Goddard

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

REPLY TO
ATTN OF: GP

November 6, 1970

TO: USI/Scientific & Technical Information Division
Attention: 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 USI, 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. : 3,509,419

Government or Corporate Employee : U.S. Government

Supplementary Corporate Source (if applicable) : NA.

NASA Patent Case No. : XGS-06628

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 N.A."

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Enclosure
Copy of Patent cited above

FACILITY FORM 602

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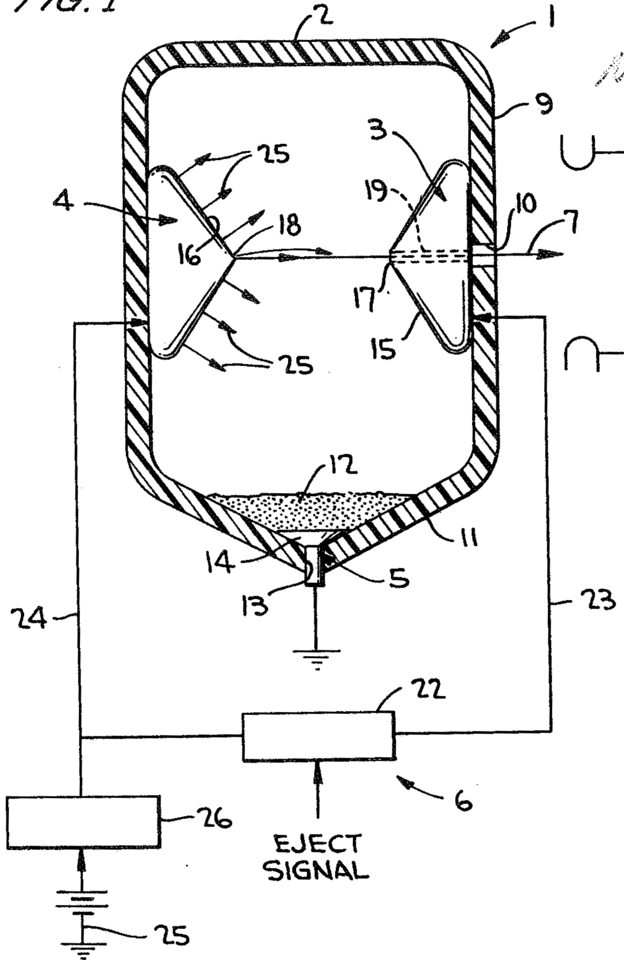
April 28, 1970 O. E. BERG 3,509,419

DUST PARTICLE INJECTOR FOR HYPERVELOCITY ACCELERATORS

Filed Aug. 31, 1967

FIG. 1

N71-16213 4070



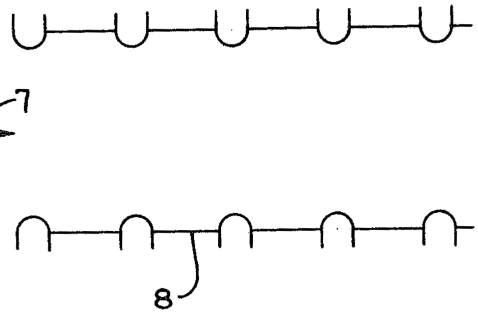


FIG. 3

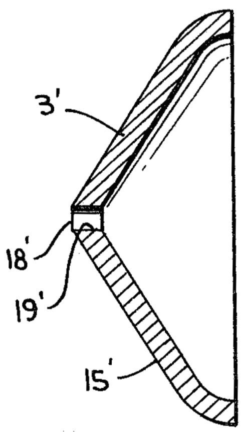
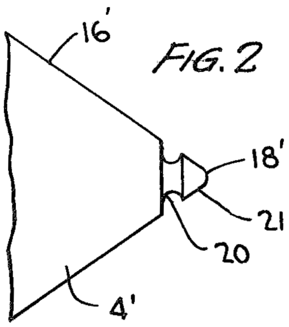


FIG. 2



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Patented Apr. 28, 1970

3,509,419
DUST PARTICLE INJECTOR FOR HYPERVELOCITY ACCELERATORS

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Int. Cl. H01j 29/56, 33/02
U.S. Cl. 315—111 7 Claims

ABSTRACT OF THE DISCLOSURE

A method and apparatus for use in forming a highly collimated beam of microparticles having a high charge-to-mass ratio and injecting such beam into a electrostatic accelerating tube. The apparatus includes an insulated housing having a particle exit opening; a pair of conically shaped electrodes which are arranged within the housing with their apex portions disposed in a spaced apart facing relationship in alignment with the housing exit opening, the electrode adjacent the housing exit opening having a particle exit passageway extending through the apex portion thereof; and an electrical circuit adapted to control charging of the particles and the application of an electrical field across the electrodes. Particles arranged within the housing are electrostatically charged to distribute the particles adjacent the electrodes, whereafter voltage pulses of appropriate sign are applied to the electrodes to produce a strongly collimated beam of charged particles having a high charge-to-mass ratio; the beam being ejected from the housing through the electrode passageway and housing exit opening, and thereafter injected into an electrostatic accelerating tube.

