ and between the charged particle source and the sample to According to an exem

deflector and entering and passing through the through-hole 25 metrically arranged with respect to the optical axis of the of the deflector.

charged particle beam, and are configured to deflect and According to an exemplary embodiment of the present project the charged particle beam to the surface of the disclosure, each of respective protrusions of each pair of sample to be tested in response to a scanning signal ap

According to an exemplary embodiment of the present ally with the optical axis and is located downstream or disclosure, the threshold angle range is 5° to 40° and the upstream of the at least one pair of the def

threshold radial distance is between 0.1 and 0.9 times of the 35 configured to focus the charged particle beam passing there-
respective inner radius at respective radial inner sides of the through onto the surface of the

shaped concave top portion.

According to an exemplary embodiment of the present

disclosure, each of the respective protrusions of each pair of 45 focusing lens and the at least one pair of the deflectors, and is configur

According to an exemplary embodiment of the present In order to more clearly illustrate technical solutions of disclosure, each of the respective protrusions of each pair of the embodiments of the present disclosure, the d tive radial inner side of the respective main body of the als denote corresponding components. It is apparent that the respective pole and is provided with a flat top portion. The drawings in the following description are According to an exemplary embodiment of the present embodiments of the present disclosure. For those skilled in disclosure, the threshold angle range for respective protru-
the art, other drawings can be obtained according

FIG. 1 illustrates a schematic structural view of a multiing that respective schematic structures of various poles are described above is used.
provided with respective protrusions protruding/projecting 5 respective schematic arrangements of various poles in which
each protrusion is in the form of a boss which projects from The technical solution of embodiments of the present FIG. 1 illustrates a schematic structural view of a multi-
pole deflector for a charged particle beam according to
example particle beam imaging apparatus according to embodiments
embodiments of the present disclosure, sch embodiments of the present disclosure, schematically show-
ing that respective schematic structures of various poles are
described above is used. inwards from respective radial inner sides thereof, and DETAILED DESCRIPTION respective schematic arrangements of various poles in which the respective radial inner side of the respective pole and is
tisclosure will be further interpreted in detail with reference
annually and is disclosure will be further interpreted in detail with reference
annually all th

tor in use as illustrated in FIG. $2(a)$;
FIG. 3 illustrates a diagram of distribution status of

FIG. 3 denotes a size (labeled by 'r') of the paraxial region FIG. 3 denotes a size (labeled by 'r') of the paraxial region beam imaging apparatus.
and a vertical axis in FIG. 3 denotes a size (labeled by 'Er') In relevant technologies, for example, in the charged FIG. 3 illustrates a diagram of distribution status of The accompanying drawings are used to illustrate the electric field intensity of a radial deflection field falling contents of embodiments of the present disclosure. D within a paraxial region of the multi-pole electric deflector 20 sions and shapes of the components in the drawings do not as illustrated in FIG. $2(a)$ on condition of different boss demonstrate true scales of component parameters (e.g., $R3/R2=0.7$), wherein a horizontal axis in deflector for a charged particle beam and a charged particle FIG. 3 denotes a size (labeled by 'r') of the paraxial region beam imaging apparatus.

boss parameters (e.g., $R3/R2=0.7$), wherein a horizontal axis

matically showing that each of the protrusions in the respec-
tive schematic structures of various poles is specifically in 45 constitutes a basic/fundamental unit of the multi-pole deflec-
the form of a multi-stage steppe the form of a multi-stage stepped boss which projects from tor.
the respective radial inner side of a main body of the One deflector having above dual-pole deflection field the respective radial inner side of a main body of the One deflector having above dual-pole deflection field
respective note and is provided with a flat top portion.

FIG. $6(b)$ illustrates a schematic structural view of an
alternative multi-pole deflector for charged particles accord-
ing to another embodiment of the present disclosure, sche-
ing to another embodiment of the present d matically showing that each of the protrusions in the respectively concerned respectively, there exist a symmetric plane and an
anti-symmetric plane, comprising an optical axis Z orthogotive schematic structures of various poles is specifically in anti-symmetric plane, comprising an optical axis Z orthogo-
the form of a partial pyramid shape which projects from the same the magnatic field generated thereb the form of a partial pyramid shape which projects from the 55 or the magnetic field generated thereby is perpendicular to respective radial inner side of a main body of the respective $\frac{1}{2}$ is order to echiove defl

alternative multi-pole deflector for charged particles accord- 60 dual-pole field deflector units (i.e., the number of the dual-
ing to another embodiment of the present disclosure, sche-
pole field deflectors functioning matically showing that each of the protrusions in the respective accordingly the multi-pole deflector having the 2N-pole
tive schematic structures of various poles is specifically in
the form of a partial sphere shape whic respective radial inner side of a main body of the respective 65 arranged collectively into a quadrupole structure. The multipole and is provided with a convex and domed top portion; pole deflector having the 2N-pole struc pole and is provided with a convex and generates N secondary deflection fields (also referred to as

sure. provided with an arc-shaped concave top portion;
FIG $\mathcal{X}(\cdot)$ ill the detection of the specification of the specification of the specification of the smaller reference numerals denote same or similar compo-FIG. $2(a)$ illustrates a schematic structural view of a similar reference numerals denote same or similar compo-
hents. The following description of embodiments of the multi-pole electric deflector based on the schematic structure
and arrangement of various poles as illustrated in FIG. 1;
ince is measured to the interpret the scompany inventive and arrangement of various poles as intustrated in FIG. 1;
FIG. $2(b)$ illustrates a schematic diagram of distribution 15 concept of embodiments of the present disclosure, rather
status of electric field lines in the mul

contents of embodiments of the present disclosure. Dimensions and shapes of the components in the drawings do not

of the radial field;

FIG. $4(a)$ shows a schematic structural view of a multi-

effection of the charged particle beam is implemented by a FIG. $4(a)$ shows a schematic structural view of a multi-
le magnetic deflector based on the schematic structure and bipolar type (i.e., a dual-pole type) deflection field which is pole magnetic deflector based on the schematic structure and bipolar type (i.e., a dual-pole type) deflection field
generated by a deflector, e.g., a dual-pole type magnetic field arrangement of various poles as illustrated in FIG. 1;
EIG $A(b)$ illustrates a schematic digaram of distribution or a dual-pole type electric field (i.e., a magnetic field FIG. $4(b)$ illustrates a schematic diagram of distribution or a dual-pole type electric field (i.e., a magnetic field in the multi-pole electric deflector in 30 formed by both N pole and S pole disposed opposite to each status of magnetic field in the multi pole electric deflector. The multi-
status of pole and S pole and S pole disposite to each other ; or an electric polarities (i.e., a positive electrode and a
FIG. 5 illustrates a dia FIG. 5 illustrates a diagram of distribution status of
electric field intensity of a radial deflection magnetic field
falling within a paraxial region of the multi-pole magnetic field
falling within a paraxial region of t FIG. $6(a)$ illustrates a schematic structural view of an as to function as two types of poles disposed opposite to alternative multi-pole deflector for charged particles accord-
each other; and as such, each arrangement a alternative multi-pole deflector for charged particles accord-

ing to another embodiment of the present disclosure, sche-

above, which generates the dual-pole type deflection field incurring deflection of charged particles in a fixed direction,

respective pole and is provided with a flat top portion; arrangement and functioning as a basic unit (thus it can be
FIG $6(b)$ illustrates a schematic structural view of an eferred to as a dual-pole field deflector unit, respective radial inner side of a main body of the respective
pole and is provided with a convex and sharpened top
portion;
FIG. $6(c)$ illustrates a schematic structural view of an
FIG. $6(c)$ illustrates a schematic struc \mathcal{L}

"
deflection sub-fields") in a coplanar distribution, and then According to a general inventive concept of the embodi-

a resultant deflection field which is obtained by a synthesis ments of the disclosure, as illustrated of these secondary deflection fields by combination of of the embodiments of the disclosure, a multi-pole deflector vectors is essentially an equivalent dual-pole field, too, by 1 for a charged particle beam is provided, w vectors is essentially an equivalent dual-pole field, too, by 1 for a charged particle beam is provided, which comprising way of example.

