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ELECTRON MULTIPLIER

Walter Henneberg, Berlin, Germany, assignor to
General Electric Company, Schenectady, N. Y.,
a corporation of New York

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This invention relates to electron multipliers and more particularly to electron multipliers in which a number of successive grid-like secondary electron emitting electrodes of successively higher potentials are passed in succession by an electron discharge which bombards the emitters in succession so that secondary electrons are released from the emitters by the impinging electrons.

In an electron multiplier where a number of grid-like emitters are equally spaced along the path of the discharge, the impinging electrons strike that side of the emitter which faces the oncoming electrons, and which for convenience may be called the front side, the secondary electrons emerge in a direction opposite to the direction of movement of the impinging electrons, and therefore in the wrong direction for being drawn directly along the multiplier to the succeeding emitters. The secondary electrons which are emitted from the front side of the grid-like emitter must be drawn through the grid-like emitter and then accelerated away from the rear of the emitter by the accelerating field at the rear of the emitter. When the potential differences between consecutive emitters are the same, the accelerating field between one emitter and the following emitter does not extend through to the front side of the first emitter and does not accelerate those secondary electrons which emerge from the front side of the emitter directly against the field between the emitter and the preceding one. As a result, many of these secondary electrons fall back into the emitter and do not take part in the multiplication at the succeeding emitters.

The principal object of the invention is to utilize in the electron multiplication a greater percentage of the secondary electrons emitted from the front side of the emitters and to facilitate the utilization of the secondary electrons emitted from the bombarded side of the grid-like emitters.

In accordance with my invention the field strength between the successive emitters of an electron multiplier having an array or series of parallel grid-like emitters at successively higher potentials is increased between the successive emitters stage by stage so that the field intensity between any given emitter and the succeeding one is greater than the field intensity between that given emitter and the preceding one. In the conventional electron multipliers of this type with equally spaced grid-like emitters and with equal potential differences between the consecu-

tive emitters the flux of the field on the rear of an emitter does not penetrate to the front side of that emitter. Such a flux penetration of the emitter occurs only when the field intensity between any pair of emitters is greater than the field intensity between the preceding pair. The stage by stage increase in field intensity between each emitter and the succeeding one may be obtained either by increasing the potential difference between equally spaced emitters from stage to stage or by applying to a number of emitters which are spaced progressively closer to each other potentials which increase in uniform steps.

My invention will best be understood in connection with the accompanying drawing in which Figure 1 shows diagrammatically the field relationship when the fields between the grid-like emitters are of the same intensity; Figure 2 when the field intensity increases from stage to stage; and Figures 3 and 4 show diagrammatically two embodiments of the invention illustrated merely as examples. Figure 1 indicates diagrammatically that if, in the usual electron multiplier having equally spaced planar grid-like emitters *N*, the emitter potentials are so chosen that there is for example a potential difference of 150 volts each between the individual emitters, the fields on either side of a given emitter, for example that at 300 volts, are of the same magnitude, and consequently there is no flux penetration of the emitter, since on the front side of a wire of the emitter there is a field which accelerates electrons along the path 1 to the emitter and also retards the secondary electrons emerging along the path 2 from the front side, and on the back side there is a field of equal intensity which accelerates the secondary electrons away from the emitter along the path 3. The equipotential surfaces *E* are planar and parallel to the emitters.

Figure 2 indicates how this field relationship in which there is no flux penetration of an emitter is changed when the fields between the emitters increase from stage to stage. If an emitter is at 300 volts, with the succeeding emitter at 450 volts and a field of 150 volts to draw electrons away from the 300 volt emitter, and the preceding emitter is at 200 volts and a field of 100 volts instead of 150 volts accelerates electrons toward the 300 volt emitter, the field ratios are such that the equipotential surfaces *E* of 400 volts and 350 volts are no longer planar, but curved, and come up toward the 300 volt emitter, as indicated by the curved equipotential lines *E* at 300, 350, and 400 volts so that the

equipotential surface of 300 volts is pushed downwardly and even entirely detached from the emitter wires, which for their part are now in effect surrounded by potential surfaces of 310 volts, as indicated by the circles around the emitter wires. A field which accelerates the secondary electrons away from the emitter is now operative on the entire emitter surface both front and back, and especially on the front side of the emitter wires, as indicated by the curved paths 2 of the secondary electrons from the front of the emitter. Obviously the yield of secondary electrons in a multiplier with such field ratios is much more favorable than in the case of the usual multipliers. It is further obvious that the desired field flux penetration of the emitter can better be realized in a case where the emitters consist of circular wires (Figure 1) instead of flat strips, so that wire mesh or wire grid-like emitters are preferred for the multiplier according to the invention.

