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Ogawa

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(54) **FUSE ELEMENT ASSEMBLIES**

(71) Applicant: **Micron Technology, Inc.**, Boise, ID (US)

(72) Inventor: **Sumio Ogawa**, Sagamihara (JP)

(73) Assignee: **Micron Technology, Inc.**, Boise, ID (US)

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(22) Filed: **Aug. 24, 2017**

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Related U.S. Application Data

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H01H 85/05 (2006.01)
H01H 85/143 (2006.01)
H01L 23/525 (2006.01)

(52) **U.S. Cl.**
CPC ***H01H 85/05*** (2013.01); ***H01H 85/143*** (2013.01); ***H01L 23/5256*** (2013.01)

(58) **Field of Classification Search**
CPC ... H01H 85/05; H01H 85/143; H01L 23/5256
USPC 337/290
See application file for complete search history.

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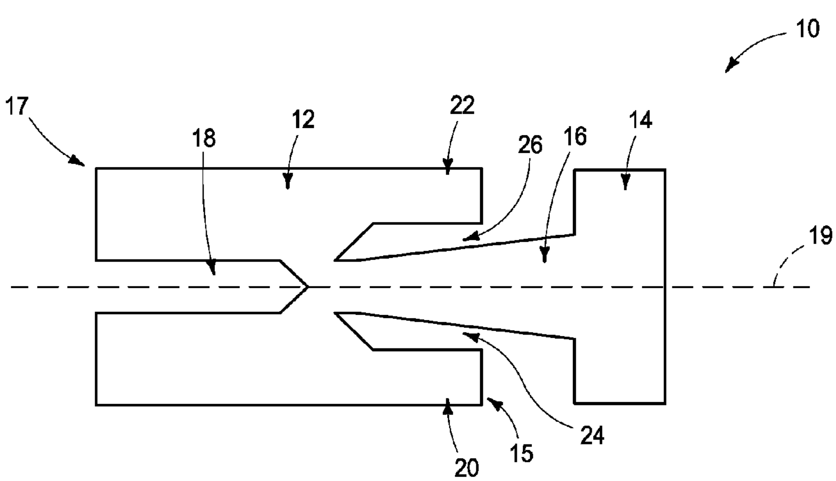
Primary Examiner — Anatoly Vortman
Assistant Examiner — Stephen S Sul
(74) *Attorney, Agent, or Firm* — Wells St. John P.S.

(57) **ABSTRACT**

Some embodiments include a fuse element assembly having a first portion configured to rupture as materials of the first portion flow to a second portion through electromigration. The assembly has a second portion configured to accumulate the materials that have flowed from the first portion. The assembly also has a control element configured to divide the flow of materials into at least two paths along the second portion. The first portion may be a fuse-link and the second portion may be a cathode coupled to the fuse-link through a narrow neck region. The control element may be, for example, a slit, a hole, a conductive contact, etc.

10 Claims, 12 Drawing Sheets



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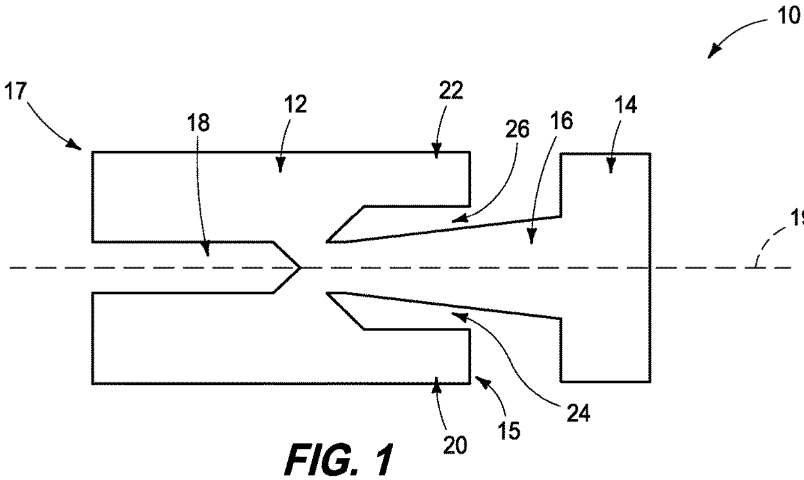