s at least two pairs of poles 100, each pole 100 in each pair of

respective two opposite poles in each dual-pole field deflec-
tropiecting from an radial inner side of the main body 101.
tor are usually two poles in the form of two opposed plates
parallel with each other, resulting in t parallel with each other, resulting in that a condition of edge 10 distribution of a respective secondary deflection field gendistribution of a respective secondary deflection field gen-
eally opposite to each other, and the at least two pairs of
erated thereby at the poles (especially at ends of the poles)
poles 100 at least partially encompass erated thereby at the poles (especially at ends of the poles) poles 100 at least partially encompass and delimit a through-
significantly differs from a condition of central distribution
of the respective secondary deflect another, centrally within the secondary deflection field), due pairs of the at least two pairs of poles 100 of the deflector 1 to a distortion of field lines of the respective secondary cooperate to generate respective sec to a distortion of field lines of the respective secondary cooperate to generate respective secondary deflection fields deflection field at the poles (especially at ends of the poles) distributed within the through-hole an deflection field at the poles (especially at ends of the poles) distributed within the through-hole and across an internal caused by an abrupt change in contour of the poles there, 20 space defined within the through-hole, caused by an abrupt change in contour of the poles there, 20 which fact is not conducive to realization of uniformity of an which fact is not conducive to realization of uniformity of an secondary deflection fields are synthesized by combination overall distribution of the respective secondary deflection of vectors into a resultant deflection f field and a smooth transition of the condition of field distribution from inside of the secondary deflection field to distribution from inside of the secondary deflection field to and is configured to deflect the charged particle beam a boundary region of the secondary deflection field. Fur- 25 passing therethrough. thermore, in the multi-pole deflector having at least two As far as the multi-pole deflector 1 of the embodiments of dual-pole field deflectors, in a condition of a relatively small the present disclosure is concerned, an number of the dual-pole field deflectors, although the multi-
pole deflector has a relatively simple structure due to the
based is above all described, hereinafter. relatively small number of poles and the relatively small 30 In the embodiments of the present disclosure, as described
number of feed ports required by the poles, the uniformity above, on the one hand, respective two main number of feed ports required by the poles, the uniformity of the resultant deflection field in a paraxial region of the of the resultant deflection field in a paraxial region of the each pair of poles in the at least two pairs of poles 100, are multi-pole magnetic deflector next to the optical axis Z is each in the form of a circular arc-sh relatively poor, resulting in a relatively higher deflection arranged concentrically with respect to the optical axis Z, aberration and an impact on quality of an off-axis beam spot; 35 and are arranged diametrically oppos number of poles and the relatively large number of feed are arranged to face towards each other in the diametrical
ports required by the poles, not only difficulties in the direction. Such an arrangement in which respectiv processing and assembly accuracy of the structure may be 40 main bodies 101 of two poles in pair are disposed diametri-
incurred, but also a need for an additional power supply will cally opposite to each other, in essence alternatively, in a condition of a relatively large number of incurred, but also a need for an additional power supply will

field in the distribution region of the deflection field which 45 circumferential direction or in a direction close to the is defined by the poles of the multi-pole deflector (especially circumferential direction, such tha in the paraxial region of the multi-pole magnetic deflector edge field lines of these secondary deflection fields gener-
next to the optical axis Z passing through the distribution ated by pairs of poles in the deflector w region of the deflection field) for the passage of charged minimally influence the charged particle beam passing
particles to be deflected therethrough, and the smoothness of 50 through the through-hole 103 which is at lea field from the center to the edge of the deflection field may pole deflector 1 and opens axially. As such, the influence of be achieved, with a structure of the multi-pole deflector the distortion of the field lines of the simplified as much as possible (e.g., the minimum number
of effection fields of individual dual-pole deflectors in the
of poles and the minimum number of feed ports), then, an 55 multi-pole deflector 1 at edges as compared

FIG. 1 illustrates a schematic structural view of a multi-
pole deflector for a charged particle beam according to respective two main bodies 101 of two poles 100 in pair are pole deflector for a charged particle beam according to respective two main bodies 101 of two poles 100 in pair are embodiments of the present disclosure, schematically show- 60 disposed opposite to each other in the circu ing that respective schematic structures of various poles are
provided with respective protrusions protruding/projecting
in the embodiments of the present disclosure, on the other
inwards from respective radial inner sides respective schematic arrangements of various poles in which with a respective protrusion 102 projecting radially inwards each protrusion is in the form of a boss which projects from ϵ from the radial inner side of it the respective radial inner side of the respective pole and is
protons of the protons of the provided with an arc-shaped concave top portion.
The provided with an arc-shaped concave top portion.

 7 8

ay of example.
For a multi-pole deflector having at least two (e.g., a poles comprising: a main body 101 constructed in the form For a multi-pole deflector having at least two (e.g., a poles comprising: a main body 101 constructed in the form plurality of pairs of) dual-pole field deflectors, first of all, of a circular arc-shaped section; and a pro of vectors into a resultant deflection field of the deflector which is distributed within and across the through-hole 103

arranged concentrically in the circumferential direction, and are arranged to face towards each other in the diametrical incurred be created.
Interefore, in order to ensure that both the uniformity of the respective two main bodies 101 in each pair of poles at the created of poles at $\frac{1}{2}$. Therefore, in order to ensure that both the uniformity of by respective two main bodies 101 in each pair of poles at the distribution of the field lines of the resultant deflection ends of the two poles in pair extend subs ends of the two poles in pair extend substantially along the circumferential direction or in a direction close to the improved multi-pole deflector is further proposed in the lines at center thereof, on the charged particle beam passing
embodiment of the disclosure.
FIG. 1 illustrates a schematic structural view of a multi-
for is minimiz

respective main body 101 of each pole, a difference between

two poles 100 in each pair of poles (such a spacing would have been relatively larger without the protrusion) and have been relatively larger without the protrusion) and respective radial outer sides; and the respective main bodies another spacing between respective end portions of respec-
101 of the at least two pairs of poles 100 ar tive two poles 100 in each pair of poles (such another 5 from one another angularly in the same circumference of the spacing is relatively smaller, as compared with the distance between respective central portions without may be decreased substantially to an extent. In other words, fields generated by all of the dual-pole field deflectors in the a gradient of the spacing between respective two poles in multi-pole deflector 1 have a same mag a gradient of the spacing between respective two poles in multi-pole deflector I have a same magnitude, respectively, each pair of poles in each dual-pole field deflector which 10 facilitating both calculation and control field lines at the edges of the poles 100 on the charged bodies 101 of the at least two pairs of poles 100 are arranged
particle beam is improved as described above, a trend that 15 to space apart from one another at a sam significant change of the spacing between the respective two body 101 in the respective poles 100, are arranged to spaced
poles in each pair of poles 100 which is caused by the 20 apart from one another at an equal angle i

Therefore, it can be seen that, a main idea of the inventive 25 concept of the embodiments of the present disclosure lies in concept of the embodiments of the present disclosure lies in the paraxial region next to the optical axis Z) which is at that, the uniformity of the resultant deflection field generated least partially encompassed and deli that, the uniformity of the resultant deflection field generated least partially encompassed and delimited by the various
by the multi-pole deflector within the through-hole 103 poles 100 of the multi-pole deflector 1, fur which is at least partially encompassed and delimited by the better uniformity of the resultant deflection field.
various poles 100 of the multi-pole deflector 1 (especially in 30 In a further embodiment of the present dis by a cooperation between two aspects of settings, i.e., the poles comprise just two pairs of poles alternately spaced arrangement in which respective two main bodies 101 of apart from one another at an angle of 90°. In oth arrangement in which respective two main bodies 101 of apart from one another at an angle of 90° . In other words, the two poles 100 in each pair are disposed opposite to each multi-pole deflector 1 comprises four p other in the circumferential direction, and the respective 35 orthogonally to one another, that is, two dual-pole field
protrusion 102 projecting radially inward from the respec-
deflectors arranged orthogonal to each othe spacing between respective two poles in each pair of poles with such a setting, the off-axis aberration introduced
in each dual-pole field deflector which spacing changes from 40 when the charged particle beam passes throu end portions thereof, which gradient is caused by the multi-pole deflector is also realized with the minimum arrangement in which respective two main bodies 101 of number of poles 100 and the minimum number of feed ports two poles 100 in each pair are disposed opposite to each required by the poles 100, thereby simplifying the structure other in the circumferential direction; and both shapes and 45 design and ensuring the simplicity of pro other in the circumferential direction; and both shapes and 45 design and ensuring the simplicity of arrangement of the various poles 100 (especially their facturing and the assembly accuracy. respective main bodies 101) are relatively simple, facilitat-
in a According to an embodiment of the present disclosure, for
ing ensuring both manufacturing simplicity and assembly
of poles are shaped and dimensioned to mi

In a further embodiment of the present disclosure, by way 50 aberration of the charged particle beam being incident on the of example, as illustrated in FIG. 1, the respective two main deflector 1 and entering and passing or example, as illustrated in FIG. 1, the respective two main
bodies 101 of each pair of poles 100 in the at least two pairs
of poles extend across an equivalent radian and have a same
spectively, in a circumferential dire of the at least two pairs of poles 100 are spaced apart from which fails to exceed a predetermined radial distance as a one another angularly and circumferentially, and are threshold radial distance.

bodies 101 of the at least two pairs of poles 100 extend 65 paraxial region.
across an equivalent radian and have a same shape, respec-
specifically, in a condition that a radius R2 of each of the
tively, in a same circumf

a spacing between respective central portions of respective respective main bodies, and have a same inner radius at two poles 100 in each pair of poles (such a spacing would respective radial inner sides and a same outer r

In a further embodiment of the present disclosure, by way

compensated for, facilitating improving the uniformity of the circumference, such that the respective secondary
the resultant deflection field generated by the multi-pole
deflection fields generated by the dual-pole deflec