The invention described herein was made by an employe 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.

The present invention is particularly adapted for use in forming a strongly collimated beam of microparticles having a high charge-to-mass ratio and injecting such beam in an electrostatic accelerating tube which is adapted to accelerate particles within the beam to meteoric velocities. The thus accelerated particles may be employed to simulate micrometeoric impacts to be used, for instance, in sensor calibration and studies of erosion and luminous effects.

Heretofore, it has been well known to accelerate charged particles by an electrical field defined by a pair of spaced electrodes. However, in attempting to employ existing techniques to obtain a beam of charged particles having a charge-to-mass ratio in excess of about 10 coulombs per kilogram, excessive electrode failure is often encountered due to the high potential difference which it is found necessary to apply to the electrodes. Further, by use of present techniques it is difficult to obtain a strongly collimated beam of such particles.

Accordingly, it is an object of the present invention to provide a method and apparatus for accelerating and focusing mirco-particles having a high charge-to-mass ratio which is not subject to the above mentioned disadvantages.

This and other objects of the present invention will become apparent from the following description taken with the accompanying drawing in which:

FIGURE 1 is a partially sectioned elevational view of the apparatus employed in the practice of the present invention;

FIGURE 2 is a fragmentary view showing a modified electrode design; and

FIGURE 3 is a sectional view illustrating another modified electrode design.

One form of the apparatus employed in the practice of the present invention is generally designated as **1** in FIGURE 1 and includes an insulated housing **2**; first, second, and third electrodes, generally designated as **3**, **4**, **5** and an electrical control circuit generally designated as **6**. As will more fully hereinafter be described, the apparatus is particularly adapted to form and inject a highly collimated beam of particles **7** axially into a hypervelocity acceleration tube **8** of conventional design.

Housing **2** is shown in FIGURE 1 as generally including an upper portion **9**, which is provided with a particle exit opening **10** adapted to be disposed in axial alignment with acceleration tube **8**; and a tapered lower portion **11**, which is adapted to receive a mass of particles **12** which tend to collect under the influence of gravity. Housing lower portion **11** is apertured, as at **13**, to receive the third electrode **5**, having an enlarged head portion **14** adapted to underlie the collected mass of particles.

For purposes of the present invention, upper housing portion **9** may be of either circular or rectangular cross section; but lower housing portion **11** is preferably conically shaped to facilitate the collection of particles about the enlarged head portion of the electrode **5**. Further, housing **2** is preferably formed of a suitable electrically insulating material, such as Lucite, and grounded in any suitable manner, not shown, to prevent the buildup of undesirable electrical charges thereon, If desired, the entire top of the housing may be removable to permit the admission of particles and to facilitate assembly of the apparatus.

First electrode **3** and second electrode **4**, which, as will become clear, function, respectively, as particle attracting and repelling electrodes, are preferably each formed with substantially conically shaped surface portions **15**, **16**, and are arranged within housing **2** with their apex portions **17** and **18**, respectively, in facing spaced relationship. Electrode **3** is provided with a particle exit passageway, shown in phantom at **19**, which extends through apex portion **17** and is disposed in axial alignment with apex portion **18** of the electrode **4** and housing exit opening **10**.

FIGURE 2 illustrates a modification of the design of the second electrode **4'**, wherein a shallow annular groove **20** is disposed immediately adjacent apex portion **18'** to create a small, substantially nipple-shaped tip or head or sphere **21**. The discontinuity in electrode surface **16'** formed by groove **20** tends to assist in operation of the second electrode in a manner to be fully hereinafter described.

Electrodes **3** and **4** may be supported on opposing side wall portions of housing **2** in any suitable manner, not shown. Further, these electrodes may be formed of any suitable electrode material and be of solid construction, or be hollow, as illustrated in the case of electrode **3'** in FIGURE 3. An electrode structure of the type shown in FIGURE 3 results not only in material savings, but facilitates the forming of the particle exit passageway **19'**.

Control circuit **6** is shown diagrammatically in FIGURE 1 as including a voltage pulser unit **22**, which is suitably connected to electrodes **3** and **4**, such as by wires **23** and **24**, respectively; a battery **25**, and a buffer or electrical filter **26**, which is arranged between pulser unit **22** and battery **25** and adapted to prevent the appearance of voltage pulses at battery **25** during operation of pulsing unit **22**. The elements of control circuit **6** are of conventional design and individually form no part of the present invention.