FIG. 1

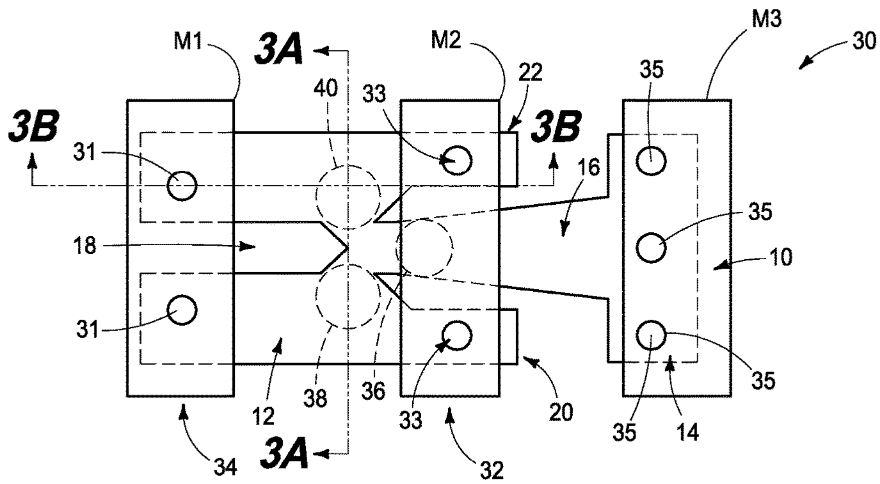

FIG. 2

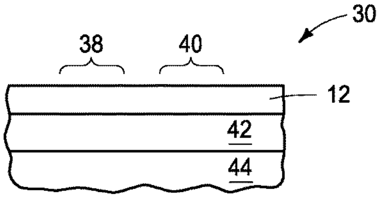

FIG. 3A

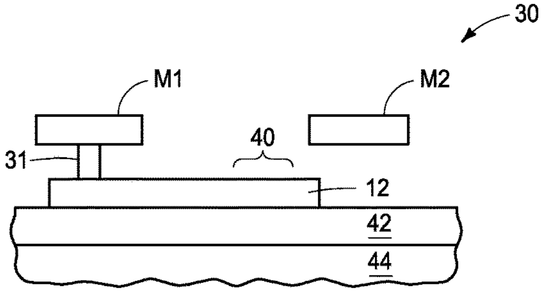

FIG. 3B

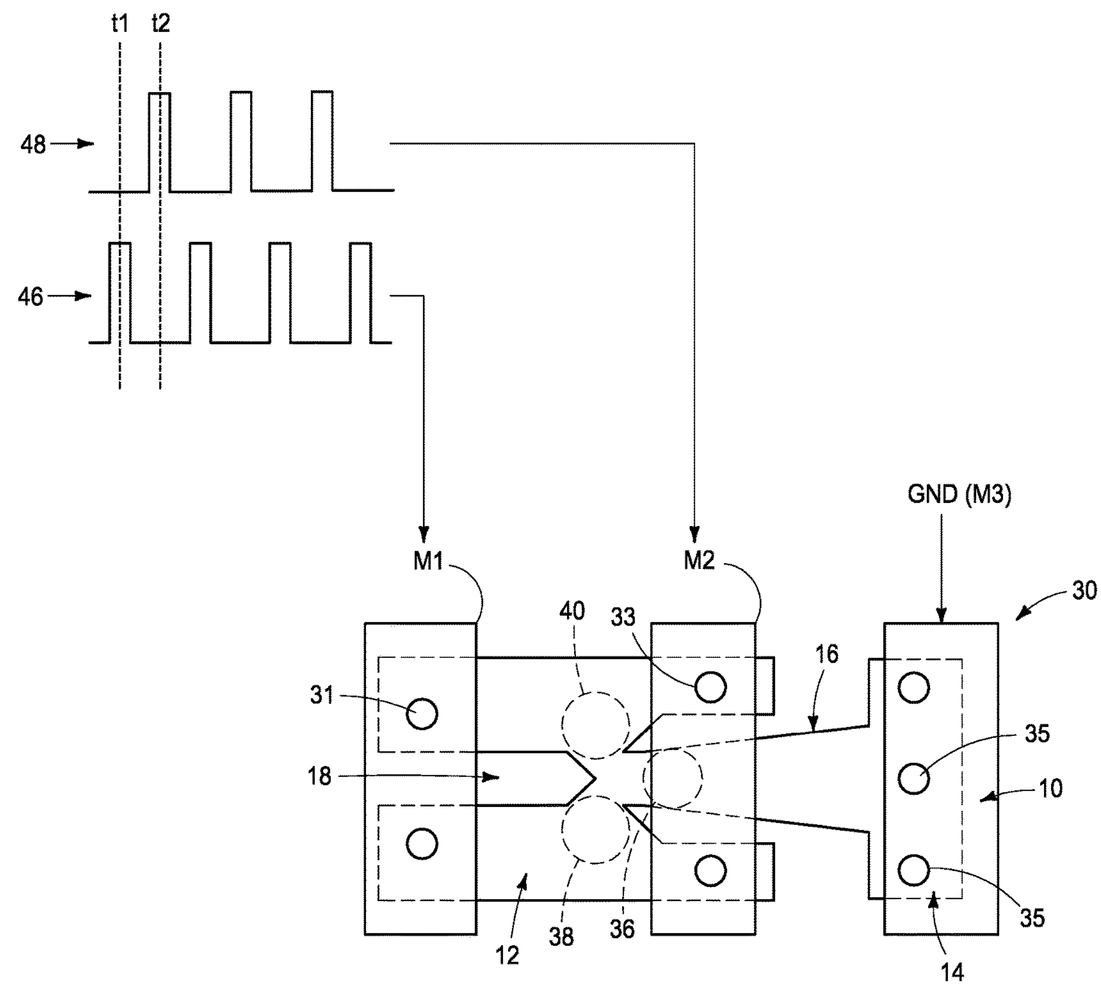

FIG. 4

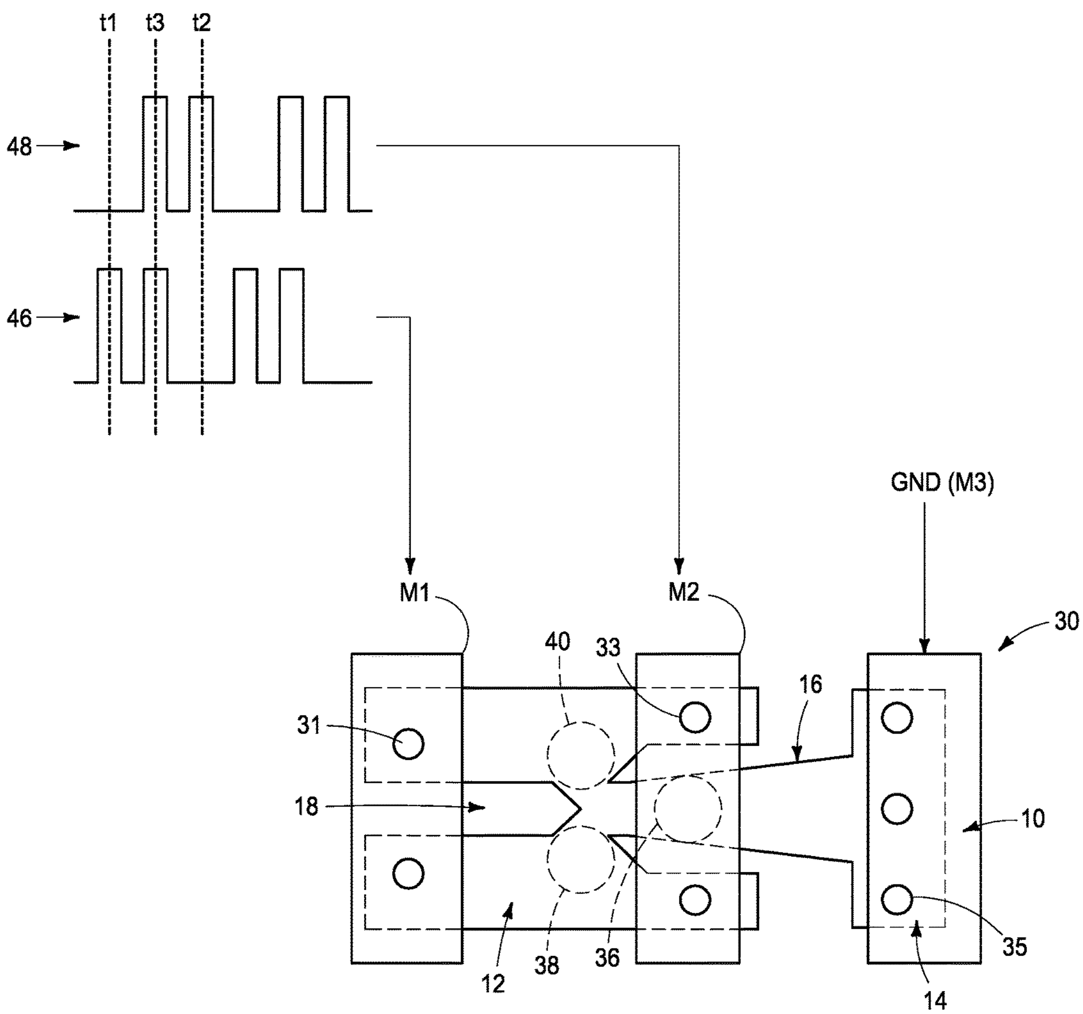

FIG. 5

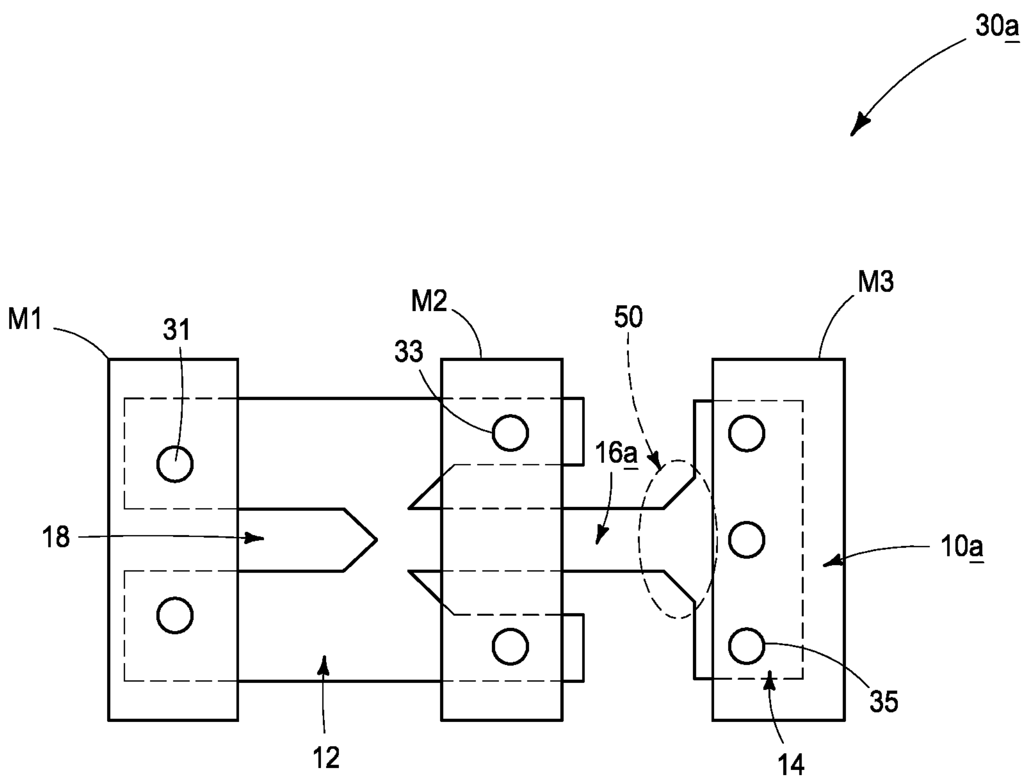

FIG. 6