In a further embodiment of the present disclosure, by way

of poles are shaped and dimensioned to minimize an off-axis aberration of the charged particle beam being incident on the

across an angle which fails to exceed a predetermined angle

arranged to be in rotational symmetry with reference to one 60 The shapes and dimensions of the protrusions 102, espe-
another, and respective poles in each pair of poles have cially a radian angle A across which each of t

respective main bodies at respective radial inner side is

given, and a ratio of a maximum length L3 of each of the protrusions 102 projecting from the inner side of respective given, and a ratio of a maximum length L3 of each of the respective radial inner side thereof, a transverse field distri-
protrusions 102 projecting from the inner side of respective bution which relatively approximates to main body 101 and in turn continuing extending radially
inwards with reference to the radius R2 of each of the
respective main bodies 101 is constant/fixed, the smaller the
radian angle is, the smaller a circumferential r the larger a degree of approximation how the shape and
dimension of each pole 100 approximate to those of a pole 10
having no respective protrusion 102 is, and the less a
disclosure, for example, as illustrated in FIG. 6 having no respective protrusion 102 is, and the less a are shown. For example, FIG. $6(a)$ illustrates a schematic compensation effect of each protrusion on a change of the structural view of an alternative multi-pole defl spacing between respective two poles in a respective pair of structural view of an alternative multi-pole deflector for realisation of the structural view of an alternative multi-pole deflector for realisation of the metho poles 100 due to the circumferential arrangement of the charged particles according to another embodiment of the poles 100 is accordingly. On the contrary the bigger the 15 present disclosure, schematically showing that ea poles 100 is, accordingly. On the contrary, the bigger the 15 present disclosure, schematically showing that each of the radian angle is the larger the circumferential range on the protrusions in the respective schematic s radian angle is, the larger the circumferential range on the protrusions in the respective schematic structures of various respective main body 101 of each of the respective poles is specifically in the form of a multi-sta respective main body 101 of each of the respective poles 100 poles is specifically in the form of a multi-stage stepped boss
which is occupied by the respective protrusion 102 is (i.e.) which projects from the respective r which is occupied by the respective protrusion 102 is (i.e., which projects from the respective radial inner side of a the wider the respective protrusion 102 in the circumferen- main body of the respective pole and i the wider the respective protrusion 102 in the circumferen-
tial direction is), and then the larger a degree of approxi- 20 top portion; FIG. $6(b)$ illustrates a schematic structural view that direction is), and then the larger a degree of approximately
mation how each pair of poles may be approximately
equivalent to a pair of plate-like poles parallel to each other
is, according to another embodiment of t

In the final pole deflection field thereof in the paraxial is specifically in the form of a partial sphere shape which distribution of the deflection field thereof in the paraxial required as projects from the respective r region next to the optical axis. It is indicated by a numerical 35 projects from the respective radial inner side of a main body
simulation, that, for a given radius **P2** of each of the spective pole and is provided with a simulation that, for a given radius $R2$ of each of the of the respective pole respective main hodies 101 at respective radial inner side domed top portion. respective main bodies 101 at respective radial inner side domed top portion.
thereof a transverse field distribution which relatively Specifically, for example, each of the respective protruthereof, a transverse field distribution which relatively
approximates to a distribution of a dual-pole field may be sions of each pair of poles is shaped to be in the form of one obtained in a relatively larger range in the paraxial region 40 of a partial sphere, a partial cone and a partial pyramid
correspondingly, by adopting a combinatorial optimization projecting from the respective radial inne

By way of example, the predetermined angle range of the

radian angle A is 5° to 40° and the predetermined radial

distance is between 0.1 and 0.9 times of the respective inner

radius at respective radial inner the optical axis Z, throughout the inside of the through-hole
the optical axis Z , through the inside of the through-hole
 $\frac{10}{2}$ of the anglumals field deflector as illustrated in EIG 1

Further, according to an embodiment of the present dis-
closure, for example, as illustrated in FIG. 1, each of the poles alternatively having the pair of imaginary protrusions, respective protrusions 102 of each pair of poles is shaped to
he in the form of a boss projecting from the
he in the form of a boss which projects from the respective
respective protrusions 102 of each pair of poles is sha be in the form of a boss which projects from the respective respective radial inner side of the respective main body 101 of the 60 is provided with an arc-shaped concave top portion, generate respective pole 100 and is provided with an arc-shaped an imaginary secondary deflection field equivalent to the concave top portion. The maximum length L3 of each of the secondary deflection field as generated practically concave top portion. The maximum length L3 of each of the secondary deflection field as generated practically by the protrusions 102 of each pair of poles projecting from the pair of poles having the respective protrusions ing extending radially inwards is a radius R3 at the arc- 65 occupied by the boss is the equivalent radian angle of the shaped concave top portion of the boss. Thus, for a given equivalent arc boss calculated depending on radius R2 of each of the respective main bodies 101 at secondary deflection field.

from the respective radial inner side of a main body of the through the axial through-hole 103 of the multi-pole deflector
tor, by the arrangement in which respective two main bodies
101 of two poles 100 in each pair in the multi-pole deflector
1 are disposed opposite to each other

102 projecting from the inner side of respective main body with a convex top portion; or alternatively, each of the 101 and in turn continuing extending radially inwards and respective protrusions of each pair of poles is e radian A of each of the protrusions 102. 45 in the form of one of a truncated frustum of a cone, a
By way of example, the predetermined angle range of the truncated spherical segment, a frustum, and a multi-stage

103 of the quadrupole field deflector as illustrated in FIG. 1. 55 by each of a pair of imaginary protrusions used instead of the pair of poles, such that a pair of poles, such that a pair of poles, such that a pair of

FIG. $2(a)$ inisticates a schematic structural view of a selectric deflector is minimized, with aforementioned
and arrangement of various poles as illustrated in FIG. 1;
FIG. $2(b)$ illustrates a schematic diagram of distri

form of a circular arc-shaped section; and a protrusion 102['] portions of respective two electrodes 100' in each pair of deflector 1' comprises: at least two pairs of electrodes 100' which a respective proudsion 102' projecting radially
formed by a conductive material (such as metal or alloy inwards from the radial inner side of its main bod like ITO, or the like), each electrode 100' in each pair of 15 from the respective main body 101' of each electrode, a
electrodes comprising: a main body 101' constructed in the difference between a spacing between resp electrodes comprising: a main body 101' constructed in the difference between a spacing between respective central
form of a circular arc-shaped section: and a protrusion 102' portions of respective two electrodes 100' in projecting from an radial inner side of the main body 101'. Bectrodes (such a spacing would have been relatively larger
Respective two main bodies 101' of each pair of electrodes without the protrusion) and another spacing 103'), which opens axially and is configured to receive the tially to an extent. In other words, a gradient of the spacing charged particle beam to be deflected and to pass there- 25 between respective two electrodes in ea pairs of the at least two pairs of electrodes 100' of the electric from the central portions of the respective two electrodes deflector 1' cooperate to generate respective secondary towards the end portions thereof, will b deflection fields distributed within the through-hole and
across an internal space defined within the through-hole, 30 field lines at the edges of the electrodes 100' on the charged respectively, and the secondary deflection fields are synthe-
stricte beam is improved as described above, a trend that
sized by combination of vectors into a resultant deflection the spacing between respective two electro electric field of the electric deflector which is distributed of electrodes 100' at the central portions is significantly within and across the through-hole 103' and is configured to different from that at the end portions the multi-electrode electric deflector 1', each pair of elec-
trodes in each pair of electrodes 100'
trodes (i.e. each dual-pole field electric deflector) generates which is caused by the arrangement of the electrodes in t trodes (i.e. each dual-pole field electric deflector) generates which is caused by the arrangement of the electrodes in the a respective secondary electric field when the two opposite circumferential direction is compensat electrodes are respectively applied with respective external improving the uniformity of the resultant deflection electric
bias voltage(s), and the secondary electric field vectors of 40 field generate by the multi-electro bias voltage(s), and the secondary electric field vectors of 40 field generate by the multi-electrode electric the pairs of electrodes are synthesized into the resultant paraxial region next to the optical axis Z. the pairs of electrodes are synthesized into the resultant paraxial region next to the optical axis Z.
deflection electric field of the multi-pole electric deflector 1'. Therefore, it can be seen that, a main idea of the i deflection electric field of the multi-pole electric deflector 1'.
In the embodiments of the present disclosure, as described

In the embodiments of the present disclosure, as described concept of the embodiments of the present disclosure lies in above, on the one hand, respective two main bodies 101' of that, the uniformity of the resultant defle each pair of electrodes in the at least two pairs of electrodes 45 100', are each in the form of a circular arc-shaped section through-hole 103' which is at least partially encompassed
and are arranged concentrically with respect to the optical and delimited by the various electrodes 100' words, respective two main bodies $101'$ in each electrode region next to the optical axis Z) is improved, by a coop-
100' are arranged concentrically in the circumferential direc- 50 eration between two aspects of settin diametrical direction. Such an arrangement in which respec-
tive two main bodies 101' of two electrodes in pair are circumferential direction, and the respective protrusion 102' tive two main bodies 101' of two electrodes in pair are circumferential direction, and the respective protrusion 102'
disposed diametrically opposite to each other, in essence, projecting radially inward from the respectiv extend substantially along the circumferential direction or in in each dual-electrode field electric deflector which spacing a direction close to the circumferential direction, such that changes from the central portions o a direction close to the circumferential direction, such that changes from the central portions of the respective two the distribution of the edge field lines of these secondary ω_0 electrodes towards the end portions t deflection fields generated by pairs of electrodes in the is caused by the arrangement in which respective two main electric deflector will minimally influence the charged par-
bodies 101' of two electrodes 100 in each pai ticle beam passing through the through-hole 103' which is at opposite to each other in the circumferential direction; and least partially encompassed and delimited by the electrodes both shapes and arrangement of the vario least partially encompassed and delimited by the electrodes both shapes and arrangement of the various electrodes 100'
100' of the multi-electrode electric deflector 1' and opens 65 (especially their respective main bodies axially. As such, the influence of the distortion of the field simple, facilitating ensuring both manufacturing simplicity
lines of the respective secondary deflection fields of indi- and assembly accuracy. 100', are each in the form of a circular arc-shaped section

 13 14

In an exemplary embodiment in the embodiments of the vidual dual-electrode electric deflectors in the multi-elec-
disclosure, by way of example, a multi-electrode electric trode electric deflector 1' at edges as compared w particle beam.
FIG. $2(a)$ illustrates a schematic structural view of a 5 electric deflector is minimized, with aforementioned

providing the protrusion $102'$ projecting radially inward from the respective main body $101'$ of each electrode, a

that, the uniformity of the resultant deflection electric field generated by the multi-electrode electric deflector within the

of example, as illustrated in FIG. $2(a)$, the respective two ensuring the simplicity of processing and manufacturing and main bodies 101' of each pair of electrodes 100' in the at the assembly accuracy. least two pairs of electrodes extend across an equivalent According to an embodiment of the present disclosure, for
radian and have a same shape, respectively, in a circumfer- $\frac{1}{2}$ example, respective protrusions 102' ential direction of the respective two main bodies, and have of electrodes are shaped and dimensioned to minimize an
a same inner radius at respective radial inner sides and a off-axis aberration of the charged particle be a same inner radius at respective radial inner sides and a off-axis aberration of the charged particle beam being inci-
same outer radius at respective radial outer sides: and dent on the electric deflector 1' and entering same outer radius at respective radial outer sides; and dent on the electric deflector Γ and entering and respective main bodies 101' of the at least two pairs of the electric deflector.