In Figures 3 and 4 two practical forms of the inventive idea are diagrammatically illustrated by way of example. Figure 3 shows a grid emitter multiplier comprising a highly evacuated envelope B enclosing a photo-cathode K, a series of wire grid-like emitters N, and an anode A. The voltages for the electrodes are taken from a direct voltage source across a voltage-divider D. The emitters are at equal distances from one another, and the voltage-divider is non-uniformly subdivided in such a way that the voltage between two successive emitters and therefore the field strength between them rises from stage to stage. Owing to the demands made by the secondary electron emission on the voltages connected between the electrodes, the need for increasing the voltages, where the distances between the emitters are equal so that the field strengths increase in adequate measure, cannot always be fulfilled. It is then expedient, as shown in Figure 4, to make the distances between the emitters smaller from stage to stage, for example, to reduce them by half each time, and for instance to make the voltages taken from the voltage-divider D equal for each stage. It is obvious that both forms may be used in combination, for example, the distance between the electrodes may be made smaller and the voltages may also increase from stage to stage. In both Figures 3 and 4 a special resistance V is further provided in the anode circuit, from the ends of which resistance the voltage can be fed to a consumption circuit.

In electron multipliers the space charge between the last emitters are higher than in the first stages and high space charge may lead to current saturation, so that amplification proportional to the primary current is no longer obtained. In order to avoid this effect, it has been proposed to space the last emitters so that with the space charges that are to be expected no saturation will occur. The spacing depends on the amplification that is to be expected, for example, at the ratio 1 to 2 with a doubling of the current through secondary emission. This expedient for dealing with saturation in the last stage has no bearing on the present invention. The increase in field intensity should not be

limited in the last stage only, because the inadequate flux penetration is present in the first stages, and the increase in field should not be dependent on the amplification, because even in the case of an extremely small current a flux penetration of the field is required to attain the advantages of the invention. It is advantageous to dimension the fields in such a way that all emitting parts of the grid-like emitters are surrounded by an acceleration field, which generally requires a much greater field increase from stage to stage than is necessary merely to eliminate the effect of space charge. By the invention the advantage of good amplification at each emitter is obtained, and also the influence of the space charge in the higher stages is suppressed automatically.

The invention is not restricted to multipliers with photo-cathodes, as shown in the practical examples. Obviously it can be used in the same way for multipliers with other electron sources, such as multipliers with thermionic cathodes, with either grid control or some other control of the electron current. Again, the emitter need not be flat, as it is known in the art, to obviate excessive loading of the last stages by constructing the emitters as coaxial cylinders surrounding one another, at least in the last stages, or else as coaxial truncated cones of increasing area surrounding one another.

I claim:

1. A secondary electron emission multiplier comprising an electron source, an output anode, an array of grid-like secondary electron emitters of high secondary electron emissivity uniformly spaced between said source and said anode and constituting the sole field forming electrodes between the first and the last of said secondary electron emitters, and means for maintaining said secondary electron emitters positive with reference to said source at potentials which produce between successive emitters potential differences which are sufficient to produce high secondary electron emission and which increase progressively with distance of said secondary electron emitters from said source and establish an undistorted electrostatic field in the space between each secondary electron emitter and an adjacent secondary electron emitter.

2. A secondary electron emission multiplier comprising an electron source, an output anode, a plurality of grid-like plane parallel secondary electron emitters having high secondary electron emissivity and uniformly spaced between said source and said anode to provide between each secondary electron emitter and the next an unobstructed space discharge path free from other electrodes and to produce in said space discharge path an undistorted electrostatic field due solely to said two secondary electron emitters, and means for maintaining said secondary electron emitters positive with reference to said source and at potentials which increase with distance from said source more than the increase in said distance to produce between successive emitters potential differences which increase successively with distance from said source.

WALTER HENNEBERG.