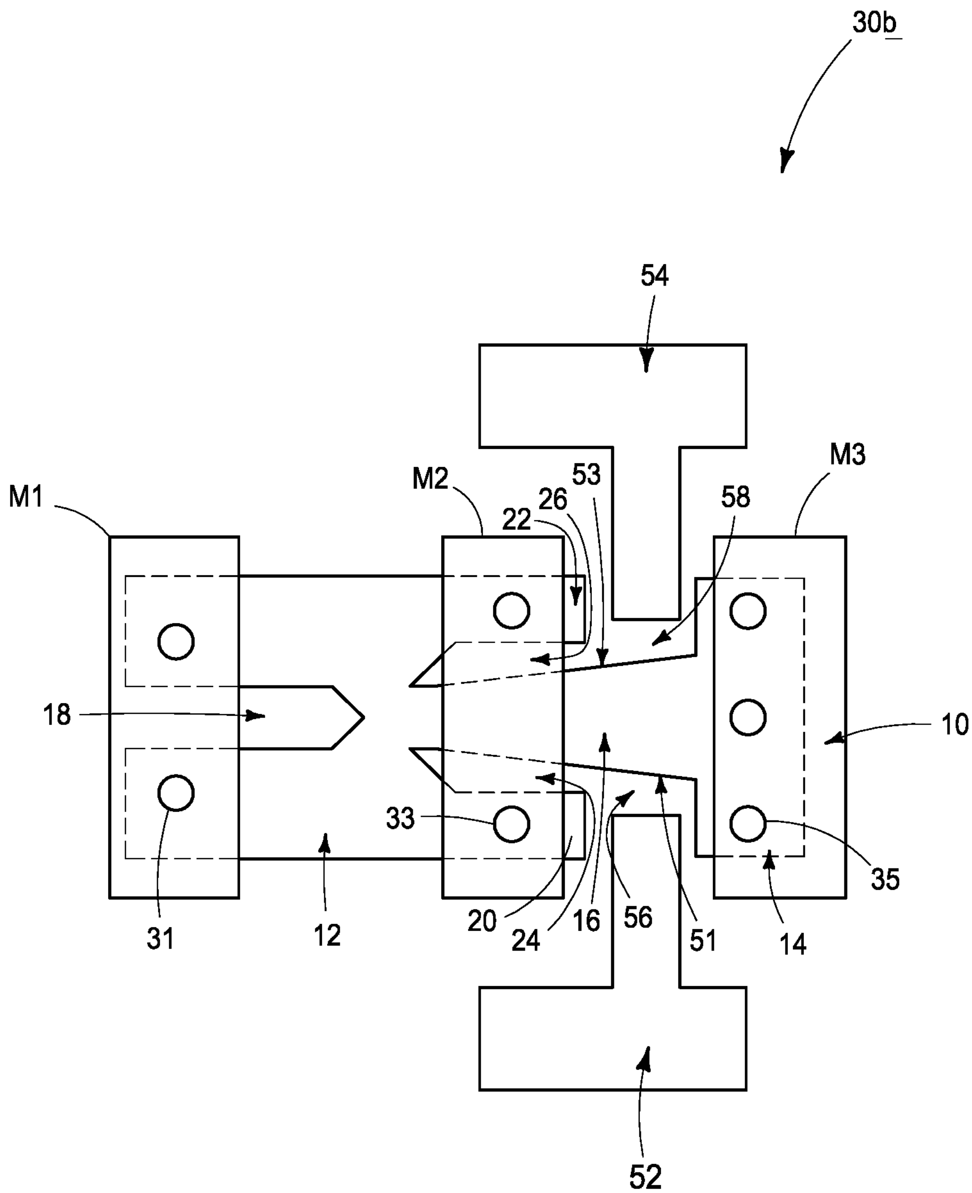

FIG. 7

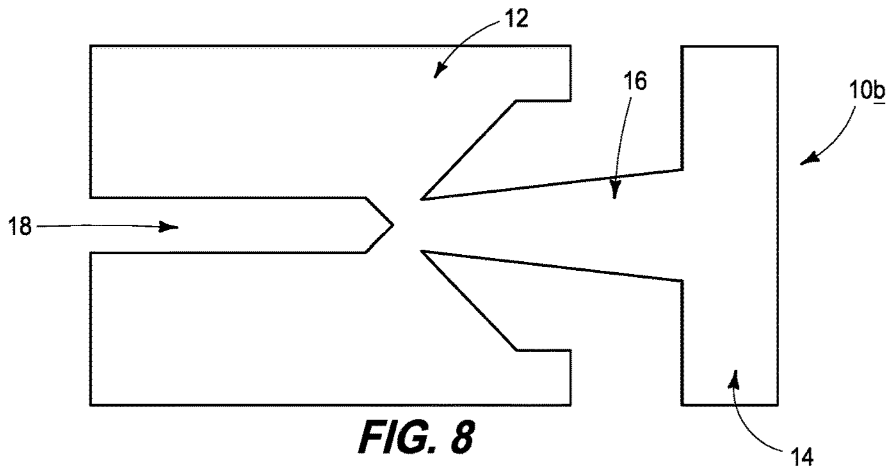

FIG. 8

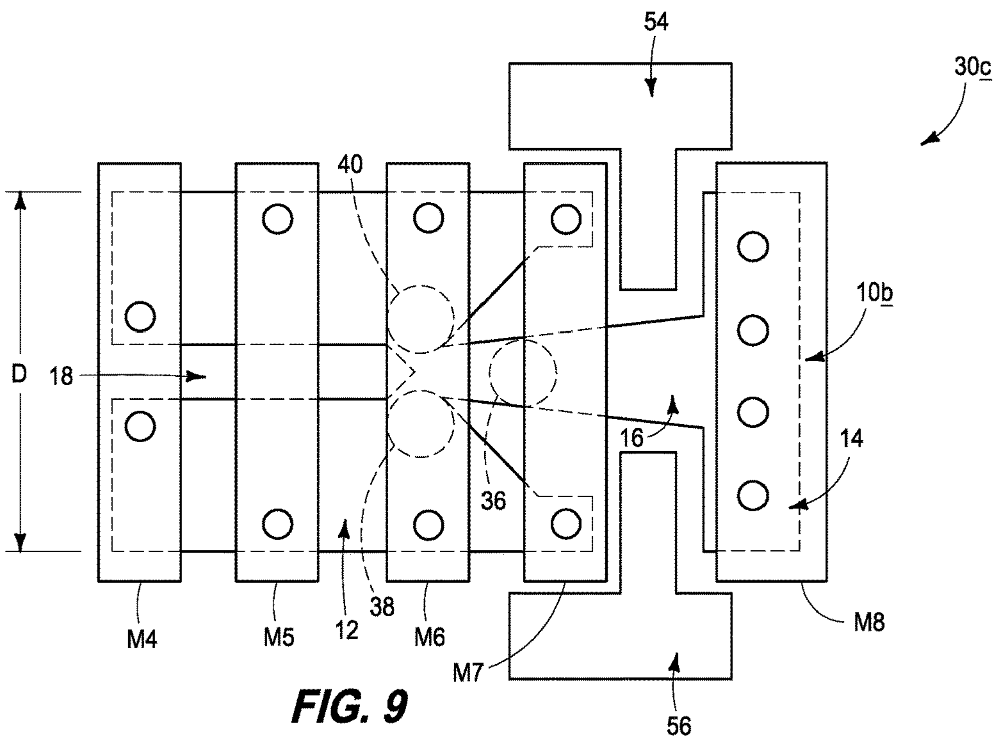

FIG. 9

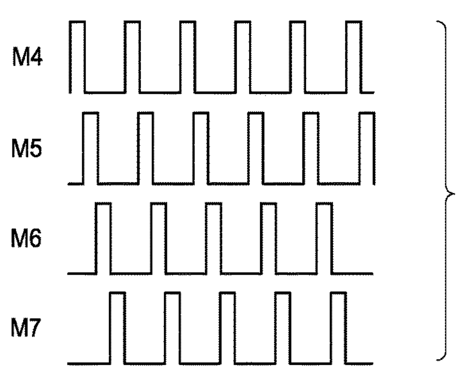

FIG. 10

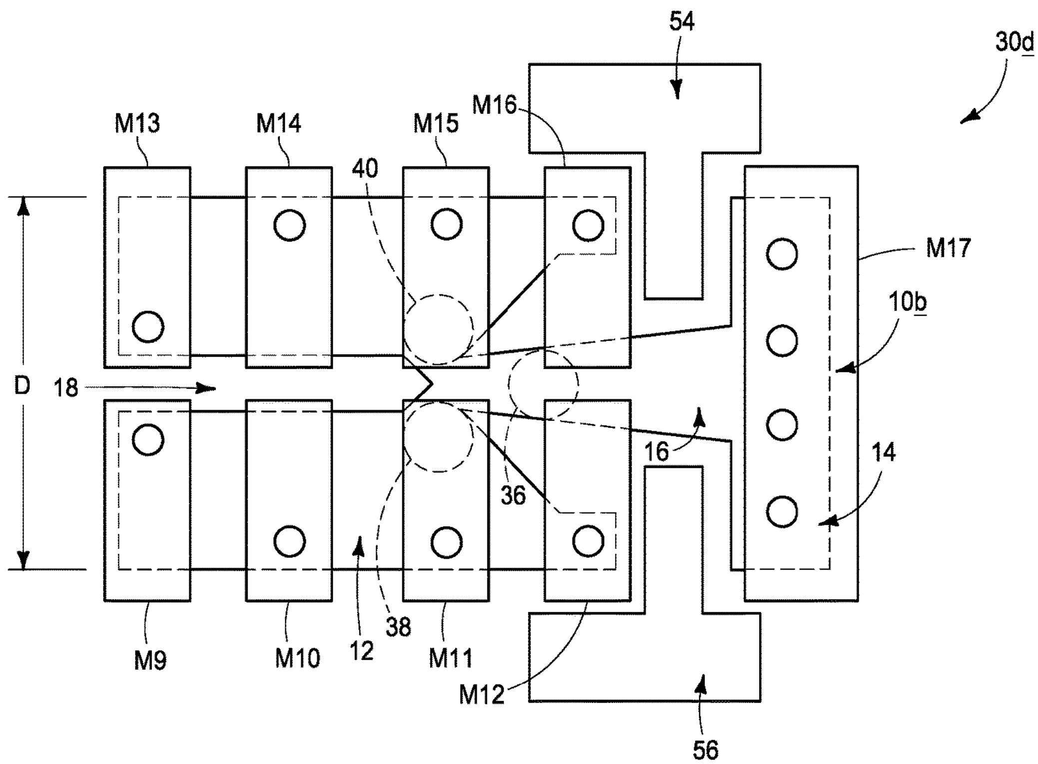
54
30d
M13
M14
M15
M16
40
M17
10b
D
18
16
14
36
38
M9
M10
12
M11
M12
56