In the practice of the preferred form of the present invention, particles collected in mass **12** are positively charged by employing battery **25** to provide a high voltage pulse across second electrode **4** and third electrode **5**, which, as indicated in FIGURE 1, is connected to ground. Upon removal of the positive pulse from the second electrode, which thereafter is permitted to return to a low positive potential, the positively charged particles within mass **12** are electrostatically agitated within housing **2** and are subsequently attracted and attached to surrounding surfaces by electrostatic attraction and by Van Der Walls polarization forces. Members of these particles are attracted to the conical surface **16** of the electrode **4** and remain attached thereto, since the low positive potential of the electrode **4** is insufficient to overcome the forces of attraction of the particles. The distribution of particles on the surface of the electrode **4** is random in nature with normally at least one or more particles being disposed immediately adjacent the electrode apex portion **18**. The presence of pulser unit **22** in the circuit between battery **25** and first electrode **3** prevents the appearance of a positive pulse on the surface thereof.

With particles attached to the surface **16** of electrode **4**, the apparatus is primed for forming and ejecting the particle beam **7** from the housing and injecting such beam into tube **8**, as will now be described. Operation is initiated by actuating suitable means, not shown, to supply an inject signal to pulser **22**, which is thereupon adapted to substantially simultaneously apply a positive voltage pulse to second electrode **4**, which thus becomes a particle repelling anode, and a negative voltage pulse to first electrode **3**, which thus becomes a particle attracting cathode. When the positive pulse appears on the conical surface **16** of the anode or repelling electrode **4**, positively charged particles attached thereto are repelled in a direction perpendicular to the segment of the surface upon which they are attached, as indicated by arrows **25**, and thereafter tend to be accelerated and focussed by the electrical field established between electrodes **3** and **4**. It will be apparent that, due to the conical configuration of electrodes **3** and **4**, the strongest portion of the electrical field is established in the region immediately between electrode apex portions **17**, **18** and that positively charged particles in or near this region are accelerated towards electrodes **3** and tend to travel along a substantially straight line path axially through th particle exit passageway **19** and into acceleration tube **8**, as a highly collimated beam of particles **7**. Particles disposed elsewhere on surface **16**, when repelled, tend to be accelerated along curved line paths between the surfaces of the electrodes and upon failure to enter the inlet of particle exit passageway **19**, either fall back into the mass of particles at the bottom of the housing or become attached elsewhere within the housing when the electrodes are permitted to return to low potential levels. Also, it will be apparent that particles which are attached to electrode **4** immediately adjacent apex portion **18** will be given a higher positive charge than particles attached elsewhere on surface **16**, since the amount of charge is proportional to the ratio of particle radius to the radius of curvature of apex portion **18**.

The provision of a shallow groove or discontinuity **20** in the conical surface of repelling electrode **4**, as shown in FIGURE 2, serves to effectively segregate particles attached adjacent the apex portion **18'** from those attached elsewhere on the conical surface, and thus reduce the likelihood of the latter porticles being included in beam **7**, which would result in an overall reduction in the degree of beam collimation. The presence of groove **20** has not been found to materially reduce the value of voltage pulse which may be applied to electrode **4'**.

It has been found in practice that it is often possible to obtain successive particle beams without the necessity of employing a separate particle agitating step each time beam **7** is to be formed, since the high voltage pulses applied to the conical electrodes tend to maintain a sufficient number of particles which have not passed into the inlet of particle exit passageway **19**, in a positively charged condition and such particles are attracted to anode or repelling electrode **4** when it is permitted to return to a low positive potential upon removal of the voltage pulse.

The utilization of relatively large mass anode and cathode structures with a relatively large spacing therebetween permits the application of higher voltage pulses than would be possible with conventional needle or spherically shaped electrode structures. Thus, the charge-to-mass ratio imparted to the particles and the degree of acceleration of particles within the ejected beam may be substantially increased over that presently obtainable. Additionally, the conically shaped construction of the anode functions to segregate or select for purposes of forming the beam to be injected into tube **8** only particles having a relatively higher charge, and the configurations of both electrodes co-act to provide a well defined electrical field or accelerating path to insure that the selected particles are not only greatly accelerated, but are formed into a severely collimated beam. Even where a conically shaped anode is employed in combination with a flat apertured plate or ring cathode, a far greater degree of particle beam collimation is to be expected.