In a further embodiment of the present disclosure, by way across an equivalent radian and have a same shape, respec-
tively, in a same circumference defined collectively by the $_{20}$ may be of vital importance to the uniformity of the resultant
respective main bodies, and have respective radial outer sides; and the respective main bodies Specifically, in a condition that a radius R2 of each of the 101' of the at least two pairs of electrodes 100' are spaced respective main bodies at respective r 101' of the at least two pairs of electrodes 100' are spaced respective main bodies at respective radial inner side is apart from one another anoularly in the same circumference 25 given, and a ratio of a maximum length L3 apart from one another angularly in the same circumference 25 of the respective main bodies.

Fields generated by all of the dual-electric inwards with reference to the radius R2 of each of the
fields generated by all of the dual-electric inwards with reference to the radius R2 of each of the
deflectors in the mult deflectors in the multi-electrode electric deflector $\bf{1}^{\prime}$ have a respective main bodies $\bf{101}^{\prime}$ is constant/fixed, the smaller the smaller the smaller the smaller the smaller a circumferential range of the

are arranged to spaced apart from one another at an equal circumferential range on the respective main body 101' of angle in the circumferential direction, that is, arranged in a each of the respective electrodes 100' whic angle in the circumferential direction, that is, arranged in a each of the respective electrodes $100'$ which is occupied by way of equally dividing the circumference, such that the the respective protrusion $102'$ is (i. respective secondary deflection fields generated by the dual-
electrode electric deflectors are respectively arranged in a 45 then the larger a degree of approximation how each pair of electrode electric deflectors are respectively arranged in a 45 roughly uniform distribution throughout the inside of the roughly uniform distribution throughout the inside of the electrodes may be approximately equivalent to a pair of through hole 103' (especially in the paraxial region next to plate-like electrodes parallel to each other is through hole 103' (especially in the paraxial region next to plate-like electrodes parallel to each other is, accordingly; as the optical axis Z) which is at least partially encompassed such, an effect of decreasing the in the optical axis Z) which is at least partially encompassed such, an effect of decreasing the influence of the distortion and delimited by the various electrodes $100'$ of the multi-
of the field lines of the respective and delimited by the various electrodes 100' of the multi-
electrode electric deflector 1', further facilitating a better 50 of individual dual-electrode electric deflectors in the multiuniformity of the resultant deflection electric field. electrode electric deflector 1' at edges as compared with the

of example, as illustrated in FIG. $2(a)$, the at least two pairs passing through the axial through-hole $103'$ of the multi-
of electrodes comprise just two pairs of electrodes alter-
electrode electric deflector, by the nately spaced apart from one another at an angle of 90° . In 55 respective two main bodies 101' of two electrodes 100' in other words, the multi-electrode electric deflector 1' are prises four electrodes 100' arranged orthogonally to one disposed opposite to each other in the circumferential direcanother, that is, two dual-electrode field electric deflectors tion, is less obvious. arranged orthogonal to each other. In other words, the In the multi-electrode electric deflector, it is usually
multi-electrode electric deflector is shaped into a quadruple- 60 focused on the distribution of the deflectio In a further embodiment of the present disclosure, by way

when the charged particle beam passes through the through-
hole 103' of the multi-electrode electric deflector 1' is radial inner side thereof, a transverse field distribution which hole 103' of the multi-electrode electric deflector 1' is radial inner side thereof, a transverse field distribution which reduced, and the multi-electrode electric deflector is also 65 relatively approximates to a distrib realized with the minimum number of electrodes 100' and
the minimum number of feed ports required by the elec-
paraxial region correspondingly, by adopting a combinato-

In a further embodiment of the present disclosure, by way trodes 100', thereby simplifying the structure design and

respective main bodies 101' of the at least two pairs of
electrodes 100' are spaced apart from one another angularly
and incounter and circumferentially, and are arranged to be in rotational
symmetry with reference to one

the respective main bodies. protrusions 102' projecting from the inner side of respective
With such a setting, the respective secondary deflection main body 101' and in turn continuing extending radially same magnitude, respectively, facilitating both calculation $\frac{30}{20}$ radial angle is, the smaller a circumnerential range of the respective and control of the resultant deflection electric field.
In a further embodimen In a further embodiment of the present disclosure, by way
of example, as illustrated in FIG. $2(a)$, the respective main
bodies 101' of the at least two pairs of electrodes 100' are
arranged to space apart from one another In a further embodiment of the present disclosure, by way field lines at center thereof, on the charged particle beam of example, as illustrated in FIG. $2(a)$, the at least two pairs passing through the axial through-hole electrode electric deflector, by the arrangement in which respective two main bodies 101' of two electrodes 100' in

ectrode electric deflector.

With such a setting, the off-axis aberration introduced indicated by a numerical simulation that, for a given radius paraxial region correspondingly, by adopting a combinatothe protrusions 102' projecting from the inner side of respec-
tive main body 101' and in turn continuing extending tially uniform, and the electric field lines are distributed tive main body 101' and in turn continuing extending tially uniform, and the electric field lines are distributed radially inwards and the radian A of each of the protrusions depending on the shapes of the electrodes and t

distance is between 0.1 and 0.9 times of the respective inner which relatively approximates to a distribution of a dual-
radius at respective radial inner sides of the respective main pole field may be obtained in a relati region next to the optical axis Z, throughout the inside of the FIG. 3 illustrates a diagram of distribution status of through-hole 103' of the quadruple-electrode field electric 15 electric field intensity of a radial def

closure, for example, as illustrated in FIG. $2(a)$, each of the parameters (e.g., R3/R2=0.7), wherein a horizontal axis in respective protrusions 102' of each pair of electrodes is FIG. 3 denotes a size (labeled by 'r') o 101' at respective radial inner side thereof, a transverse field (i.e. an electrostatic deflector in relevant art, corresponding distribution which relatively approximates to a distribution 30 to the figure line of A0 in F of a dual-electrode field may be obtained in a relatively larger range in the paraxial region correspondingly, by adopting a combinatorial optimization of both the radius R3 disclosure is better than that of quadruple-electrode electro-
at the arc-shaped concave top portion of the boss and the static deflector structure without radial at the arc-shaped concave top portion of the boss and the static deflector structure without radial inner boss as in radian A of each of the protrusions 102'.

present disclosure is illustrated in FIG. $2(a)$, illustrating a larger range of the figure lines A20 and A30 on the hori-
quadruple-electrode electrostatic deflector. As far as the zontal coordinate axis corresponding to quadruple-electrode electrostatic deflector is concerned, in mately equal to the reference value 1 of the relative field geometric structure thereof, for the optical axis (Z-axis), 40 strength on the vertical coordinate ax geometric structure thereof, for the optical axis (Z -axis), 40 strength on the vertical coordinate axis (a value of the field there are four plane symmetries each plane containing the Z strength of the resultant def there are four plane symmetries each plane containing the Z axis; and in feeding distribution thereof, there are features of axis; and in feeding distribution thereof, there are features of 1, which serves as the reference value, and vertical coordi-
one plane symmetry and one plane anti-symmetry. Respec-
ate values of the figure lines are the r tive arc-shaped main bodies of the four electrodes 100' are field strengths at various point relative to the reference value shaped to be electrodes each being in the form of circular 45 1, respectively). In case of a same shaped to be electrodes each being in the form of circular 45 1, respectively). In case of a same deflection aberration, the arc-shaped section having an outer radius R1 and an inner electrostatic deflector of the embodime radius R2 which is less than R1, respectively, and are spaced disclosure has a larger field of view, as compared with a apart from one another at a same gap occupying an equal quadruple-electrode electrostatic deflector wi radian circumferentially, i.e., with a gap angle θ between inner boss as in relevant art. And the embodiments of the adjacent electrodes (i.e., an inter-polar gap angle θ). On this 50 present disclosure can be exten basis, on the radial inner side of the main body of each cation examples. For example, the outer radius R2 of the electrode, there is also provided with a boss-shaped structure boss being in the range of $3~-100$ mm, the inner radius R3 of having an arc-shaped concave top portion, which has its the boss being in the range of $0.1R2-0$ having an arc-shaped concave top portion, which has its the boss being in the range of 0.1R2~0.9R2, and the radian inner radius of R3 (less than R2) and its radian of A. Voltages value A of the boss in the range of 5° Vy, -Vx, -Vy, Vx are applied on the electrodes 100' sequen-55 scope of protection as claimed in the present disclosure.