FIG. 11

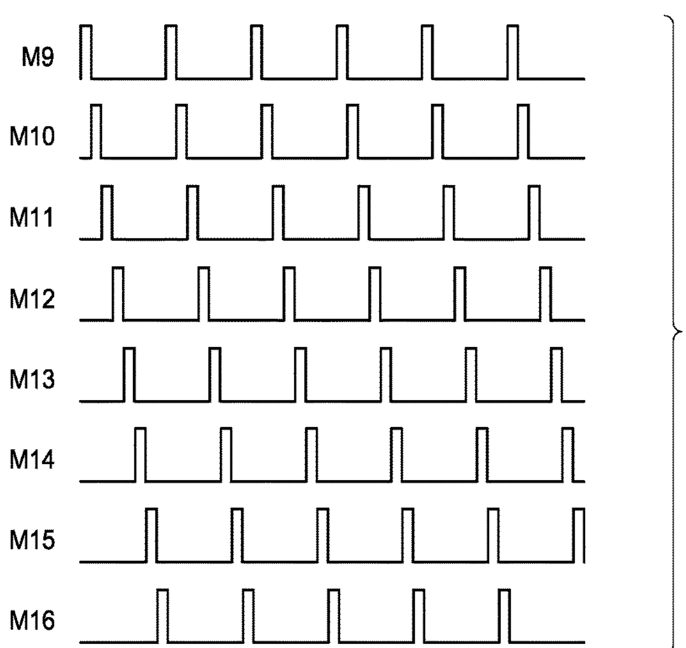
M9
M10
M11
M12
M13
M14
M15
M16

FIG. 12

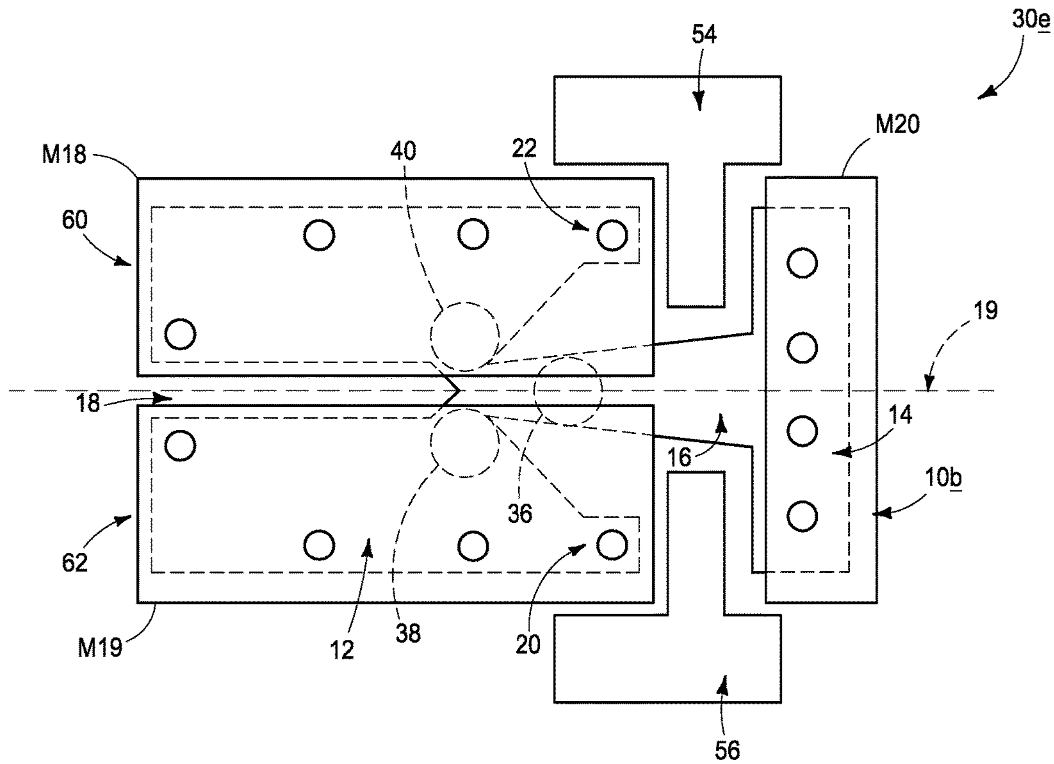

FIG. 13

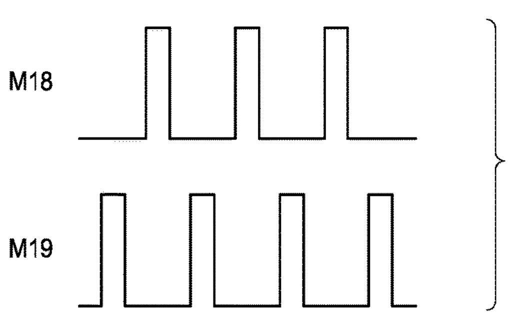

FIG. 14

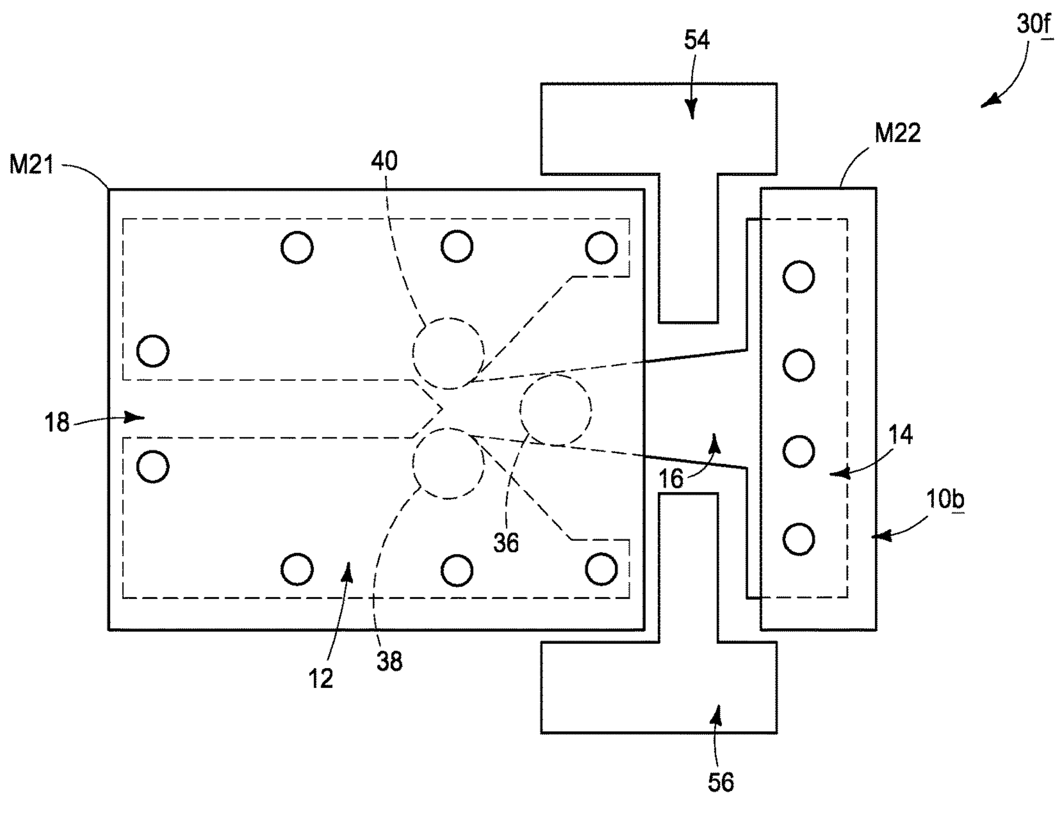

FIG. 15

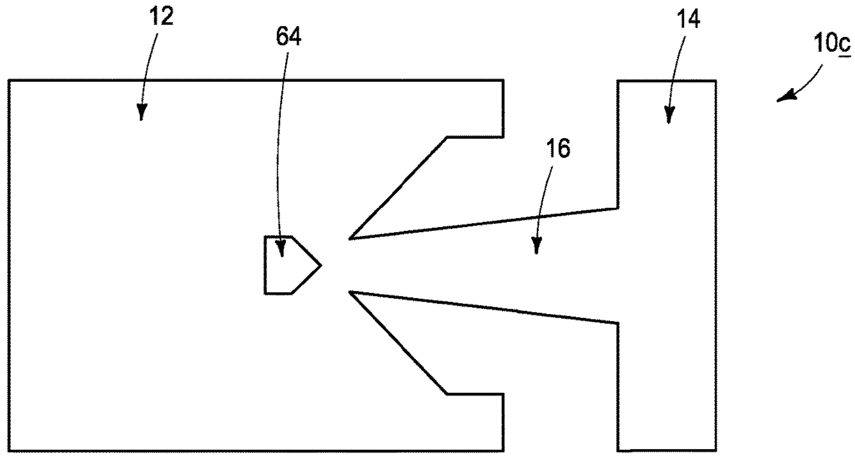

FIG. 16

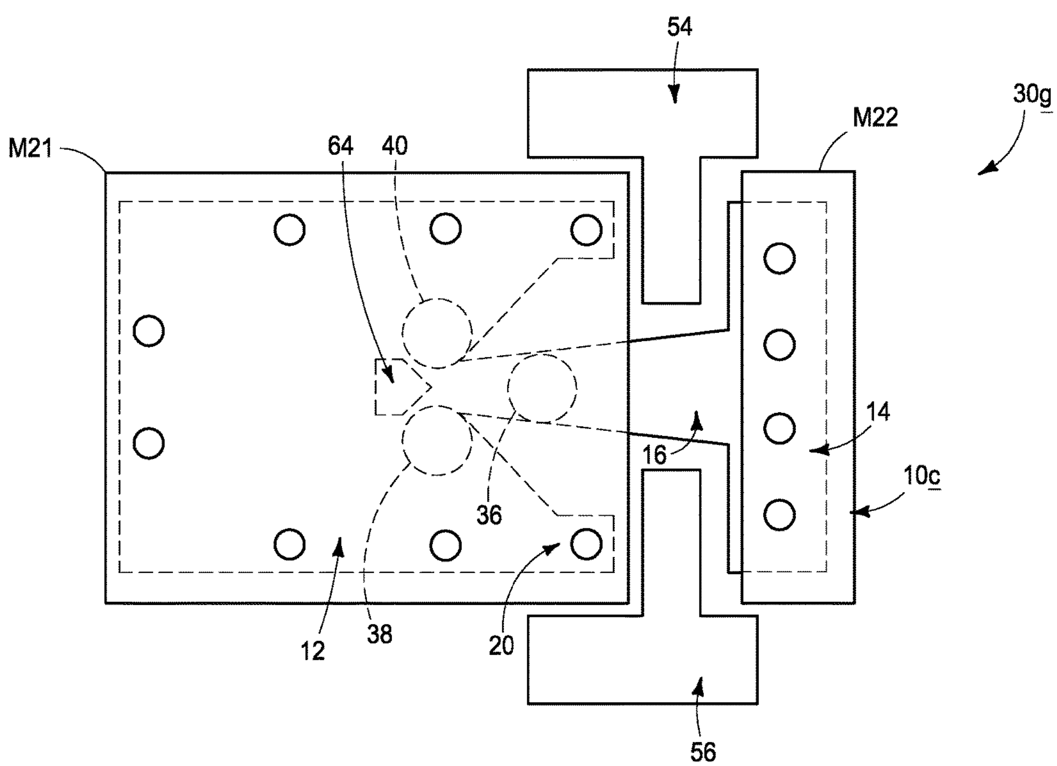

FIG. 17

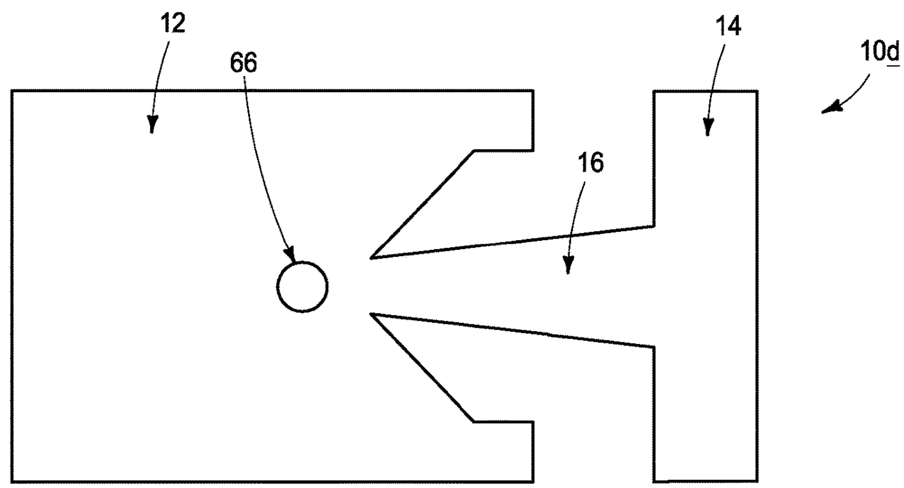

FIG. 18

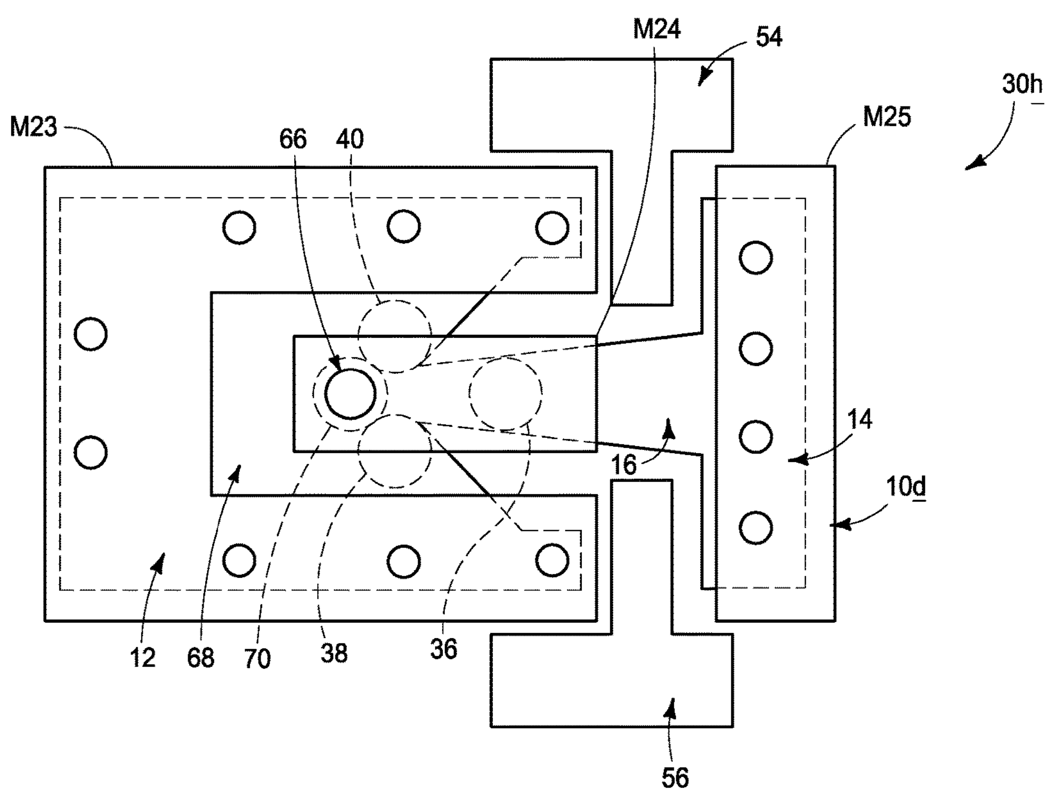

FIG. 19

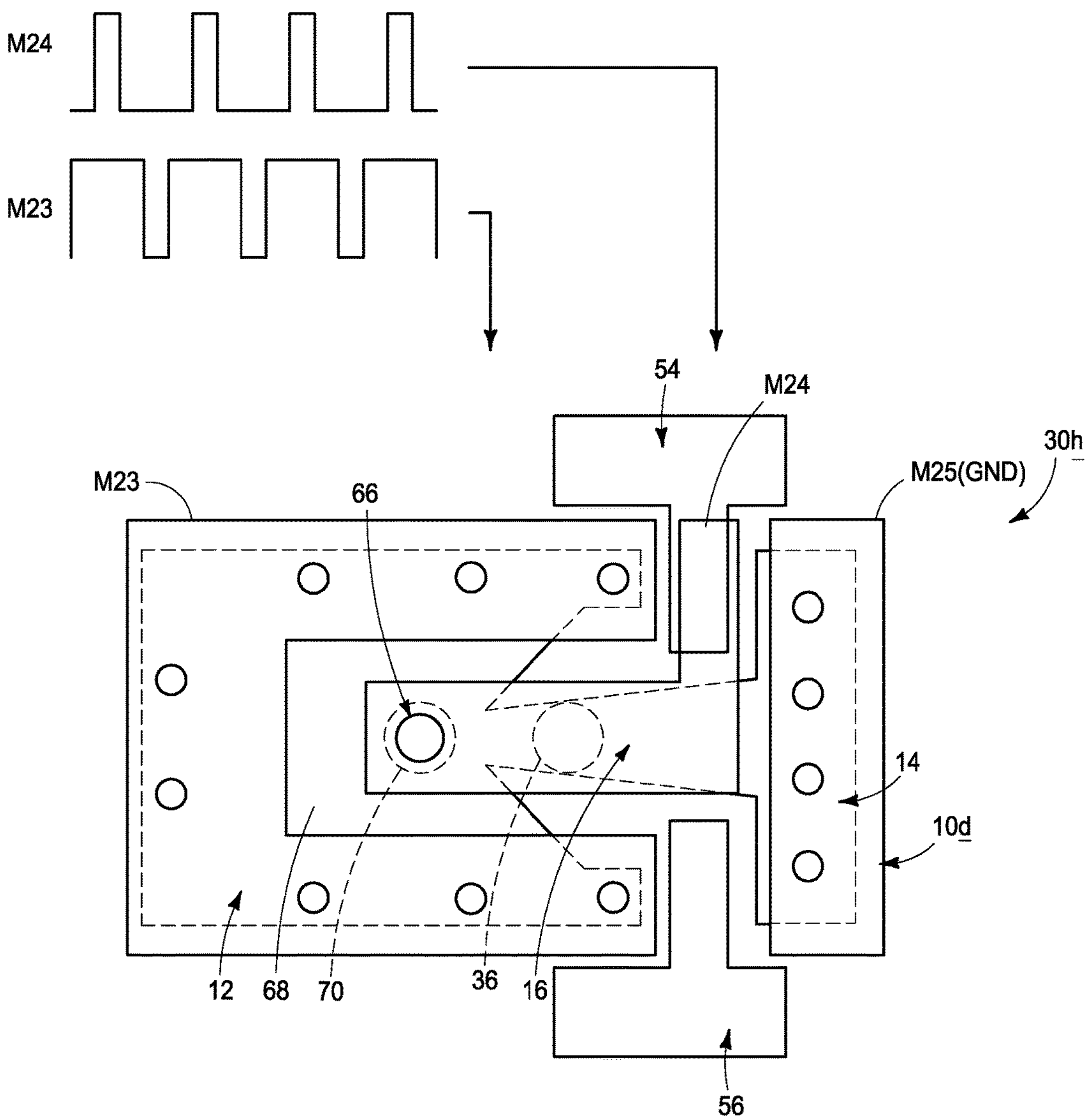

FIG. 20

FUSE ELEMENT ASSEMBLIES

RELATED PATENT DATA

This patent resulted from a continuation of U.S. patent application Ser. No. 14/847,235, which was filed Sep. 8, 2015, and which is hereby incorporated herein by reference.

TECHNICAL FIELD

Fuse element assemblies.

BACKGROUND

E-fuses may be incorporated into integrated circuitry, and may serve numerous functions. For example, E-fuses may provide overcurrent and/or overvoltage protection. As another example, E-fuses may be utilized in conjunction with redundant circuitry to reroute current flow onto a redundant path in the event that faulty circuitry is identified on a primary path subsequent to a manufacturing process.

E-fuses may comprise a fuse-link between an anode and a cathode. In operation, the fuse-link may be ruptured by electromigration of material from the fuse-link to the cathode when electrical characteristics (e.g., current flow, voltage differential, etc.) across the fuse-link exceed a predetermined threshold.

