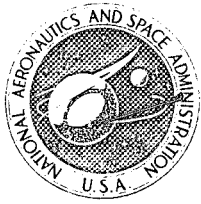


Lewis



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

AUG 6 1974

REPLY TO
ATTN OF: GP

TO: KSI/Scientific & Technical Information Division
Attn: Miss Winnie M. Morgan

FROM: GP/Office of Assistant General
Counsel for Patent Matters

SUBJECT: Announcement of NASA-Owned U.S. Patents in STAR

In accordance with the procedures agreed upon by Code GP and Code KSI, the attached NASA-owned U.S. Patent is being forwarded for abstracting and announcement in NASA STAR.

The following information is provided:

U.S. Patent No. : 3,826,729

Government or Corporate Employee : U.S. Government

Supplementary Corporate Source (if applicable) : ~~~~~

NASA Patent Case No. : LEW-11,646-1

NOTE - If this patent covers an invention made by a corporate employee of a NASA Contractor, the following is applicable:

YES NO

Pursuant to Section 305(a) of the National Aeronautics and Space Act, the name of the Administrator of NASA appears on the first page of the patent; however, the name of the actual inventor (author) appears at the heading of column No. 1 of the Specification, following the words "...with respect to an invention of ..."

Bonnie L. Woerner

Bonnie L. Woerner
Enclosure

(NASA-Case-LEM-11646-1) SPUTTERING HOLES
WITH ION BEAMLETS Patent Pat
02inventors (to NASA) (NASA) 2 P

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3,826,729

SPUTTERING HOLES WITH ION BEAMLETS

David C. Byers, North Olmsted, and Bruce A. Banks, Olmsted Township, Ohio, assignors to the United States of America as represented by the Administrator of the National Aeronautics and Space Administration
No Drawing. Filed Sept. 27, 1972, Ser. No. 292,686

Int. Cl. C23c 15/00

U.S. Cl. 204-192

10 Claims

ABSTRACT OF THE DISCLOSURE

Ion beamlets of predetermined configurations are formed by shaped apertures in the screen grid of an ion thruster having a double grid accelerator system. A plate is placed downstream from the screen grid holes and attached to the accelerator grid. When the ion thruster is operated holes having the configuration of the beamlets formed by the screen grid are sputtered through the plate at the accelerator grid.

ORIGIN OF THE INVENTION

The invention described herein was made by employees of the United States Government and may be manufactured and used by or for the Government for governmental purposes without the payment of any royalties thereon or therefor.

BACKGROUND OF THE INVENTION

This invention is concerned with forming holes of various shapes. The invention is particularly directed to sputtering holes with ion beamlets. The invention also relates to the correlation between screen grid hole configuration and ion beamlet shape in the plane of the accelerator grid of an ion thruster.

Electron-bombardment ion thrusters of the type described in U.S. Pat. Nos. 3,156,090 and 3,324,659 are being considered for a variety of space missions for which the optimum specific impulse is between about 2,000 and 3,000 seconds. As the specific impulse decreases, the discharge energy required per beam ion, eV/ion, becomes an increasingly important loss mechanism. The eV/ion decreases as the open area fraction of the screen grid increases.

The standard thruster grid configuration has consisted of a hexagonal array of circular holes in both the screen and accelerator grids as shown in U.S. Pat. Nos. 3,238,715 and 3,262,262. The maximum open area fraction for a hexagonal array of circular holes is 0.906, which occurs when the minimum web distance is zero. Larger open area fractions can be obtained with arrays of hexagonal, square, or triangular holes if the web thicknesses are made equal to that of the hexagonal arrays of circular holes. Grids with such hole shapes would provide improved discharge performance.

In addition, electrostatic beam deflection concepts have been proposed for thrusters sized for satellite station-keeping application. By way of example, vector grids having square apertures have been used. It is contemplated that screen grid hole shapes other than circular may provide optimum beam deflection characteristics.