tially in the circumferential direction, respectively (i.e., in

counter-clockwise direction from +Y as illustrated. The deflection electric field mainly along the 60 radial direction is obtained in the paraxial area as in the cross radial direction is obtained in the paraxial area as in the cross deflector for charged particles according to another embodi-
section shown in the Figure, with an radian α formed ment of the present disclosure, schema section shown in the Figure, with an radian α formed ment of the present disclosure, schematically showing that between this direction and the X axis being determined by each of the protrusions in the respective schema between this direction and the X axis being determined by each of the protrusions in the respective schematic structures a calculation of arctan(Vy/Vx), as illustrated in FIG. $2(b)$ of various electrodes is specifically which shows a diagram of the distribution status of electric 65 stage stepped boss which projects from the respective radial field lines of the resultant electric field in practical applica-
field in practical applica-
inn field lines of the resultant electric field in practical applica-
tion of the respective electrode and is
provided with a flat top portion; FIG. $6(b)$ illustrates a electrode, there is also provided with a boss-shaped structure

rial optimization of both the maximum length L3 of each of It can be seen from FIG. $2(b)$ that the distribution status the protrusions $102'$ projecting from the inner side of respection of the electric field lines in the 102.
By way of example, the predetermined angle range of the simulation that, for a given radius R2 of each of the By way of example, the predetermined angle range of the simulation that, for a given radius R2 of each of the radian angle A is 5° to 40° and the predetermined radial respective main bodies 101, a transverse fie radian angle A is $\bar{5}^{\circ}$ to 40° and the predetermined radial respective main bodies 101, a transverse field distribution distance is between 0.1 and 0.9 times of the respective inner which relatively approximates to radius at respective radial inner sides of the respective main pole field may be obtained in a relatively larger range in the bodies of each pair of electrodes. As such, in case of such a 10 paraxial region correspondingly bodies of each pair of electrodes. As such, in case of such a 10 paraxial region correspondingly, by adopting a combinato-
dimensional setting, it is possible to obtain a maximum rial optimization of both the radius R3 at distribution of the resultant deflection electric field equiva-
learning concave top portion of the boss and the radian A of each of
lent to a distribution of a dual-electrode field in the paraxial the protrusions 102.

FIG. 3 denotes a size (labeled by 'r') of the paraxial region detected may indicate that, in a condition of $R3/R2=0.7$, and
in case that the angle A of the boss is equal to 30° (see Figure deflector as illustrated in FIG. $2(b)$. within a paraxial region of the multi-pole electric deflector
Further, according to an embodiment of the present dis-
as illustrated in FIG. $2(a)$ on condition of different boss Further, according to an embodiment of the present dis-
as illustrated in FIG. $2(a)$ on condition of different boss
closure, for example, as illustrated in FIG. $2(a)$, each of the parameters (e.g., $R3/R2=0.7$), wherein a respective protrusions 102' of each pair of electrodes is FIG. 3 denotes a size (labeled by 'r') of the paraxial region
shaped to be in the form of a boss which projects from the 20 and a vertical axis in FIG. 3 denotes a arc-shaped concave top portion. The maximum length L3 of
each time A 30 as illustrated in FIG. 3), the uniformity of deflec-
projecting from the inner side of respective main body 101' 25 tion of the electric field is bet trated in FIG. $2(a)$ and FIG. $2(b)$ in the embodiment of the disclosure is better than that of quadruple-electrode electroradian A of each of the protrusions 102'.
Specifically, figure lines A20 and A30 indicate
Specifically, for example, an application example of the that, as compared with figure line A0, there is a relatively quadruple-electrode electrostatic deflector without radial inner boss as in relevant art. And the embodiments of the inner radius of R3 (less than R2) and its radian of A. Voltages value A of the boss in the range of 5° -40 $^{\circ}$, all fall into the

> are shown. For example, FIG. $6(a)$ illustrates a schematic structural view of an alternative multi-electrode electric provided with a flat top portion; FIG. $6(b)$ illustrates a of various electrodes is specifically in the form of a multi-

schematic structural view of an alternative multi-electrode radial side (e.g., a radial outer side or the radial inner side)
electric deflector for charged particles according to another of the magnetic pole 100", with res embodiment of the present disclosure, schematically show-
independent in the excitation coil 104 in a same direction, as
ing that each of the protrusions in the respective schematic
illustrated in FIG. $4(a)$, where solid structures of various electrodes is specifically in the form of 5 indicating a front side flowing direction while dotted line a partial pyramid shape which projects from the respective arrows therein indicating a back side radial inner side of a main body of the respective electrode
and is provided with a convex and sharpened top portion;
and $\text{FIG. } 6(c)$ illustrates a schematic structural view of and diametrically opposite to each other, alternative multi-electrode electric deflector for charged 10 pairs of magnetic poles 100" at least partially encompass and particles according to another embodiment of the present delimit a through-hole 103" thereamong (i disclosure, schematically showing that each of the protru-
sions in the respective schematic structures of various elec-
receive the charged particle beam to be deflected and to pass trodes is specifically in the form of a partial sphere shape therethrough deflected charged particle beam; and magnetic which projects from the respective radial inner side of a 15 poles in pairs of the at least two pairs

pyramid projecting from the respective radial inner side of deflection magnetic field of the magnetic deflector which is
the respective main body of the respective electrode and is distributed within and across the through provided with a convex top portion; or alternatively, each of configured to deflect the charged particle beam passing
the respective protrusions of each pair of electrodes is therethrough. In the multi-magnetic pole magnet shaped to be in the form of one of a truncated frustum of a 25 1", each pair of magnetic poles (i.e. each dual-pole field cone, a truncated spherical segment, a frustum, and a multi- magnetic deflector) generates a respect stage stepped boss projecting from the respective radial and metic field when the excitation current passes through the inner side of the respective main body of the respective respective excitation coil, and the secondary inner side of the respective main body of the respective respective excitation coil, and the secondary magnetic field
electrode and is provided with a flat top portion.
ectors of the pairs of magnetic poles are synthesized

Accordingly, the predetermined angle range of the radian 30 the resultant deflection magnetic field of the multi-pole
angle A', A" and A"' as illustrated in FIG. $6(a)$, FIG. $6(b)$ and magnetic deflector 1".
FIG. $6(c)$ (as each pair of electrodes is equal to a radian angle range above, on the one hand, respective two main bodies 101" of occupied by each of a pair of imaginary protrusions used each pair of magnetic poles in the at least two p instead of the respective protrusions in the pair of electrodes, 35 magnetic poles 100", are each in the form of a circular such that a pair of electrodes alternatively having the pair of arc-shaped section and are arrange imaginary protrusions, each of which is in the form of a boss
projection the espective radial inner side of the opposite; in other words, respective two main bodies 101" in
respective main body and is provided with an arcrespective main body and is provided with an arc-shaped each magnetic pole 100" are arranged concentrically in the concave top portion, generate an imaginary secondary 40 circumferential direction, and are arranged to face deflection field equivalent to the secondary deflection field each other in the diametrical direction. Such an arrangement as generated practically by the pair of electrodes having the in which respective two main bodies 1 respective protrusions other than the pair of imaginary poles in pair are disposed diametrically opposite to each protrusions; in other words, the arc angle occupied by the other, in essence, facilitates that edge field li boss is the equivalent radian angle of the equivalent arc boss 45 tive secondary deflection field formed by respective two calculated depending on respective secondary deflection main bodies 101" in each pair of magnetic p calculated depending on respective secondary deflection main bodies 101" in each pair of magnetic poles at ends of the two magnetic poles in pair extend substantially along the such that a pair of electrodes alternatively having the pair of

the disclosure, by way of example, a multi-pole magnetic circumferential direction, such that the distribution of the deflector functions as the multi-pole deflector for a charged 50 edge field lines of these secondary def

pole magnetic deflector based on the schematic structure and
arrangement of various poles as illustrated in FIG. 1; FIG. encompassed and delimited by the magnetic poles 100" of
4(b) illustrates a schematic diagram of distr magnetic field in the multi-pole electric deflector in use as axially. As such, the influence of the distortion of the field illustrated in FIG. $4(a)$.
lines of the respective secondary deflection fields of indi- $4(b)$ illustrates a schematic diagram of distribution status of 55

netic deflector 1" comprises: at least two pairs of magnetic magnetic pole magnetic deflector 1" at edges as compared
poles 100" formed by a magnetically permeable material 60 with the field lines at center thereof, on the example a soft magnetic material, such as ferrosilicon, soft multi-magnetic pole magnetic deflector is minimized, with magnetic ferrite, or the like), each magnetic pole 100" in aforementioned arrangement in which respecti magnetic ferrite, or the like), each magnetic pole 100" in aforementioned arrangement in which respective two main each pair of magnetic poles comprising: a main body 101" bodies 101" of two magnetic poles 100" in pair are constructed in the form of a circular arc-shaped section; a 65 opposite to each other in the circumferential direction.
protrusion 102" projecting from an radial inner side of the The embodiments of the present disclosure,

illustrated in FIG. $4(a)$, where solid line arrows therein indicating a front side flowing direction while dotted line Specifically, for example, each of the respective protru-
sions of each pair of electrodes is shaped to be in the form hole, respectively, and the secondary deflection fields are
of one of a partial sphere, a partial cone

each pair of magnetic poles in the at least two pairs of magnetic poles 100", are each in the form of a circular field.
In another exemplary embodiment in the embodiments of circumferential direction or in a direction close to the circumferential direction or in a direction close to the circumferential direction, such that the distribution of the particle beam.
FIG. $4(a)$ shows a schematic structural view of a multi-
minimally influence the charged particle beam passing ustrated in FIG. $4(a)$.
As illustrated in FIG. $4(a)$, the multi-magnetic pole mag-
As illustrated in FIG. $4(a)$, the multi-magnetic pole mag-
vidual dual-magnetic pole magnetic deflectors in the multi-