Problems may occur during operation of E-fuses in that material from the fuse-link accumulates at the cathode as the fuse-link is ruptured, and such accumulating material may cause cracks or other defects to develop in structures adjacent the cathode. It would be desirable to develop new E-fuse configurations which alleviate or prevent such problems.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a diagrammatic top view of an example embodiment fuse element assembly.

FIG. **2** is a diagrammatic top view of the example embodiment fuse element assembly of FIG. **1** incorporated into an example embodiment circuit assembly.

FIG. **3**A is a diagrammatic cross-sectional side view along the line **3**A-**3**A of FIG. **2**.

FIG. **3**B is a diagrammatic cross-sectional side view along the line **3**B-**3**B of FIG. **2**.

FIG. **4** diagrammatically illustrates an example pulse sequence that may be utilized relative to the circuit assembly of FIG. **2** to rupture a fuse-link of the fuse element assembly.

FIG. **5** diagrammatically illustrates another example pulse sequence that may be utilized relative to the circuit assembly of FIG. **2** to rupture a fuse-link of the fuse element assembly.

FIG. **6** is a diagrammatic top view of another example embodiment fuse element assembly incorporated into another example embodiment circuit assembly.

FIG. **7** is a diagrammatic top view of the example embodiment fuse element assembly of FIG. **1** incorporated into another example embodiment circuit assembly.

FIG. **8** is a diagrammatic top view of another example embodiment fuse element assembly.

FIG. **9** is a diagrammatic top view of the example embodiment fuse element assembly of FIG. **8** incorporated into an example embodiment circuit assembly.

FIG. **10** diagrammatically illustrates an example pulse sequence that may be utilized relative to the circuit assembly of FIG. **9** to rupture a fuse-link of the fuse element assembly.

FIG. **11** is a diagrammatic top view of the example embodiment fuse element assembly of FIG. **8** incorporated into another example embodiment circuit assembly.

FIG. **12** diagrammatically illustrates an example pulse sequence that may be utilized relative to the circuit assembly of FIG. **11** to rupture a fuse-link of the fuse element assembly.

FIG. **13** is a diagrammatic top view of the example embodiment fuse element assembly of FIG. **8** incorporated into another example embodiment circuit assembly.

FIG. **14** diagrammatically illustrates an example pulse sequence that may be utilized relative to the circuit assembly of FIG. **13** to rupture a fuse-link of the fuse element assembly.

FIG. **15** is a diagrammatic top view of the example embodiment fuse element assembly of FIG. **8** incorporated into another example embodiment circuit assembly.

FIG. **16** is a diagrammatic top view of another example embodiment fuse element assembly.

FIG. **17** is a diagrammatic top view of the example embodiment fuse element assembly of FIG. **16** incorporated into an example embodiment circuit assembly.

FIG. **18** is a diagrammatic top view of another example embodiment fuse element assembly.

FIG. **19** is a diagrammatic top view of the example embodiment fuse element assembly of FIG. **18** incorporated into an example embodiment circuit assembly.

FIG. **20** diagrammatically illustrates an example pulse sequence that may be utilized relative to the circuit assembly of FIG. **19** to rupture a fuse-link of the fuse element assembly.

DETAILED DESCRIPTION OF THE ILLUSTRATED EMBODIMENTS

In some embodiments, the invention includes new fuse element (e.g., E-fuse) configurations which are designed to more uniformly spread accumulating material across a cathode as compared to conventional fuse element configurations. The improved spreading of the accumulating material may reduce a thickness of the accumulating material as compared to conventional fuse element configurations. Such reduced thickness of the accumulating material may alleviate or prevent undesired effects of the accumulating material on structures adjacent the E-fuse as compared to conventional fuse element configurations. For instance, cracking and/or other defects may be alleviated or prevented. Example embodiments are described with reference to FIGS. **1-20**.

Referring to FIG. **1**, an example embodiment fuse element configuration **10** is shown to comprise a cathode **12**, an anode **14**, and a fuse-link **16** between the cathode and the anode. In some embodiments, the fuse-link may be considered an example of a first portion of the fuse element configuration **10**, the cathode may be considered an example of a second portion, and the anode may be considered an example of a third portion. Unlike a conventional fuse element configuration, the configuration **10** includes a slit **18** extending into the cathode **12**.

In the illustrated configuration, the cathode **12** comprises a first side **15** along the fuse-link **16**, and comprises a second side **17** in opposing relation to the first side. The slit **18** extends into the cathode **12** from the second side **17**.

In the shown embodiment, the fuse-link **16** tapers from the anode **14** to the cathode **12** so that the fuse-link couples to the cathode through a narrow neck region. During operation of the fuse element, current density in the narrow neck region of the fuse-link may be higher than in wider regions of the fuse-link more distal from the cathode. Such may advantageously cause rupture of a fuse-link formed in accordance with the illustrated embodiment to reproducibly occur in the region near the cathode rather than in regions more distal from the cathode, which may improve reliability and performance of the example embodiment fuse element as compared to conventional configurations. The current density across the narrow neck region of the fuse-link may be imparted by, for example, direct current (DC), pulse current, etc. It may be desired to have a smooth bend (or other transition) where the fuse-link joins the anode in order to achieve smooth electron flow, and to avoid undesired build-up of current concentration at the interface of the fuse-link and anode.

The illustrated fuse element configuration **10** has mirror symmetry along a plane **19** which bifurcates the fuse element into two halves.

The cathode **12** comprises a pair of projections **20** and **22** which extend along opposing sides of the fuse-link **16**. The projections **20** and **22** are spaced from the fuse-link by gaps **24** and **26**. In some embodiments, the illustrated fuse-link may be considered to have a relatively wide region adjacent anode **14**, and a relatively narrow region adjacent cathode **12**, and the illustrated projections **20** and **22** may be considered to extend along opposing sides of the relatively narrow region.

FIG. **2** shows the fuse element **10** incorporated into an assembly **30** (i.e., a fuse element assembly) comprising three different wirings M**1**, M**2** and M**3** (which may be considered to comprise three separate electrodes in some embodiments). The wirings M**1** and M**2** are coupled to the cathode **12** through contacts **31** and **33**, respectively; and the wiring M**3** is coupled to the anode through contacts **35**. The illustrated contacts are example configurations, and the total number of contacts, locations of the contacts, and sizes of contacts may vary in other embodiments. The wirings may comprise any suitable conductive material (for example, tungsten, etc.).

In the illustrated embodiment, the cathode **12** may be considered to comprise a first region **32** comprising projections **20** and **22**, and a second region **34** offset from the first region. The wiring M**2** may be considered to be first wiring connected to the first region **32** of the cathode, and the wiring M**1** may be considered to be second wiring connected to the second region **34** of the cathode. The first and second wirings may be configured to be operated independently of one another for providing a pulse train to impart rupture of the fuse-link **16**, as described in more detail below with reference to FIGS. **4** and **5**.

The slit **18** within the assembly **30** of FIG. **2** may be considered to be an example of a control element that modifies flow of transferred material during rupture of the fuse-link **16**, and which directs the transferred material along two or more paths across the cathode to reduce an overall height of the material accumulating on the cathode. For instance, during operation of assembly **30** the fuse-link **16** may be ruptured within an illustrated rupture-region **36** due to electromigration of material from such rupture-region to the cathode **12**. The slit **18** may disperse flow of the electromigrating material along two paths so that the material accumulates in two locations **38** and **40**. Conventional fuse element assemblies lack a control element to modify flow of transferred material along the cathode, and thus transferred material accumulates in a single location. A volume of material accumulating in a single location will form a higher mound as compared to a same volume accumulating in two or more locations. Accordingly, the illustrated embodiment of FIG. **2** may reduce an overall height of the accumulating material on cathode **12** during fuse-rupture as compared to conventional fuse element assemblies. Such reduced overall height may lead to reduced stresses on structures adjacent the fuse element assembly, which may alleviate or prevent cracking and/or other problems associated with the operation of conventional fuse element assemblies. In some embodiments, the right-most region of slit **18** may overlap a region where transferred material would accumulate in the absence of the slit so that the slit extends across an optimum location for redirecting the transferred material.

FIGS. **3**A and **3**B show cross-sections along the cathode **12** of fuse element assembly **30** in crossing directions, and show the accumulation regions **38** and **40** laterally spread apart from one another. The cross-sections of FIGS. **3**A and **3**B also show that the cathode **12** may be formed over an insulative material **42**, which in turn is formed over a semiconductor substrate **44**.

The insulative material **42** may comprise any suitable composition or combination of compositions, including, for example, one or more of silicon dioxide, silicon nitride, borophosphosilicate glass, fluorosilicate glass, etc.

The semiconductor substrate **44** may comprise any suitable semiconductor material; and may, for example, comprise, consist essentially of, or consist of monocrystalline silicon. The term "semiconductor substrate" means any construction comprising semiconductive material, including, but not limited to, bulk semiconductive materials such as a semiconductive wafer (either alone or in assemblies comprising other materials), and semiconductive material layers (either alone or in assemblies comprising other materials). The term "substrate" refers to any supporting structure, including, but not limited to, the semiconductor substrates described above.

The cathode **12** may comprise any suitable material, and some embodiments may comprise one or more of conductively-doped silicon, metal, etc. For instance, in some embodiments the cathode may comprise a layer of metal or metal-containing composition (for instance, metal silicide) over a layer of conductively-doped silicon; in some embodiments the cathode may comprise only metal or metal-containing material; etc. The anode **14** and fuse-link **16** (FIG. **2**) may comprise the same composition as the cathode **12** in some embodiments; and in other embodiments one or both of the anode and fuse-link may comprise a different composition than the cathode.