Apparatus embodying the principles of the present invention has been successfully constructed and tested for use in accelerating microparticles, such as dust particles, having diameters ranging between about 0.1 and 100 microns. The electrodes employed were in the shape of cones having an included angle of about 120° and were arranged within a Lucite housing in the manner shown in FIGURE 1 with a spacing of approximately 2½ centimeters between apex portions. The particle exit passageway of the first electrode or cathode had a diameter of approximately 25 microns and the radius of curvature of the second electrode or anode was approximately 100 microns. The pulser unit employed had the capability of applying pulses of 10,000 volts to each electrode to produce a differential of 20,000 volts. The rise time of the voltage pulse applied to the anode was 0.1 microsecond and the pulse duration was 2 microseconds. The voltage pulse applied to the cathode had a rise time of 1 microsecond and a duration which was selectively equal to or up to ten times greater than that of the pulse applied to the anode. It was found that particles within the beam were accelerated by the electrical field between the electrodes to a speed of approximately 500 meters per second and that the charge-to-mass ratio of such particles was on the order of about 10 coulombs per kilogram.

It is believed that under operating conditions expected to be encountered in use, the conical electrodes should have an included angle of about 120°. Angles much less than 130°, i.e., electrodes approaching a needle shape, would result in structures having insufficient mass adjacent the apex portion to retard spattering and failure. Alternatively, by employing an included angle much in excess of 120°, the electrodes tend to assume more and more the characteristics of flat plate electrodes, which would fail, in the case of the anode, to provide initial segregation of highly charged particles attached to its surface in the manner discussed above.

It will be understood that, while particles to be ejected from the housing may be either positively or negatively charged and then subjected to an electrostatic acceleration field of an opposite sign, it is preferable to charge the particles positively, since it is well known that higher electrical charge densities are obtainable on positively charged particles.

Further, while charging of particles within the housing has been described as being accomplished by employing a battery to create a potential across the second and third electrodes, various modifications are anticipated. Exemplatory of such modifications is to apply a voltage pulse of suitable polarity to the third electrode, to maintain the third electrode at a desired steady state potential, or to subject the particles to a beam of positive ions or Xray radiation. Furthermore, rather than normally retaining a supply of particles within the housing, particles having a charge thereon may be injected into the housing immediately prior to pulsing the conically shaped electrodes. Also, while the particles have been described as micro particles, such as dust particles, it is anticipated that the present invention is equally suitable for use in forming a highly collimated beam of particles including protons, ions, and electrons. Accordingly, since these and other modifications of the present invention will occur to others skilled in the art in view of the foregoing description, I wish to be limited only by the scope of the appended claims wherein:

What is claimed is:

1. An apparatus for forming a substantially collimated beam of charged particles for injection into an accelerating tube which comprises a housing having a particle exit opening provided in one wall thereof; a first electrode arranged within and insulated from said housing, said first electrode having a particle exit passageway aligned with said exit opening; a second electrode arranged within and insulated from said housing, said second electrode being of a substantially conically shaped configuration and having the apex portion thereof facing said first electrode in alignment with said passageway and said exit opening; discontinuity means immediately adjacent to said apex portion of said second electrode for segregating particles adjacent said apex portion from those attached elsewhere on the conical surface of said second electrode to increase the degree of beam collimation; and circuit means, said circuit means being adapted to selectively maintain said second electrode at a predetermined potential to permit at least some of said particles, when having a predetermined electrical charge, to be electrostatically attracted to the conical surface of said second electrode, and said circuit means being selectivley adapted to substantially simultaneously apply pulses of voltage of opposite polarity to said electrodes, the polarity of the voltage pulse applied to said second electrode being of like sign to said predetermined charge.

2. The apparatus according to claim 1, wherein said first electrode is of a substantially conically shaped configuration having the apex portion thereof facing said

second electrode and said passageway extending through the apex portion thereof.

3. The apparatus according to claim 2, wherein said first electrode is hollow and said passageway is defined by the walls of an aperture passing through said apex portion.

4. The apparatus according to claim 1, wherein said first and second electrodes are arranged adjacent vertically extending side wall portions of said housing, said housing is provided with a lower portion adapted to receive particles tending to collect in mass under the influence of gravity, a third electrode is arranged within the lower portion of said housing and electrically insulated therefrom, and said circuit means is further adapted to selectivley apply a pulse of electrical potential across said said third electrode and at least one of said first and second electrodes to apply said predetermined charge to and thus effect electrostatic agitation of said particles.

5. The apparatus according to claim 4, wherein said first electrode is of a substantially conically shaped configuration having an apex portion facing said second electrode and said passageway extends through the apex portion thereof.

6. The apparatus according to claim 4, wherein said third electrode is connected to ground and said circuit means is adapted to apply said pulse of electrical potential selectively to said second electrode.

7. The apparatus according to claim 1, wherein said discontinuity means is an annular groove.

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U.S. Cl. X.R.

328—233; 313—63, 230; 250—41.9