hand, as described above, each magnetic pole 100" is also

provided with a respective protrusion 102" projecting radi-
ally inwards from the radial inner side of its main body 101". Inagnetic poles 100" are spaced apart from one another ally inwards from the radial inner side of its main body 101". magnetic poles 100" are spaced apart from one another By providing the protrusion 102" projecting radially inward angularly and circumferentially, and are arra By providing the protrusion 102" projecting radially inward angularly and circumferentially, and are arranged to be in from the respective main body 101" of each magnetic pole, rotational symmetry with reference to one ano from the respective main body 101" of each magnetic pole, rotational symmetry with reference to one another, and a difference between a spacing between respective central 5 respective magnetic poles in each pair of magneti a unierality between a spacing between is pective tend and pair of magnetic poles in each pair of magnetic poles
of magnetic poles (such a spacing would have been rela-
tively larger without the protrusion) and another spa may be decreased substantially to an extent . In other words, by the respective main bodies, and have a same inner radius a respective radius at respective radial inner sides and a same outer radius at respective radius at a gradient of the spacing between respective two magnetic at respective radial inner sides and a same outer radius at respective radial outer sides, and the respective main bodies poles in each pair of magnetic poles in each dual-magnetic 15 respective radial outer sides; and the respective main bodies
note field magnetic deflector which changes from the central 101" of the at least two pairs of mag pole field magnetic deflector which changes from the central 101" of the at least two pairs of magnetic poles 100" are
portions of the respective two magnetic poles towards the spaced apart from one another angularly in th portions of the respective two magnetic poles towards the spaced apart from one another angularly end portions thereof, will be decreased. As such in the cumference of the respective main bodies. end portions thereof, will be decreased. As such, in the cumference of the respective main bodies.
condition that the influence of the distortion of the field lines With such a setting, the respective secondary deflection at the edges of the magnetic poles 100" on the charged 20 fields generated by all of the dual-magnetic pole field
particle beam is improved as described above, a trend that magnetic deflectors in the multi-magnetic pole ma significantly different from that at the end portions is also magnetic field.
alleviated, such that the significant change of the spacing 25 In a further embodiment of the present disclosure, by way
between the respective magnetic poles 100" which is caused by the arrangement of bodies 101" of the at least two pairs of magnetic poles 100" the magnetic poles in the circumferential direction is com-
are arranged to space apart from one anothe pensated for, facilitating improving the uniformity of the circumferentially.

resultant deflection magnetic field generate by the multi- 30 With such a setting, essentially, respective magnetic poles

magnetic pole magnet

concept of the embodiments of the present disclosure lies in another at an equal angle in the circumferential direction, that, the uniformity of the resultant deflection magnetic field 35 that is, arranged in a way of equa generated by the multi-magnetic pole magnetic deflector ference, such that the respective secondary deflection fields within the through-hole 103" which is at least partially generated by the dual-magnetic pole magnetic de encompassed and delimited by the various magnetic poles respectively arranged in a roughly uniform distribution 100" of the multi-magnetic pole magnetic deflector 1" throughout the inside of the through hole 103" (especial 100" of the multi-magnetic pole magnetic deflector 1" throughout the inside of the through hole 103" (especially in (especially in the paraxial region next to the optical axis 2) which is at (especially in the paraxial region next to the optical axis Z) 40 the paraxial region next to the optical axis Z) which is a
is improved, by a cooperation between two aspects of least partially encompassed and delimit compensate for a gradient of the spacing between respective alternately spaced apart from one another at an angle of 90°.
two magnetic poles in each pair of magnetic poles in each and the multi-magnetic pole magnetic defle gradient is caused by the arrangement in which respective other words, the multi-magnetic pole magnetic deflector is two main bodies 101" of two magnetic poles 100" in each shaped into a quadruple-pole magnetic deflector. pair are disposed opposite to each other in the circumfer- 55 With such a setting, the off-axis aberration introduced
ential direction; and both shapes and arrangement of the when the charged particle beam passes through-
 main bodies 101") are relatively simple, facilitating ensuring is reduced, and the multi-magnetic pole magnetic deflector both manufacturing simplicity and assembly accuracy. is also realized with the minimum number of mag

of example, as illustrated in FIG. $4(a)$, the respective two magnetic poles 100", thereby simplifying the structure main bodies 101" of each pair of magnetic poles 100" in the design and ensuring the simplicity of process main bodies 101" of each pair of magnetic poles 100" in the design and ensuring the simplicity of processing and manu-
at least two pairs of magnetic poles extend across an facturing and the assembly accuracy. equivalent radian and have a same shape, respectively, in a According to an embodiment of the present disclosure, for circumferential direction of the respective two main bodies, 65 example, respective protrusions 102" of

the optical axis Z . particular the respective main body 101 in the respective Therefore, it can be seen that, a main idea of the inventive magnetic poles 100 , are arranged to spaced apart from one

th manufacturing simplicity and assembly accuracy. is also realized with the minimum number of magnetic poles In a further embodiment of the present disclosure, by way $\frac{60}{100}$ and the minimum number of feed ports req

and have a same inner radius at respective radial inner sides of magnetic poles are shaped and dimensioned to minimize and a same outer radius at respective radial outer sides; and an off-axis aberration of the charged par an off-axis aberration of the charged particle beam being

a distance which fails to exceed a predetermined radial distance as a threshold radial distance.

The shapes and dimensions of the protrusions 102",

expecially a radian angle A across which each of the pro-

trusions 102" correspondingly spans in the circumferential

direction, may be of vital importance to the unifo

Specifically, in a condition that a radius R2 of each of the given, and a ratio of a maximum length L3 of each of the shaped to be in the form of a boss which projects from the protrusions 102" projecting from the inner side of respective 20 respective radial inner side of the respective main body 101" main body 101" and in turn continuing extending radially of the respective magnetic pole 100" a inwards with reference to the radius R2 of each of the arc-shaped concave top portion. The maximum length L3 of respective main bodies 101" is constant/fixed, the smaller each of the protrusions 102" of each pair of magnet the radian angle is, the smaller a circumferential range of the projecting from the inner side of respective main body 101"
respective protrusion 102" is (i.e., the narrower the respec- 25 and in turn continuing extending then the larger a degree of approximation how the shape and
dimension of each magnetic pole 100" approximate to those 101" at respective radial inner side thereof, a transverse field dimension of each magnetic pole $100"$ approximate to those of a magnetic pole having no respective protrusion $102"$ is, of a magnetic pole having no respective protrusion 102" is, distribution which relatively approximates to a distribution and the less a compensation effect of each protrusion on a 30 of a dual-magnetic pole field may be ob change of the spacing between respective two magnetic larger range in the paraxial region correspondingly, by poles in a respective pair of magnetic poles 100 " due to the adopting a combinatorial optimization of both th circumferential arrangement of the magnetic poles 100 " is, at the arc-shaped concave top portion of the boss and the accordingly. On the contrary, the bigger the radian angle is, radian A of each of the protrusions 102 the larger the circumferential range on the respective main 35 Specifically, for example, an application example of the body 101" of each of the respective magnetic poles 100" present disclosure is illustrated in FIG. which is occupied by the respective protrusion 102 " is (i.e., quadruple-pole magnetic deflector. The shape of the boss on the wider the respective protrusion 102 " in the circumfer-
a radial inner surface of each of th the wider the respective protrusion 102" in the circumfer-
example in a radial inner surface of each of the magnetic poles may still
ential direction is), and then the larger a degree of approxi-
be described with paramete ential direction is), and then the larger a degree of approxi-
mation how each pair of magnetic poles may be approxi- 40 the respective main body, the inner radius R2 of the respecmately equivalent to a pair of plate-like magnetic poles tive main body, the inner radius R3 of the boss, and the parallel to each other is, accordingly; as such, an effect of radian angle A of the boss. With the excitatio parallel to each other is, accordingly; as such, an effect of radian angle A of the boss. With the excitation of a certain decreasing the influence of the distortion of the field lines of current in the excitation coils, t the respective secondary deflection fields of individual dual-
the respective secondary deflection fields of individual dual-
magnetic pole magnetic deflectors in the multi-magnetic 45 in the cross section. As illustrated passing through the axial through-hole 103 " of the multi-coils (606 and 608) are excited. As illustrated in FIG. $4(b)$, magnetic pole magnetic deflector, by the arrangement in it shows a diagram of the distribution stat poles 100" in each pair in the multi-magnetic pole magnetic of the multi-pole deflector.
deflector 1" are disposed opposite to each other in the It can be seen from FIG. 4(b) that the distribution status
circumferential di