FIG. **4** shows an example pulse sequence that may be utilized for rupturing fuse-link **16** and causing electromigration of material from the rupture-region **36** of the fuse-link to the accumulation regions **38** and **40** of the cathode **12**. The pulse sequence includes a set of pulses **46** imparted to wiring M**1**, a set of pulses **48** imparted to wiring M**2**; and ground (GND), or other suitable static condition, at wiring M**3**. The pulses **46** and **48** establish a pulse train. When the voltage at wiring M**1** is at a high level at time t**1**, migration proceeds between the wiring M**1** and the fuse-link **16**; and when the wiring M**2** is at the high level at time t**2**, migration proceeds between the wiring M**2** and the fuse-link **16**. The train of pulses may be tailored to achieve desired properties (for instance, to achieve a short OFF period of current in the fuse-link). Utilization of two pulses may enable the cathode **12** to cool between pulses, while keeping the fuse-link hot. Such may enable rupture to be induced within the fuse-link without overheating the cathode.

The pulse sequence of FIG. **4** is an example sequence, and numerous other sequences may be utilized in other embodiments. For instance, FIG. **5** shows another example pulse sequence. The sequence of FIG. **5** includes high-level pulses on both of wirings M**1** and M**2** at time t**3** which may induce electromigration of material across an entirety of cathode **12**. Some example operating conditions may include:

M**1**:3V, M**2**:0V—migration direction: M**1**

M**1**:0V, M**2**:3V—migration direction: M**2**

M**1**:3V, M**2**:3V—migration direction: intermediate between M**1** and M**2**

In some embodiments, a degree of overlap voltages between wirings M**1** and M**2** may be designed as an analog triangular waveform rather than as a digital rectangular waveform. Some example operating conditions may include:

M**1**:3V, M**2**:1V—migration direction: between M**1** and M**2**, closer to M**1**

M**1**:1V, M**2**:3V—migration direction: between M**1** and M**2**, closer to M**2**

The fuse element **10** of FIGS. **1-5** includes a fuse-link **16** having a uniform taper from anode **14** to cathode **12**. In other embodiments, the fuse-link may have other configurations in order to achieve the desired relatively narrow region adjacent cathode **12** and relatively wide region adjacent anode **14**. For instance, FIG. **6** shows an assembly **30***a* having a fuse element **10***a* in which the fuse-link **16***a* is triangle-shaped in a region **50** adjacent the anode **14**.

In some embodiments it is recognized that it may be difficult to fabricate a fuse-link having a desired shape due to light-interference and/or other problems that may manifest during the patterning of such desired shape. FIG. **7** illustrates a potential solution to such fabrication difficulties. Specifically, FIG. **7** shows an assembly **30***b* having dummy elements **52** and **54** provided adjacent the fuse-link **16** to assist during fabrication of such fuse-link. The elements are referred to as “dummy” elements to indicate that they have no function in the integrated circuit, but rather are provided solely to assist during the patterning of fuse element **10**. The dummy elements may comprise any suitable composition or combination of compositions, including, for example silicon dioxide, silicon nitride, silicon, metal, etc. Although the illustrated elements **52** and **54** are described as dummy elements; in other embodiments one or both of the elements **52** and **54** may be a circuit element rather than a dummy element.

In the shown embodiment of FIG. **7**, the fuse-link **16** comprises a pair of opposing sidewalls **51** and **53** that extend from anode **14** to cathode **12**. Such sidewalls may be referred to as a first sidewall and a second sidewall, respectively. The dummy features **52** and **54** may be referred to as first and second dummy features that are along the first and second sidewalls, respectively. The first dummy feature **52** is spaced from the first sidewall **51** by a first gap **56**, and the second dummy feature **54** is spaced from the second sidewall **53** by a second gap **58**. The embodiment of FIG. **7** has the gap **24** between projection **20** and fuse-link **16**, and has the gap **26** between projection **22** and the fuse-link **16**. The gaps **24** and **26** may be referred to as third and fourth gaps.

The fuse element **10** of FIG. **1** is an example configuration, and other configurations may be utilized in other embodiments. For instance, FIG. **8** shows a fuse element **10***b* having a slightly different configuration than the fuse element **10** of FIG. **1**. The fuse element **10***b* is used in describing example embodiments shown in FIGS. **9**, **11**, **13** and **15**.

Referring to FIG. **9**, an assembly **30***c* is shown to comprise multiple wirings (or electrodes) M**4**, M**5**, M**6** and M**7** in contact with cathode **12**, and to comprise wiring M**8** in contact with anode **14**. The wiring M**8** may be analogous to the wiring M**3** described above with reference to FIG. **2**. The wirings M**4**, M**5**, M**6** and M**7** may be considered to comprise first and second wirings (for instance M**4** and M**7**) analogous to the wirings M**1** and M**2** of FIG. **2**, and to further comprise additional wirings (for instance, M**5** and M**6**). Utilization of multiple wirings coupled with the cathode may enable the pulse train utilized for rupturing the fuse-link to be tailored for particular applications. An advantage of utilizing a larger number of wirings in contact with the cathode is that the pulse train may be more finely tailored, but a disadvantage is that the fabrication becomes increasingly complicated with the larger number of wirings. Another advantage is that cooling of cathode **12** through thermal conduction into adjacent wirings may be enhanced by providing a larger number of adjacent wirings.

In the illustrated embodiment of FIG. **9**, four wirings (M**4**, M**5**, M**6** and M**7**) associated with the cathode may enable concentration points of current density to be dispersed amongst four different times and places. FIG. **10** illustrates an example pulse sequence that may be utilized with the embodiment of FIG. **9** (the wiring M**8** is not shown in FIG. **10**, and may be maintained at an electrical ground or other suitable static condition). The additional wirings of FIG. **9** relative to those of FIG. **2**, and the associated additional pulses that may be interspersed utilizing such additional wirings, may enable better control of assembly **30***c* of FIG. **9** relative to the assembly **30** of FIG. **2** during rupture of the fuse-link; and specifically may enable such rupture to be achieved with better cooling of the cathode and an accelerated rate of rupture.

The wirings associated with cathode **12** of FIGS. **2** and **9** span continuously across an entire width dimension of the cathode. For instance, FIG. **9** shows the cathode having a width dimension D, and shows the wirings M**4**, M**5**, M**6** and M**7** all spanning continuously across the entirety of such width dimension. In other embodiments, wirings are provided in segments which span only a portion of the width dimension of the cathode. For instance, FIG. **11** shows an assembly **30***d* comprising wirings M**9**, M**10**, M**11**, M**12**, M**13**, M**14**, M**15** and M**16** coupled with the cathode **12**, with each of such wirings being a segment which spans only a portion of the width dimension D of the cathode. The assembly **30***d* further includes wiring M**17** coupled with the anode **14**. The wiring M**17** may be analogous to the wiring M**3** described above with reference to FIG. **2**. The wirings M**9**, M**10**, M**11**, M**12**, M**13**, M**14**, M**15** and M**16** may be considered to comprise first, second, third, fourth, etc. wirings. Utilization of multiple wirings coupled with the cathode may enable the pulse train utilized for rupturing the fuse-link to be tailored for particular applications, analogously to advantages discussed above with reference to FIG. **9**.

FIG. **12** illustrates an example pulse sequence that may be utilized with the embodiment of FIG. **11**. The eight wirings (M**9**-M**16**) associated with the cathode may enable concentration points of current density to be dispersed amongst eight different times and places (eight dispersions). The wiring M**17** may be maintained at electrical ground, or other suitable static condition, during the fuse-rupture.

The embodiments of FIGS. **2**, **4**, **5**, **6**, **7**, **9** and **11** utilize wirings which divide electron current/migration laterally in view of a time-divided manner initiated by a pulse train. FIG. **13** illustrates an alternative fuse element assembly wherein wiring is configured to divide electron current/migration longitudinally in the view of a time-divided manner initiated by a pulse train. Specifically, FIG. **13** shows a fuse element assembly **30***e* having wirings M**18** and M**19** extending longitudinally along cathode **12**. Alternatively considered, the cathode **12** may be considered to comprise mirror symmetry along the plane **19**. The plane **19** bifurcates the cathode into a first half **60** comprising projection **22**, and a second half **62** comprising projection **20**. The first wiring M**18** is electrically connected to the first half **60**, and the second wiring M**19** is electrically connected to the second half **62**. The first and second wirings may be configured to be operated independently one another for providing a pulse train to impart rupture of fuse-link **16** within the rupture-region **36**. Since four contacts are located between each of the wirings M**18** and M**19** and the cathode, the electron current/migration under each of the wirings may expand into a fan-shape during rupture of the fuse-link. The assembly **30***e* also comprises a third wiring M**20** coupled with the anode **14**. Such third wiring may be maintained at ground, or other suitable static condition, during rupture of the fuse-link.

FIG. **14** illustrates an example pulse sequence that may be utilized with the embodiment of FIG. **13**. A high-level voltage may be alternately applied to each of the wirings M**18** an M**19** to allow electron current to flow therethrough. The utilization of the illustrated wiring configuration may enable the cathode to remain cool during rupture of a fuse-link even though the electron current may flow through the fuse-link for substantial duration so that the fuse-link may stay hot. Specifically, current is pulsed alternately on opposing halves of the cathode to enable each half to alternately heat and cool, and yet the current remains relatively steady on the fuse-link to keep the fuse-link hot.

