

the outer edge and centerline thereof over the outer area of the sputtering surface;

the resultant magnetic fields being such that plasma is confined ~~thereby~~ predominantly by the first magnetic tunnel when the target is uneroded and
5 progressively changing to fields that are such that plasma predominantly
confined by the second and third magnetic tunnels after the target has eroded,
so that the plasma produces a target erosion rate that is greater at the
centerline than at the inner and outer areas when the target is uneroded and
that continuously and progressively changes to a target erosion rate that is less
10 at the centerline than at the inner and outer areas as the target erodes.



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6. The ~~magnetron sputtering cathode assembly~~apparatus of claim 4

wherein the magnet assembly further comprises:

- a plurality of circular magnetic rings arranged in a cone behind, and
- 5 parallel to, the conical sputtering target, each ring having a circumference, a diameter and a common central axis through the center of the cone and the center of the target, the magnetic rings each having a first and a second magnetic pole and a polar axis extending between the poles thereof and perpendicular to the circumference of the ring, the plurality of magnetic rings
- 10 including an inner magnetic ring having the inner pole forming the first pole thereof, an outer magnetic ring having the outer pole forming the second pole thereof and an intermediate magnetic ring having the outer-central pole forming the first pole thereof and the inner-central pole forming the second pole thereof, the diameter of the inner magnetic ring being less than that of the intermediate
- 15 magnetic ring which is less than the diameter of the outer magnetic ring.

7. The ~~magnetron sputtering cathode assembly~~ apparatus of claim 4 wherein the magnet assembly further comprises:

a plurality of circular magnetic rings arranged in a cone behind and parallel to, the conical sputtering target, each ring having a circumference, a diameter and a common central axis through the center of the cone and the
5 center of the target, the magnetic rings each having a first and a second magnetic pole and a polar axis extending between the poles thereof and perpendicular to the circumference of the ring;

the polar axes of the magnetic rings being further oriented:

10 parallel to the cone for the inner magnetic ring with the first pole thereof closer to the axis than the second pole thereof,

parallel to the cone for the intermediate magnetic ring with the second pole thereof closer to the axis than the first pole thereof, and

perpendicular to the cone for the outer magnetic ring with the
15 second pole thereof closer to the axis than the first pole thereof.

8. The ~~magnetron sputtering cathode assembly~~apparatus of claim 4
wherein the magnet assembly further comprises:

a plurality of circular magnetic rings arranged in a cone behind, and
parallel to, the conical sputtering target, each ring having a circumference, a
5 diameter and a common central axis through the center of the cone and the
center of the target, the magnetic rings each having a first and a second
magnetic pole and a polar axis extending between the poles thereof and
perpendicular to the circumference of the ring; and

a yoke of magnetically permeable material behind the cone and
10 magnetically interconnecting the second pole of the inner magnetic ring with the
first pole of the outer magnetic ring.

10. The ~~magnetron sputtering cathode assembly~~apparatus of claim 1
wherein the magnet assembly further comprises:

a plurality of circular magnetic rings arranged in a cone behind, and
parallel to, the conical sputtering target, each ring having a circumference, a
5 diameter and a common central axis through the center of the cone and the
center of the target, the magnetic rings each having a first and a second
magnetic pole and a polar axis extending between the poles thereof and
perpendicular to the circumference of the ring, the plurality of magnetic rings
including an inner magnetic ring, an outer magnetic ring and an intermediate
10 magnetic ring, the diameter of the inner magnetic ring being less than that of the
intermediate magnetic ring which is less than the diameter of the outer magnetic
ring.

11. The ~~magnetron sputtering cathode assembly~~apparatus of claim 1
wherein the magnet assembly further comprises:

a plurality of circular magnetic rings arranged in a cone behind, and
parallel to, the conical sputtering target, each ring having a circumference, a
5 diameter and a common central axis through the center of the cone and the
center of the target, the magnetic rings each having a first and a second
magnetic pole and a polar axis extending between the poles thereof and
perpendicular to the circumference of the ring;

the polar axes of the magnetic rings being further oriented:

10 parallel to the cone for the inner magnetic ring with the first pole
thereof closer to the axis than the second pole thereof,

parallel to the cone for the intermediate magnetic ring with the
second pole thereof closer to the axis than the first pole thereof, and

perpendicular to the cone for the outer magnetic ring with the
15 second pole thereof closer to the axis than the first pole thereof.

12. The ~~magnetron sputtering cathode assembly~~apparatus of claim 1
wherein the magnet assembly further comprises:

5 a plurality of circular magnetic rings arranged in a cone behind, and
parallel to, the conical sputtering target, each ring having a circumference, a
diameter and a common central axis through the center of the cone and the
center of the target, the magnetic rings each having a first and a second
magnetic pole and a polar axis extending between the poles thereof and
perpendicular to the circumference of the ring; and

10 a yoke of magnetically permeable material behind the cone and
magnetically interconnecting the second pole of the inner magnetic ring with the
first pole of the outer magnetic ring.

13. A magnetron sputtering cathode assembly comprising:

a frusto-conical sputtering target having an interior conical sputtering surface, a circular inner edge, a circular outer edge and a circular erosion centerline between the inner and outer edges thereof, and

5 a frusto-conical magnet assembly situated behind, and parallel to, the sputtering target, the magnet assembly having:

an inner pole of a first polarity and an outer pole of a second polarity producing a first magnetic tunnel formed of a first magnetic field extending between the inner and outer poles,

10 an inner-central pole of the second polarity and an outer-central pole of the first polarity producing a reverse magnetic field opposing the first magnetic field on the centerline of the target such that the resulting flux of the first and reverse magnetic fields flattens on the centerline as the sputtering surface erodes into the target,

15 the inner pole and the inner-central pole producing a second magnetic tunnel formed of second magnetic field lines extending between the inner and inner-central poles beneath the first magnetic tunnel and beneath the sputtering surface when the target is uneroded, and which emerge over an annular inner area of the sputtering surface predominantly between the
20 inner edge and centerline thereof as the target erodes, and

the outer pole and the outer-central pole producing a third magnetic tunnel formed of third magnetic field lines extending between the outer and outer-central poles beneath the first magnetic tunnel and beneath the sputtering surface when the target is uneroded, and which emerge over

an annular outer area of the sputtering surface predominantly between the outer edge and centerline thereof as the target erodes;

whereby the relative contributions of the magnetic tunnels are such that confined plasma produces a target erosion rate that is greater at the centerline
5 than at the inner and outer areas when the target is uneroded and that continuously and progressively changes to a target erosion rate that is less at the centerline than at the inner and outer areas as the target erodes.