In the multi-magnetic pole magnetic deflector, it is usually tially uniform, and the magnetic field lines are distributed focused on the distribution of the deflection magnetic field 55 depending on the shapes of the magne thereof in the paraxial region next to the optical axis. It is voltages applied on the magnetic poles. It is indicated by a indicated by a numerical simulation that, for a given radius numerical simulation that, for a give indicated by a numerical simulation that, for a given radius numerical simulation that, for a given radius $R2$ of each of $R2$ of each of the respective main bodies 101, a transverse field distriburadial inner side thereof, a transverse field distribution which tion which relatively approximates to a distribution of a
relatively approximates to a distribution of a dual-magnetic 60 dual-pole field may be obtained in pole field may be obtained in a relatively larger range in the in the paraxial region correspondingly, by adopting a comparaxial region correspondingly, by adopting a combinato-

rial optimization of both the maximum lengt rial optimization of both the maximum length L3 of each of shaped concave top portion of the boss and the radian A of the protrusions 102" projecting from the inner side of each of the protrusions 102. respective main body 101 " and in turn continuing extending 65 FIG. 5 illustrates a diagram of distribution status of radially inwards and the radian A of each of the protrusions magnetic field intensity of a radial defle radially inwards and the radian A of each of the protrusions magnetic field intensity of a radial deflection magnetic field

falling within a paraxial region of the multi-pole magnetic relatively approximates to a distribution of a dual-magnetic 60

incident on the magnetic deflector 1 " and entering and
passing through the through-hole of the magnetic deflector.
Specifically, for example, each of the respective protru-
distance is between 0.1 and 0.9 times of the r Specifically, for example, each of the respective protru-
sions 102" of each pair of magnetic poles extends circum-
radius at respective radial inner sides of the respective main ferentially across an angle which fails to exceed a predeter- 5 bodies of each pair of magnetic poles. As such, in case of mined angle range as a threshold angle range, and projects such a dimensional setting, it is possib mined angle range as a threshold angle range, and projects such a dimensional setting, it is possible to obtain a maxi-
from respective radial inner side of respective main body at mum distribution of the resultant deflect from respective radial inner side of respective main body at mum distribution of the resultant deflection magnetic field in
a distance which fails to exceed a predetermined radial equivalent to a distribution of a dual-mag the paraxial region next to the optical axis Z, throughout the paraxial region next to the optical axis Z, throughout the stance as a threshold radial distance.
The shapes and dimensions of the protrusions 102 ⁿ, ¹⁰

> and in turn continuing extending radially inwards is a radius of a dual-magnetic pole field may be obtained in a relatively

> field in radial direction in a condition that merely a group of

cumferential direction, is less obvious. of the magnetic field lines in the paraxial region is substan-
In the multi-magnetic pole magnetic deflector, it is usually uniform, and the magnetic field lines are distributed

falling within a paraxial region of the multi-pole magnetic

boss parameters (e.g., $R3/R2=0.7$), wherein a horizontal axis in FIG. 3), the uniformity of deflection of the magnetic field
is better than that under other structural parameters, in the boss parameters (e.g., $R3/R2=0.7$), wherein a horizontal axis respective magnetic pole and is provided with a convex and for the figure lines in FIG. 3 denotes a size (labeled by 'r') domed top portion. of the paraxial region and a vertical axis in FIG. 3 denotes Specifically, for example, each of the respective protru-
a size (labeled by 'Br') of the radial magnetic field. The signs of each pair of magnetic poles is sha experimental data as practically detected may indicate that, form of one of a partial sphere, a partial cone and a partial
in a condition of $R3/R2=0.7$, and in case that the angle A of pyramid projecting from the respecti in FIG. 3), the uniformity of deflection of the magnetic field and is provided with a convex top portion; or alternatively, is better than that under other structural parameters, in the 10 each of the respective protrusion range of 300 um in the paraxial region. It can also be seen poles is shaped to be in the form of one of a truncated
from FIG. 5 that, as compared with a multi-pole magnetic frustum of a cone, a truncated spherical segment, deflector structure without boss (i.e. an magnetic deflector in and a multi-stage stepped boss projecting from the respec-
relevant art, corresponding to the figure line of A0 in FIG. tive radial inner side of the respecti deflectors as illustrated in FIG. $4(a)$ and FIG. $4(b)$ in the portion.

embodiment of the disclosure is better than that of qua-

druple-pole magnetic deflector structure without radial inner angle A', A'' and A''' as ill druple-pole magnetic deflector structure without radial inner angle A', A" and A"' as illustrated in FIG. $6(a)$, FIG. $6(b)$ and boss as in relevant art; especially, figure lines A20 and A30 FIG. $6(c)$ (as marked therein) indicate that, as compared with figure line A0, there is a 20 each pair of magnetic poles is equal to a radian angle range relatively larger range of the figure lines A20 and A30 on the cocupied by each of a pair of imagin mately equal to the reference value 1 of the relative magnetic poles, such that a pair of magnetic poles alternatively having
field strength/intensity on the vertical coordinate axis (a the pair of imaginary protrusions, e value of the magnetic field strength/intensity of the resultant 25 deflection field at the optical axis is 1, which serves as the deflection field at the optical axis is 1, which serves as the side of the respective main body and is provided with an reference value, and vertical coordinate values of the figure arc-shaped concave top portion, generate reference value, and vertical coordinate values of the figure arc-shaped concave top portion, generate an imaginary sec-
lines are the relative ratio of specific field strengths at ondary deflection field equivalent to the various point relative to the reference value 1, respectively). tion field as generated practically by the pair of magnetic In case of a same deflection aberration, the magnetic deflec- 30 poles having the respective protr tor of the embodiment of the present disclosure has a larger field of view, as compared with a quadruple-pole magnetic field of view, as compared with a quadruple-pole magnetic pied by the boss is the equivalent radian angle of the deflector without radial inner boss as in relevant art. And the equivalent arc boss calculated depending on r embodiments of the present disclosure can be extended to secondary deflection field.
more general application examples. For example, the outer 35 Therefore, the embodiments of the disclosure have the radius R2 of the boss radius R2 of the boss being in the range of $3 \sim 100$ mm, the following superior technical effect: in the embodiments of inner radius R3 of the boss being in the range of the disclosure, the uniformity of the resultant de inner radius R3 of the boss being in the range of the disclosure, the uniformity of the resultant deflection field 0.1R2~0.9R2, and the radian value A of the boss in the range generated by the multi-pole deflector within t

disclosure, for example, as illustrated in FIG. $6(a)$, FIG. $6(b)$ by a cooperation between two aspects of settings, i.e., the and FIG. $6(c)$, other alternative forms of the projections 102" arrangement in which respective and FIG. $6(c)$, other alternative forms of the projections 102 " arrangement in which respective two main bodies of two are shown. For example, FIG. $6(a)$ illustrates a schematic poles in each pair are disposed opposite are shown. For example, FIG. $6(a)$ illustrates a schematic poles in each pair are disposed opposite to each other in the structural view of an alternative multi-magnetic pole mag- 45 circumferential direction, and the r netic deflector for charged particles according to another jecting radially inward from the respective main body of embodiment of the present disclosure, schematically show- each pole; and both shapes and arrangement of th each pole, and both shapes and arrangement of the various
ing that each of the protrusions in the respective schematic
structures of various magnetic poles is specifically in the
form of a multi-stage stepped boss which pr not of the present disclosure, in which the finally between the multi-magnetic pole magnetic deflector for charged particles
according to another embodiment of the present disclosure, 55 In another aspect of the embodiment specifically in the form of a partial pyramid shape which least one pair of the aforementioned deflectors, the charged
projects from the respective radial inner side of a main body particle beam imaging apparatus 2 being c of the respective magnetic pole and is provided with a 60 project the charged particle beam to a surface of a sample to convex and sharpened top portion; and FIG. $6(c)$ illustrates be tested and in turn to excite and coll convex and sharpened top portion; and FIG. $6(c)$ illustrates be tested and in turn to excite and collect second cashination is a schematic structural view of an alternative multi-magnetic particles therefrom for imaging, pole magnetic deflector for charged particles according to a charged particle source 201 configured to emit the another embodiment of the present disclosure, schematically charged particle beam; and showing that each of the protrusions in the respective 65 a secondary charged particle detector 202, which is schematic structures of various magnetic poles is specifi-
located to be offset from an optical axis of the char

25 26

deflector as illustrated in FIG. $4(a)$ on condition of different from the respective radial inner side of a main body of the

form of a boss projecting from the respective radial inner

of $5^{\circ} \sim 40^{\circ}$, all fall into the scope of protection as claimed in hole which is at least partially encompassed and delimited the present disclosure. 40 by the various poles of the multi-pole deflector (especially i the present disclosure.
According to alternative embodiments of the present the paraxial region next to the optical axis Z) is improved,

FIG. 7 illustrates a schematic structural view of a charged

cally in the form of a partial sphere shape which projects particle beam and between the charged particle source and

the sample to be tested and is configured to collect and
image the secondary charged particles generated by the
charged particle beam projected to the sample to be tested.
The at least one pair of the deflectors 1 are symm

 $\frac{1}{2}$ a main body constructed in the form of a circular arc-
arranged with respect to the optical axis Z of the charged $\frac{5}{2}$ a main body constructed in the form of a circular arc-The at least one pair of the deflectors 1 are symmetrically a man body constructed in the form of a circular arc-
particle beam, and are configured to deflect and project the
charged particle beam to the surface of the sample to be
tested in response to a scanning signal applied th

15 Since the at least one pair of deflectors 1 is contained in ¹⁰ metrically opposite to each other, and the at least two the charged particle beam imaging apparatus 2, the specific structural features of the at least one p structural features of the at least one pair of deflectors 1 a through-hole thereamong, which opens axially and is
described above will not be repeatedly described bere; and configured to receive and to pass therethrough t described above will not be repeatedly described here; and configured to receive therefore the charged particle beam imaging annaratus 2 therefore, the charged particle beam imaging apparatus $\frac{2}{15}$ charged particle beam;
class has the trabulated of the multi-pale deflector $\frac{1}{1}$ is wherein respective two poles in pairs of the at least two