FIG. **15** illustrates a fuse element assembly **30***f* illustrating another example embodiment. Specifically, a single wiring M**21** extends across the entirety of cathode **12**, and another wiring M**22** extends across anode **14**. It may be simpler to fabricate the embodiment of FIG. **15** having only two wirings, as compared to some of the other embodiments described herein which comprise multiple wirings. The embodiment of FIG. **15** may be useful in applications in which a relatively simple pulse train may be utilized to rupture fuse-link **16** while maintaining desired performance characteristics.

The slit **18** of the fuse element **10** of FIG. **1** and the fuse element **10***b* of FIG. **8** is an example control element which may be utilized to modify flow of transferred material along a cathode during fuse rupture. FIG. **16** shows a fuse element **10***c* having a different configuration; and specifically shows a control element corresponding to a hole **64** extending through the cathode **12**. The hole may have any suitable shape; and may, for example, be elliptical, circular, home-based-shaped, rectangular, polygonal, square, etc. The hole is entirely laterally surrounded by conductive material of the cathode **12**. The hole may be filled with solid or semisolid insulative material (e.g., silicon dioxide, silicon nitride, etc.).

FIG. **17** shows the fuse element **10***c* incorporated into a fuse element assembly **30***g* comprising wirings M**21** and M**22** of the type described above with reference to FIG. **15**. In other embodiments, other wiring configurations may be utilized, including, for example, any of the other wiring configurations described above with reference to FIGS. **2** and **4-14**. The hole **64** may be placed in a location where transferred material from fuse-link **16** would accumulate in the absence of such hole. In the illustrated embodiment, the hole **64** redirects accumulating material into locations **38** and **40** (i.e., directs the accumulating material into two paths, one of which leads to location **38** and the other of which leads to location **40**).

The hole **64** of FIG. **17**, and slits **18** of FIGS. **1** and **8**, are examples of static control elements (i.e., control elements which remain the same in all operational phases of the fuse elements). Another type of control element which may be utilized in some embodiments is a non-static control element, such as, for example, a control element which is charged in some operational states of the fuse element. FIG. **18** shows a fuse element **10***d* comprising an electrically conductive contact **66** incorporated into a control element. In some embodiments, electrical pulses are provided to the contact during operation of the fuse element.

FIG. **19** shows the fuse element **10***d* incorporated into a fuse element assembly **30***h* comprising wirings M**23**, M**24** and M**25**. The wiring M**23** is coupled with cathode **12** and the wiring M**25** is coupled with anode **14**. The wiring M**24** is coupled with the electrically conductive contact **66**, and may be utilized to impart electrical current and/or potential across an interface between the contact **66** and the cathode **12**. In the illustrated embodiment, the wiring M**24** is electrically isolated from the wiring M**23** by an insulative region **68**. Such insulative region may comprise any suitable composition or combination of compositions; and may, for example, comprise one or both of silicon nitride and silicon dioxide.

In operation, an electrically-altered region **70** may be formed around contact **66** utilizing electrical potential and/or current flow generated with wiring M**24**. In some embodiments, the contact **66** (specifically, the electrically-altered region **70**) may redirect accumulating material into locations **38** and **40** (i.e., directs the accumulating material into two paths, one of which leads to location **38** and the other of which leads to location **40**). In some embodiments, the contact **66** may be electrically floating. In some embodiments, the contact **66** may have a voltage of opposite polarity (i.e., reverse relation) to that utilized to induce rupture of fuse-link **16**, and such opposite polarity may redirect accumulating material along two or more paths to reduce a height of the accumulating material (i.e., to flatten the accumulating material). FIG. **20** illustrates a pulse sequence which may be utilized relative to wirings M**23** and M**24** to induce a reverse flow of electrons within the region **70** (i.e., a region proximate the contact **66**) as compared to the general flow of the electrons utilized to rupture the fuse-link **16**. The overall influence of electrical flow along contact **66** on the migration of accumulating material may be tailored by modifying the amplitude, duration and/or overall shape of pulses provided at the contact **66** through wiring M**24**.

Although the embodiments described herein specifically show accumulating material on cathode **12** divided amongst two paths (a path leading to region **38**, and another path leading to region **40**) utilizing the illustrated control elements, in other embodiments control elements may be configured to direct accumulating material along more than two paths.

The fuse elements and fuse element assemblies discussed above may be utilized in electronic systems. Such electronic systems may be used in, for example, memory modules, device drivers, power modules, communication modems, processor modules, and application-specific modules, and may include multilayer, multichip modules. The electronic systems may be any of a broad range of systems, such as, for example, cameras, wireless devices, displays, chip sets, set top boxes, games, lighting, vehicles, clocks, televisions, cell phones, personal computers, automobiles, industrial control systems, aircraft, etc.

The particular orientation of the various embodiments in the drawings is for illustrative purposes only, and the embodiments may be rotated relative to the shown orientations in some applications. The description provided herein, and the claims that follow, pertain to any structures that have the described relationships between various features, regardless of whether the structures are in the particular orientation of the drawings, or are rotated relative to such orientation.

The cross-sectional views of the accompanying illustrations only show features within the planes of the cross-sections, and do not show materials behind the planes of the cross-sections in order to simplify the drawings.

Some embodiments include a fuse element assembly (e.g., **30**, **30***a-h*) comprising a first portion (e.g., **16**, **16***a*) configured to be ruptured as materials of the first portion flow to a second portion (e.g., **12**) through electromigration. The second portion is configured to accumulate the materials that have flowed from the first portion. The assembly includes a control element (e.g., slit **18**, hole **64**, contact **66**) configured to divide the flow of materials into at least two paths along the second portion.

Some embodiments include a fuse element assembly (e.g., **30**, **30***a-h*) comprising an anode (e.g., **14**), a cathode (e.g., **12**), a fuse-link (e.g., **16**, **16***a*) between the anode and the cathode and configured to rupture during transfer of material from the fuse-link into the cathode, and a control element (e.g., slit **18**, hole **64**, contact **66**) modifying flow of the transferred material along the cathode.

Some embodiments include a fuse element assembly (e.g., **30**, **30***a-h*) comprising an anode (e.g., **14**), a cathode (e.g., **12**), and a fuse-link (e.g., **16**, **16***a*) between the anode and the cathode. The fuse-link is configured to rupture during transfer of material from the fuse-link into the cathode. The fuse-link has a relatively narrow region adjacent the cathode and a relatively wide region adjacent the anode. The cathode has a pair of projections (e.g., **20**, **22**) that extend along opposing sides of the relatively narrow region and that are spaced from the relatively narrow region by gaps (e.g., **24**, **26**). The assembly includes a control element (e.g., slit **18**, hole **64**, contact **66**) which modifies flow of the transferred material along the cathode and which disperses said flow along at least two paths.

In compliance with the statute, the subject matter disclosed herein has been described in language more or less specific as to structural and methodical features. It is to be understood, however, that the claims are not limited to the specific features shown and described, since the means herein disclosed comprise example embodiments. The claims are thus to be afforded full scope as literally worded, and to be appropriately interpreted in accordance with the doctrine of equivalents.

I claim:

1. A fuse element assembly comprising:
- a cathode having a first end and an opposing second end; the cathode having a slit into the first end that spaces a first projecting portion from a second projecting portion, the first and second projecting portions being substantially parallel to each other and merging at a merge region; and
- a fuse link extending from the merge region and beyond the second end of the cathode; and further comprising
- a third projecting portion of the cathode and a fourth projecting portion of the cathode, the third and fourth projecting portions extending from the merge region toward the second end of the cathode on opposing sides of the fuse link.

2. The fuse element assembly of claim **1**, wherein the first portion of the cathode, and the third projecting portion of the cathode are different in width from each other, and the second projecting portion of the cathode and the fourth projecting portion of the cathode are different in width from each other.

3. The fuse element assembly of claim **2**, wherein the first projecting portion of the cathode is wider than the third projecting portion of the cathode, and the second projecting portion of the cathode is wider than the fourth projecting portion of the cathode.

4. The fuse element assembly of claim **2**, wherein the first projecting portion of the cathode and the second projecting portion of the cathode are equal in width to each other, and the third projecting portion of the cathode and the fourth projecting portion of the cathode are equal in width to each other.

5. The fuse element assembly of claim **1**, wherein the fuse link has a relatively narrow portion adjacent the merge region and a relatively wide portion further away from the merge region.

6. A fuse element assembly comprising:
- a first cathode projection extending in a first direction;
- a second cathode projection branching from the first cathode projection, at least a portion of the second cathode projection extending in the first direction; the first cathode projection and the at least a portion of the second cathode projection having a first offset therebetween in a second direction perpendicular to the first direction; and
- a third cathode projection branching from the first cathode projection, at least a portion of the third cathode projection extending in a direction opposite to the first cathode projection;
- a fourth cathode projection branching from the second cathode projection and extending in a direction opposite to the second cathode projection, the third and fourth cathode projections having a second offset therebetween in the second direction.

7. The fuse element assembly of claim **6**, wherein the first offset is less than to the second offset.

8. An apparatus comprising:
- a first electrode configured to be supplied with a first voltage;
- a second electrode;
- a third electrode; and
- a fuse element assembly including a first region coupled to the first electrode, a second region coupled to the second electrode and a third region coupled to the third electrode, the fuse element assembly having a cathode that has a first end comprising the first region, the first end being divided into two projections with each projection being independently connected to the first electrode; the cathode further having a second end having two projections that independently connect to the second electrode; the fuse element assembly further comprising an anode comprising the third region and connected to the third electrode and a fuse fink extending between, the second region and the third region.

9. The apparatus of claim **8**, wherein the first and second electrodes are configured to be operated independently relative to one another.

10. The apparatus of claim **9**, further comprising first, second and third contacts provided on the first, second and third electrodes, respectively.

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