SUMMARY OF THE INVENTION

Holes of various shapes are ion sputtered in accordance with the present invention. An electron-bombardment ion thruster with a double grid accelerator system has a plate in which holes are to be formed attached to the accelerator grid. This plate is positioned in front of the screen grid holes having the desired configuration.

During thruster operation holes are sputtered through this plate. A correlation between screen grid holes shapes

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and ion beamlet shape in the plane of the accelerator grid may be made from information obtained.

OBJECTS OF THE INVENTION

5 It is, therefore, an object of the present invention to provide an improved process for sputtering holes of a predetermined configuration through metal plates.

Another object of the present invention is to provide ion beamlets having a predetermined configuration for ion sputtering.

10 A further object of the invention is to increase the open area fraction of a screen grid of an ion thruster.

15 These and other objects and advantages of the invention will be apparent from the specification which follows.

DESCRIPTION OF THE PREFERRED EMBODIMENT

20 Sheets having various shaped holes were used with a 30-cm. thruster of the electron bombardment type to illustrate the features of the present invention. The thruster had a double grid accelerator system including a screen grid and an accelerator grid. The screen grid was 1.52 mm. thick with 5.0 mm. holes drilled on a 5.6 mm. center-to-center spacing. The accelerator grid was 2.0 mm. thick with 4.0 mm. diameter holes.

25 Various screen grid hole shapes were electric-discharge machined into 0.13 mm. thick tantalum sample sheets. Each sheet had a diameter of about 3.8 cm. The number of holes machined into each sample sheet was such as to surround the central hole with holes in a regular pattern.

30 The tantalum sheets were placed on the upstream side or triangular holes if the web thicknesses are made equal hole in each tantalum sheet was at a radius of 7 cm. from the thruster axis.

35 Solid tantalum sheets between 0.5 and 0.13 mm. thick were then placed on the upstream side of four matching areas cut into the accelerator grid. Ions extracted by the holes in the screen sample plate then impinged on the sheets on the accelerator grid and sputtered through in about one-half hour. The shapes of the holes sputtered through the accelerator grid tantalum sheets had the same configuration as the corresponding holes in the sample sheets mounted on the screen grid. The shapes of the hole patterns eroded on the accelerator grid sheets were representative of the focusing characteristics of the corresponding screen grid holes.

40 All the holes were ion sputtered in a 1.5 mm. diameter, 4.5 mm. long, vacuum facility. The operating pressures were about 7×10^{-6} torr during sputtering. Some thruster operating parameters during the sputtering are shown in Table I.

45 The length, L, given on Table I was the measured grid-to-grid spacing plus the screen grid hole sample sheet thickness. The grid spacing was measured before and after thruster operation and agreed within about 7%.

TABLE I.—THRUSTER OPERATING PARAMETERS

	Screen		Accelerator		Spacing, L, mm.
	V	A	V	A	
Test:					
1	2,000	0.42	870	0.010	3.52±0.3
2	2,000	.54	1,220	0.010	4.1±0.3
3	2,000	.75	1,330	.011	4.1±0.3
4	2,000	.40	1,330	.006	4.1±0.3
5	2,000	.55	1,330	.005	4.1±0.3

70 The ion focusing characteristics of circular, hexagonal, square and triangular holes were studied. The geometries of screen and accelerator holes are shown in Table II.

TABLE II.—GEOMETRY OF SCREEN AND ACCELERATOR HOLES

Test	Screen hole geometry	R _s , mm.	D _s , mm.	R _A /R _s	D _A /D _s	θ _s , deg.	θ _s , deg. ±5
1	Circle	2.5	2.5	0.45	0.45	180	180
2	Circle	2.5	2.5	.50	.50	180	180
	Hexagon	2.5	2.8	.57	.64	120	55
	Square	2.5	3.5	.49	.68	90	43
	Triangle	2.9	5.7	.63	.91	60	33±10
3	Circle	2.5	2.5	.64	.64	180	180
	Hexagon	2.5	2.8	.55	.62	120	74
	Square	2.5	3.5	.51	.74	90	49
	Triangle	2.9	5.7	.66	.91	60	27±10
4	Curvesided squares—						
	A	2.3	2.6	.57	.67	139±3	79
	B	2.2	2.5	.51	.64	134±3	76
	C	2.4	2.9	.64	.75	136±3	78
	D	2.3	2.5	.53	.64	121±3	67