25 axis Z and is located downstream of the at least one pair of tant deflection field of the deflector which is distributed the deflectors 1 (e.g., as illustrated; or alternatively, located within and across the through-hole the deflectors 1 (e.g., as illustrated; or alternatively, located within and across the through-hole and is configured to upstream of the at least one pair of the deflectors 1), and is deflect the charged particle beam pas configured to focus the charged particle beam passing there-
through onto the surface of the sample to be tested.
25 deflector comprising merely at least two pairs of

source 201 and the at least one pair of the deflectors 1, and 30 with the optical axis Z and between the charged particle ured to generate respective electric fields coopera-
source 201 and the at least one pair of the deflectors 1, and 30 tively when bias voltages are applied ther is configured to pre-focus and collimate the charged particle beam which is about to be incident to the multi-pole deflec-
synthesized by combination of vectors into a resultor; and

a restricting stop 205, which is disposed between the at least one focusing lens 204 and the at least one pair of the 35 deflectors **1**, and is comigured to adjust at least one of shape wherein the deflector is a multi-pole magnetic deflector

ration correction device, which is arranged coaxially with 40 tive radial sides of the at least two pairs of magnetic
the optical axis and between the at least one pair of deflec-
tors and the objective lens, and is config

In a further embodiment, for example, as illustrated in 45 synthesized by combination of vectors into a resultant FIG. 7, the charged particle beam imaging apparatus 22 deflection magnetic field of the multi-pole magnetic Further comprises a Wien deflector which is located in the deflector, without generating electric field, and objective lens 203 and is operable to deflect the secondary wherein respective protrusions of the at least two pa charged particles passing therethrough to a side of the poles are shaped and dimensioned to minimize an optical axis Z such that the secondary charged particles are so off-axis aberration of the charged particle beam being

and the same or similar parts of various embodiments can be the respective two main bodies, and have a same inner radius referred to each other. In addition, according to the afore-
at respective radial inner sides and a s mentioned embodiments of the present disclosure, it can be understood that any technical solution constructed through a 60 understood that any technical solution constructed through a 60 wherein respective main bodies of the at least two pairs of combination of any two or more solutions may also fall poles are spaced apart from one another ang

invention and are not intended to limit the disclosure. Any poles in each pair of poles have central symmetry with modification, equivalent replacement, improvement, and the 65 reference to each other. like made within the spirit and principles of the invention 3. The deflector according to claim 2, wherein the respec-
shall be contained in the protection scope of disclosure. The main bodies of the at least two pairs of

27 28

-
-
-
- are synthesized by combination of vectors into a resulalso has the technical effect of the multi-pole deflector 1
described above, and will not be repeatedly described here.
In a further embodiment, for example, the charged par-
ticle beam imaging apparatus 2 further comprise
- tively, and the respective electric fields are the surface of the sample to be tested. $\frac{25}{25}$ deflector comprising merely at least two pairs of the sample, the charged par-
In a further embodiment, for example, the charged par-
electrodes, which are formed by a co In the charged parameter and function as the at least two pairs of poles but at least one focusing lens 204, which is arranged coaxially are not multiplexed as magnetic poles, and configtant deflection electric field of the multi-pole electrostatic deflector, without generating magnetic field; or
- and size of the charged particle beam comprision comprising merely at least two pairs of magnetic poles, In a further embodiment, for example, the charged par-
ticle beam imaging apparatus 2 further comprises an aber-
have dynamic correction on a beam spot of the charged particle tively when an excitation current flows through the
excitation coils, and the respective magnetic fields are
In a further embodiment, for example, as illustrated in
	-

optical axis Z such that the secondary charged particles are 50 of axis aberration of the charged particle beam being
incident towards the secondary charged particle detector 202 incident on the deflector and entering and at respective radial inner sides and a same outer radius at respective radial outer sides; and

within the scope of protection of the present disclosure. Circumferentially, and are arranged to be in rotational
The above are merely preferred embodiments of the symmetry with reference to one another, and respective

across an equivalent radian and have a same shape, respec-
tively, in a same circumference defined collectively by the pair of imaginary protrusions. the respectively main bodies, and have a same inner radius at 12. The deflector according to claim 10, wherein the respective radial inner sides and a same outer radius at threshold angle range for respective protrusions o respective radial inner sides and a same outer radius at respective radial outer sides; and

arranged to space apart from one another at a same angle circumferentially.

5. The deflector of claim 4, wherein the at least two pairs pair of poles having the respection of poles comprise just two pairs of poles alternately spaced 15 pair of imaginary protrusions.

respective main body at a distance not exceeding a threshold Frequencies according to claim 1, wherein each of the deflector is each pair of poles extends circum-
ferentially across an angle not exceeding a threshold angle in at least one pair of the deflectors according to claim 1, relationships and angles not exceeding a unconout angle.

Transport angles in the charged particle beam imaging apparatus being config-

range, and projects from respective radial inner side of 20 the charged particle beam

7. The deflector according to claim 6, wherein the thresh charged particles therefrom for imaging, further comprising:
a charged particle source configured to emit the charged old angle range is 5° to 40° and the threshold radial distance a charged particle source configured to emit the charged particle beam; and is between 0.1 and 0.9 times of the respective inner radius 25 particle beam; and
a secondary charged particle detector, which is located to at respective radial inner sides of the respective main bodies of each pair of poles.

respective protrusions of each pair of poles is shaped to be sample to be tested and is configured to collect and
in the form of a base which projects from the properties 30 in the form of a boss which projects from the respective 30 image the secondary charged particles generated by the redial inner side of the respective main body of the records. radial inner side of the respective main body of the respective charge charge particle beam projected. tive pole and is provided with an arc-shaped concave top portion.

9. The deflector according to claim 6, wherein each of the metrically arranged with respect to the optical axis of metrically arranged particle beam, and are configured to deflect respective protrusions of each pair of poles is shaped to be 35 the charged particle beam, and are configured to deflect
in the form of one of a partial sphere a partial cone and a in the form of one of a partial sphere, a partial cone and a and project the charged particle beam to the surface of the surface of the sample to be tested in response to a scanning signal partial pyramid projecting from the respective radial inner the sample to be side of the respective main body of the respective pole and $\frac{applied\,\,therefore}{a}$ side of the respective main body of the respective pole and applied thereon.
is provided with a convex top portion.
in the charged particle beam imaging apparatus according to the charged particle beam imaging apparatus ac

the respective protrusions of each pair of poles is disposed coaxially with the optical axis and is located
the respective protrusions of each pair of the come of poles is shaped to is disposed coaxially with the optical a be in the form of one of a truncated frustum of a cone, a downstream or upstream or the at least one pair of the truncated enhanced accreament a frustum and a multi stage deflectors, and is configured to focus the charged truncated spherical segment, a frustum, and a multi-stage deflectors, and is comfigured to focus the charged particle
beam passing therethrough onto the surface of the sample to
the sample to stepped boss projecting from the respective radial inner side beam passed to the surface of the surfa of the respective main body of the respective pole and is 45 provided with a flat top portion.

11. The deflector according to claim 9, wherein the ing to claim 15, further comprising:
reshold angle range for respective protrusions of each pair at least one focusing lens, which is arranged coaxially threshold angle range for respective protrusions of each pair at least one focusing lens, which is arranged coaxially
of pales is aggregated to a redisponent process commission of the special axis and between the charged p of poles is equal to a radian angle range occupied by each of with the optical axis and between the charged particle
and the atleast one pair of the deflectors, and is a pair of imaginary protrusions used instead of the respective 50 source and the at least one pair of the deflectors, and is
configured to pre-focus and collimate the charged parprotrusions in the pair of poles, such that a pair of poles configured to pre - formulation and configured particle beam; and alternatively having the pair of imaginary protrusions, each a restricting stop, which is disposed between the at least of which is in the form of a boss projecting from the a restricting stop, which is disposed between the at least
non-contraction of the respective main bedy and
he focusing lens and the at least one pair of the respective radial inner side of the respective main body and one focusing lens and the at least one pair of the
is provided with an are shaned concerns to partien concerte. 55 deflectors, and is configured to adjust at l is provided with an arc-shaped concave top portion, generate 55 deflectors, and is configured to adjust at lea
an imaginary secondary deflection field equivalent to the shape and size of the charged particle beam. an imaginary secondary deflection field equivalent to the shape and size of the charged secondary deflection field as generated practically by the $* * * * *$

 $29 \hspace{3.1em} 30$

of poles is equal to a radian angle range occupied by each of a pair of imaginary protrusions used instead of the respective wherein the respective main bodies of the at least two a pair of imaginary protrusions used instead of the respective protrusions in the pair of poles, such that a pair of poles pairs of poles are spaced apart from one another protrusions in the pair of poles, such that a pair of poles property in the came circumforence defined collectually having the pair of imaginary protrusions, each angularly in the same circumference defined collec-
tively having the pair of imaginary protrusions, each
of which is in the form of a boss projecting from the tively by the respective main bodies.
The deflector according to claim 2, wherein the respective radial interval in the side of the respective main body and 4. The deflector according to claim 2, wherein the respec- 10^{-1} respective radial inner side of the respective main body and is provided with an arc-shaped concave top portion, generate tive main bodies of the at least two pairs of poles are is provided with an arc-shaped concave top portion, generate secondary deflection field as generated practically by the pair of poles having the respective protrusions other than the

of poles comprise just two pairs of poles alternately spaced 15 a.m. The deflector according to claim 1, wherein the at least two pairs of poles are just two pairs of poles.
6. The deflector according to claim 1, wherein

sample to be tested and in turn to excite and collect second charged particles therefrom for imaging, further comprising:

-
- be offset from an optical axis of the charged particle beam and between the charged particle source and the 8. The deflector according to claim ϵ , wherein each of the beam and between the charged particle source and the sample to be tested and is configured to collect and the sample to be tested and is configured to collect
	- wherein, the at least one pair of the deflectors are sym-
metrically arranged with respect to the optical axis of

10. The deflector according to claim 6, wherein each of $40 \frac{\text{kg}}{\text{kg}}$ is recomprising and objective lens which $\frac{1}{2}$

16. The charged particle beam imaging apparatus according to claim 15, further comprising:

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-