The erosion of holes on the accelerator sample plates was observed visually during the tests. The locations of maximum erosion within each beamlet then could be determined because these locations would erode through first and were illuminated by the discharge plasma. In addition, the small areas of accelerator grid samples opposite the holes in the screen grid sample holes would fall off during the test and areas of erosion could be determined after the test.

Circular, hexagonal, square and triangular holes were tested simultaneously in tests 2 and 3. Two characteristic dimensions were selected to specify the erosion ratios for the noncircular shapes. The distance from the sample center of symmetry to a side is specified as R_S or R_A on the screen or accelerator sample, respectively. The distance from the center of symmetry to the intersection of the sample corners is called D_S and D_A. The characteristic dimensions of the hexagonal and square samples were about the same as the circular sample. The triangular holes were made somewhat larger than the other samples.

The relation between the angles in the screen holes and the angles of the eroded accelerator grid samples was determined. These angles are described as θ_S and θ_A, respectively. The value of θ_A is taken to be that of the fringe area, and in some cases it is difficult to specify exactly due the difficulty of or determining the fringe edges. The values of θ_S and θ_A are shown in Table II along with the estimated uncertainty of measurement. As indicated in Table II the uncertainty was estimated to be five degrees except where otherwise shown.

While the preferred method has been described it will be appreciated that various modifications may be made without departing from the spirit of the invention or the scope of the subjoined claims.

What is claimed is:

1. A method of producing apertures having predetermined configurations in members comprising the steps of forming ion beamlets having said predetermined configurations by extracting ions from a source through a sheet having at least one aperture therein contoured to said predetermined configuration, and

directing said ion beamlets toward said members to sputter the same whereby apertures are sputtered therein having the configurations of said ion beamlets.

2. A method of producing apertures as claimed in claim 1 including the step of

mounting said members normal to said ion beamlets.

3. A method of producing apertures as claimed in claim 2 wherein the ion beamlets are formed in an ion thruster.

4. A method of producing apertures as claimed in claim 3 wherein the ion thruster has an accelerator grid, including the step of

mounting said members on said accelerator grid.

5. A method of producing apertures as claimed in claim 4 wherein the members are mounted in an upstream side of said accelerator grid.

6. A method of producing apertures as claimed in claim 4 wherein the ion beamlets are formed by a screen having apertures therein, said apertures having said predetermined configurations of said ion beamlets.

7. A method of producing apertures as claimed in claim 6 wherein the ion thruster has a screen grid located upstream of an accelerator grid, said screen being mounted on said screen grid.

8. A method as claimed in claim 7 wherein the screen is mounted on the upstream surface of the screen grid.

9. A method as claimed in claim 1 wherein the ion beamlets are formed in a vacuum.

10. A method as claimed in claim 9 wherein the vacuum has a pressure of about 7×10^{-6} torr.

References Cited

UNITED STATES PATENTS

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3,133,874	5/1964	Morris	204—298
3,472,751	10/1969	King	204—192
3,708,418	1/1973	Quinn	204—298

JOHN H. MACK, Primary Examiner

D. R. VALENTINE, Assistant Examiner

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,826,729 Dated July 30, 1974
Inventor(s) David C. Byers and Bruce A. Banks

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 51, cancel "are" and insert therefor --area--.

Column 2, line 34, cancel "or triangular holes if the web thicknesses are made equal" and insert therefor --of the screen grid over four large open areas. The central--.

Signed and sealed this 5th day of November 1974.

(SEAL)
Attest:

McCOY M. GIBSON JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents