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NASA CASE NO. LAR 15172-1

PRINT FIG. 2

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(NASA. Langley Research Center)
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NASA Case No. LAR 15172-1-CU

CIRCULAR ELECTRODE GEOMETRY METAL-SEMICONDUCTOR-METAL PHOTODETECTORS

AWARDS ABSTRACT

High speed, metal-semiconductor-metal (MSM) photodetectors operating at speeds of 1 GHz and above have a wide range of uses in optoelectronic integrated circuits (OEICs). Of particular relevance is the application to optically based telecommunications systems. Current technology employs electrodes which are rectangular, interdigitated arrays.

Improved performance of these electrodes can be obtained with circular electrode geometries, rather than the traditional rectangular arrays. A high speed, metal-semiconductor-metal photodetector is formed which comprises a pair of generally circular, electrically conductive electrodes formed on an optically active semiconductor layer. Various embodiments of the invention include a spiral, intercoiled electrode geometry and an electrode geometry comprised of substantially circular, concentric electrodes which are interposed.

The novel aspect of the present invention is the generally circular geometry of the interdigitated electrode array. These electrode geometries result in photodetectors with lower capacitances, dark currents and lower inductance which reduces the ringing seen in the optical pulse response.

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CIRCULAR ELECTRODE GEOMETRY METAL-SEMICONDUCTOR-METAL PHOTODETECTORS

Origin of the Invention

The invention described herein was jointly made by an employee of the United States Government, an employee of the College of William and Mary, an employee of the University of Virginia, and during the performance of work by an employee working under NASA Grant No. NAG-1-1434. In accordance with 35 U.S.C. 202, the contractor elected not to retain title.

Background of the Invention

1. Field of the Invention

The present invention relates generally to photodetectors and more particularly to high speed metal-semiconductor-metal photodetectors with increased signal-to-noise ratios and data transmission rates for use in optoelectronic integrated circuits.

2. Description of the Related Art

High speed, metal-semiconductor-metal (MSM) photodetectors operating at speeds of 1 GHz and above have a wide range of uses in optoelectronic integrated circuits (OEICs). Of particular relevance is the application to optically based telecommunications systems. An

compared to the rectangular electrode array, as a result of the opposing direction of current flow through the two arms of the spiral. This lowered inductance results in a reduction of ringing seen in the optical pulse response. The spiral geometry also results in lower capacitance and dark current.

In an alternate embodiment illustrated in FIG. 3, lower capacitances have been obtained when compared to conventional, rectangular electrode arrays. In this embodiment, each electrode has a number of substantially circular, concentric branches and the branches of each electrode are interposed without contacting each other. The circular electrodes are not fully closed, forming a split-ring structure, in order to accommodate the interconnect structure for each electrode needed to provide the proper bias potential and carry the signal current to an external circuit.

Located within the concentric rings of the circular electrode structure is a central disk. If this disk were absent, carriers generated in the central region would encounter very low electric fields and be very slowly transported to the innermost electrode. The result would be a significant degradation of the response time. The split-ring type structure for the electrodes is easiest to fabricate, however, other embodiments, such as closed rings with a multilayer dielectric isolation containing via holes for the interconnect structure, as illustrated in FIG. 4, are possible.

Although MSM photodetectors are typically fabricated using materials such as GaAs or InGaAs as the optically active semiconductor material, any other material can be used on which can be formed patterned electrodes that exhibit rectifying behavior (i.e., Schottky contacts) or non-rectifying behavior (i.e., ohmic contacts) and which absorb light in a desired wavelength. Such materials may include Si, SiC, AlGaAs, AlN, GaN, AlGaN, BN, ZnSe and HgCdTe. In like manner, any electrically conductive material that is capable of forming Schottky contacts or ohmic contacts with the semiconductor layer may be used for the electrodes. Some typical metalization schemes which are commonly used include Ti/Au, Ti/Pt/Au, Al, Cr/Au, Ni/Au, Pt/Au, W/Au and Ag.

Brief Description of the Drawings

FIG. 1 is a plan view of a conventional, rectangular array of interdigitated electrodes;

FIG. 2 is a plan view of a photodetector according to one embodiment of the present invention;

FIG. 3 is a plan view of a second embodiment of the present invention;

FIG. 4(a) is a plan view of a third embodiment of the present invention;

FIG. 4(b) is a cross-sectional view of the embodiment shown in FIG. 4(a), taken along the line a-a'.

Description of the Preferred Embodiments

Referring now to FIG. 2, the preferred embodiment of a photodetector **30** according to the present invention is shown. This device consists two spiral electrodes **40** and **42** disposed on the surface of a layer of optically active semiconductor material **50**. Any material can be used for the semiconductor on which can be formed patterned electrodes that exhibit rectifying behavior (i.e., Schottky contacts) or non-rectifying behavior (i.e., ohmic contacts) and which absorb light in a desired wavelength. Such materials may include GaAs, InGaAs, Si, SiC, AlGaAs, AlN, GaN, AlGaN, BN, ZnSe and HgCdTe. The electrodes can be any electrically conductive material which can be formed into patterned electrodes and which are capable of forming Schottky contacts or ohmic contacts with the semiconductor material. Typical metalization schemes which are commonly used for electrodes include Ti/Au, Ti/Pt/Au, Al, Cr/Au, Ni/Au, Pt/Au/ W/Au and Ag.

For convenience of illustration, the semiconductor layer is represented as a rectangular area slightly larger than the area covered by the electrode pattern. It is understood by those of ordinary skill in the art, however, that the semiconductor layer can actually be much larger than the area covered by the electrode pattern. The only limitation on the size of the semiconductor layer is that the semiconductor layer can not have an area that is less than that spanned by the electrode pattern. This semiconductor layer can be a simple active layer, as depicted in the enclosed figures, or any of a number of appropriate heterostructures that are well known in the art.

These spiral electrodes **40** and **42** turn in the same direction and are parallel to each other for the entire length of the spiral, resulting in interpositioning of one spiral electrode within the spiral of the other electrode. The space between spiral electrodes is maintained essentially constant and the two electrodes are not in contact with each other at any point along their length. The end of each electrode that extends beyond the spiral connects to a bonding pad **44** or other device as part of a circuit or more complicated optoelectronic system. Any suitable external voltage source (not shown) may be used to bias the electrodes.

In the alternate embodiment shown in FIG. 3, a first electrode **60** is disposed on the surface of an optically active semiconductor material **50** and is comprised of a first element **65** which intersects a plurality of substantially circular second elements **66** and **67**. The area of the semiconductor and the semiconductor material may vary as discussed in reference to FIG. 2, above. Each of these circular elements **66** and **67** are concentric with respect to each other and are open at a point approximately 180 degrees from the point of intersection with the first element of the first electrode **65**, creating the appearance of split rings. The first element **65** is connected to a central disk **68** which is located at the approximate center of the concentric circular elements **66** and **67**.

A second electrode **70** is also disposed on the surface of the semiconductor layer **50** and has a first element **75** that is similar to element **65** of the first electrode **60**. This element **75** lies within the openings created by the split rings in the concentric second elements of the first electrode **66** and **67**. A plurality of substantially circular second elements **76** and **77** intersect the first element **75**. These second elements **76** and **77** are essentially concentric with the second elements of the first electrode **66** and **67** and are disposed such that the second elements of the second electrode **76** and **77** alternate with the second elements of the first electrode **66** and **67**. These second elements of the second electrode **76** and **77** are also split where they would otherwise intersect the first element of the first electrode **65**. The split ends of these second **76** and **77** elements terminate at a space apart from the first element of the first electrode **65**. Unlike the first electrode **60**, the first element of the second electrode **75** terminates at an intersecting second element **77** rather than at a circular disk.

Any material can be used for the semiconductor on which can be formed patterned electrodes that exhibit rectifying behavior (i.e., Schottky contacts) or non-rectifying behavior (i.e., ohmic contacts) and which absorb light in a desired wavelength. Such materials may include GaAs, InGaAs, Si, SiC, AlGaAs, AlN, GaN, AlGaN, BN, ZnSe and HgCdTe. The electrodes can be any electrically conductive material which can be formed into patterned electrodes and which are capable of forming Schottky contacts or ohmic contacts with the semiconductor material.

Typical metalization schemes which are commonly used for electrodes include Ti/Au, Ti/Pt/Au, Al, Cr/Au, Ni/Au, Pt/Au/ W/Au and Ag.

In the alternate embodiment illustrated in FIGS. 4(a) and 4(b), a first electrode **80** is comprised of a first element **85** which is connected to a plurality of substantially circular second elements **86** and **87**. The second elements **86** and **87** are disposed on an optically active semiconductor layer **50**. Each of these second elements **86** and **87** are closed circles and concentric with each other.

A second electrode **90** is comprised of a first element **95** which is connected to a plurality of substantially circular second elements **96** and **97**. The second elements **96** and **97** are disposed on an optically active semiconductor layer **50**. Each of these second elements **96** and **97** are closed circles and concentric with each other and with the second elements of the first electrode **86** and **87**.

A layer of suitable dielectric isolation material **100**, such as SiO2, is disposed on the semiconductor surface to a thickness sufficient to completely cover the second elements of the first electrode **86** and **87** and the second elements of the second electrode **96** and **97** and to provide adequate insulative properties. The first element of the first electrode **85** lies on the surface of the isolation layer **100** and connects to each of the second elements of the first electrode **86** and **87** through small holes **102** and **104** positioned above the second elements **86** and **87** and extending through the isolation layer **100**. The first element of the second electrode **95** also lies on the surface of the isolation layer **100** and connects to each of the second elements of the second electrode **96** and **97** through small holes **106** and **108** positioned above the second elements **96** and **97** and extending through the isolation layer **100**. In addition to dielectric isolation schemes, it is possible to substitute an air bridge for the isolation material.

Any material can be used for the semiconductor on which can be formed patterned electrodes that exhibit rectifying behavior (i.e., Schottky contacts) or non-rectifying behavior (i.e., ohmic contacts) and which absorb light in a desired wavelength. Such materials may include GaAs, InGaAs, Si, SiC, AlGaAs, AlN, GaN, AlGaN, BN, ZnSe and HgCdTe. The electrodes can be any electrically conductive material which can be formed into patterned electrodes and which are capable of forming Schottky contacts or ohmic contacts with the semiconductor material. Typical metalization schemes which are commonly used for electrodes include Ti/Au, Ti/Pt/Au, Al, Cr/Au, Ni/Au, Pt/Au/ W/Au and Ag.

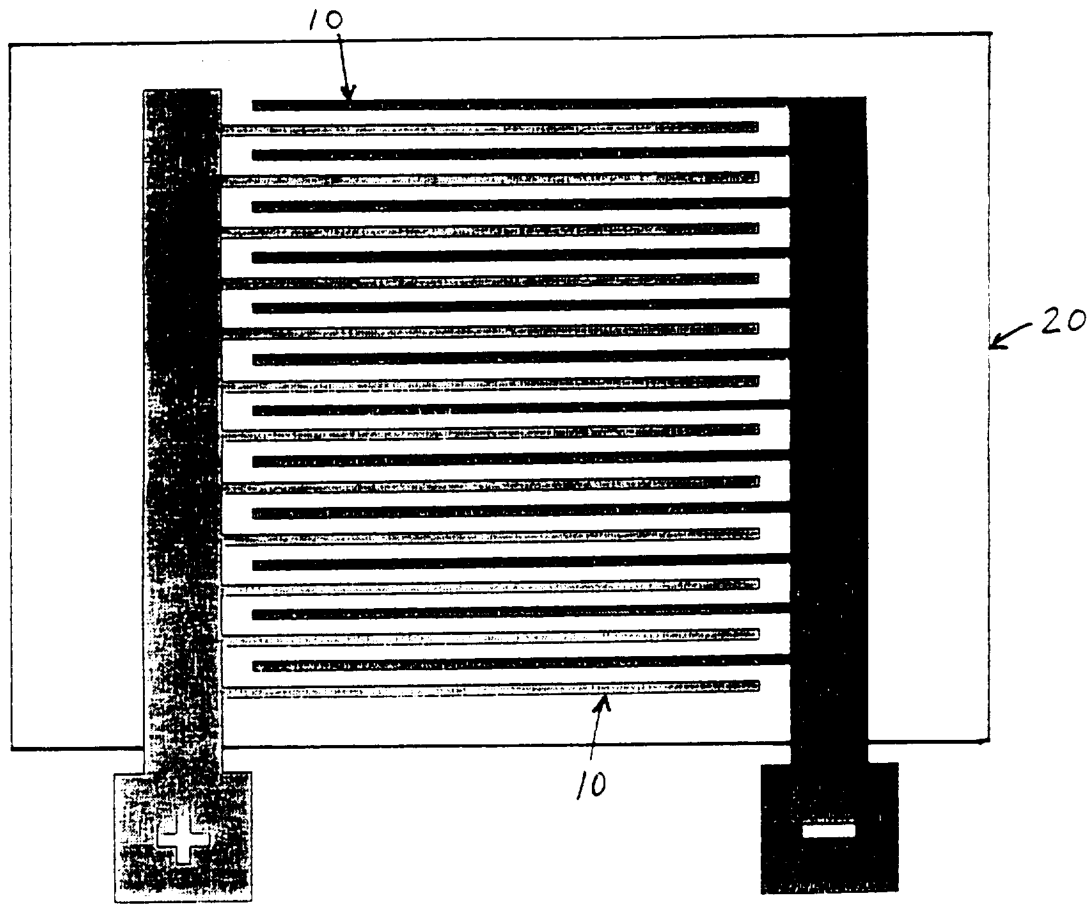
Many modifications, improvements and substitutions will be apparent to one skilled in the art without departing from the spirit and scope of the present invention as described herein and defined in the following claims.

What is claimed is:

CIRCULAR ELECTRODE GEOMETRY METAL-SEMICONDUCTOR-METAL PHOTODETECTORS

Abstract

The invention comprises a high speed, metal-semiconductor-metal photodetector which comprises a pair of generally circular, electrically conductive electrodes formed on an optically active semiconductor layer. Various embodiments of the invention include a spiral, intercoiled electrode geometry and an electrode geometry comprised of substantially circular, concentric electrodes which are interposed. These electrode geometries result in photodetectors with lower capacitances, dark currents and lower inductance which reduces the ringing seen in the optical pulse response.



Prior Art

FIG. 1

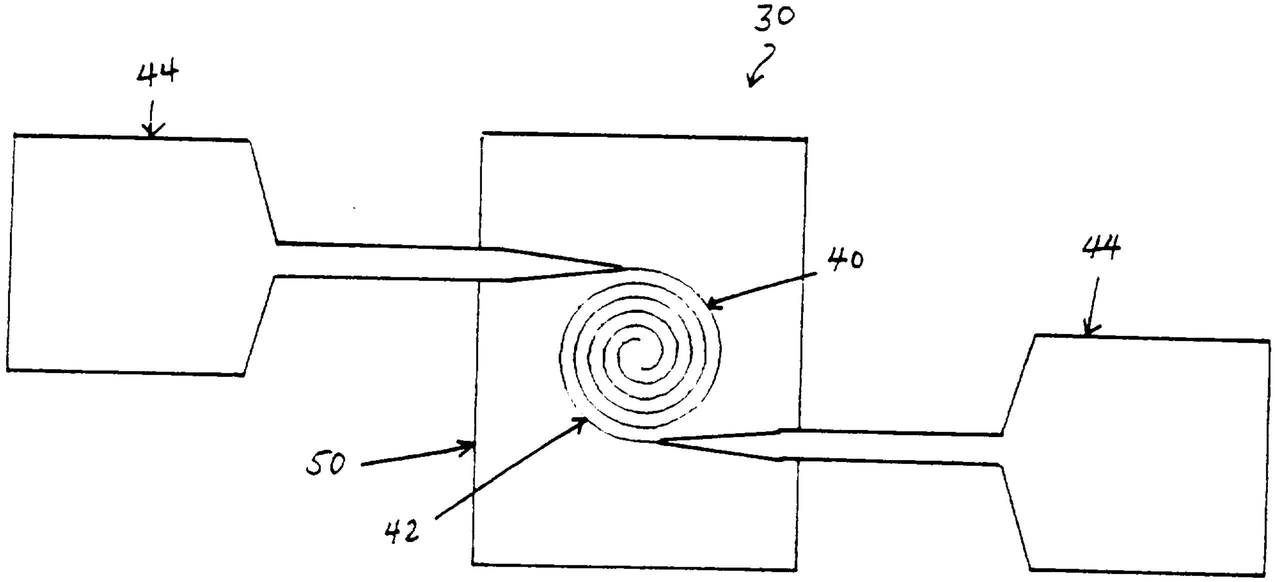
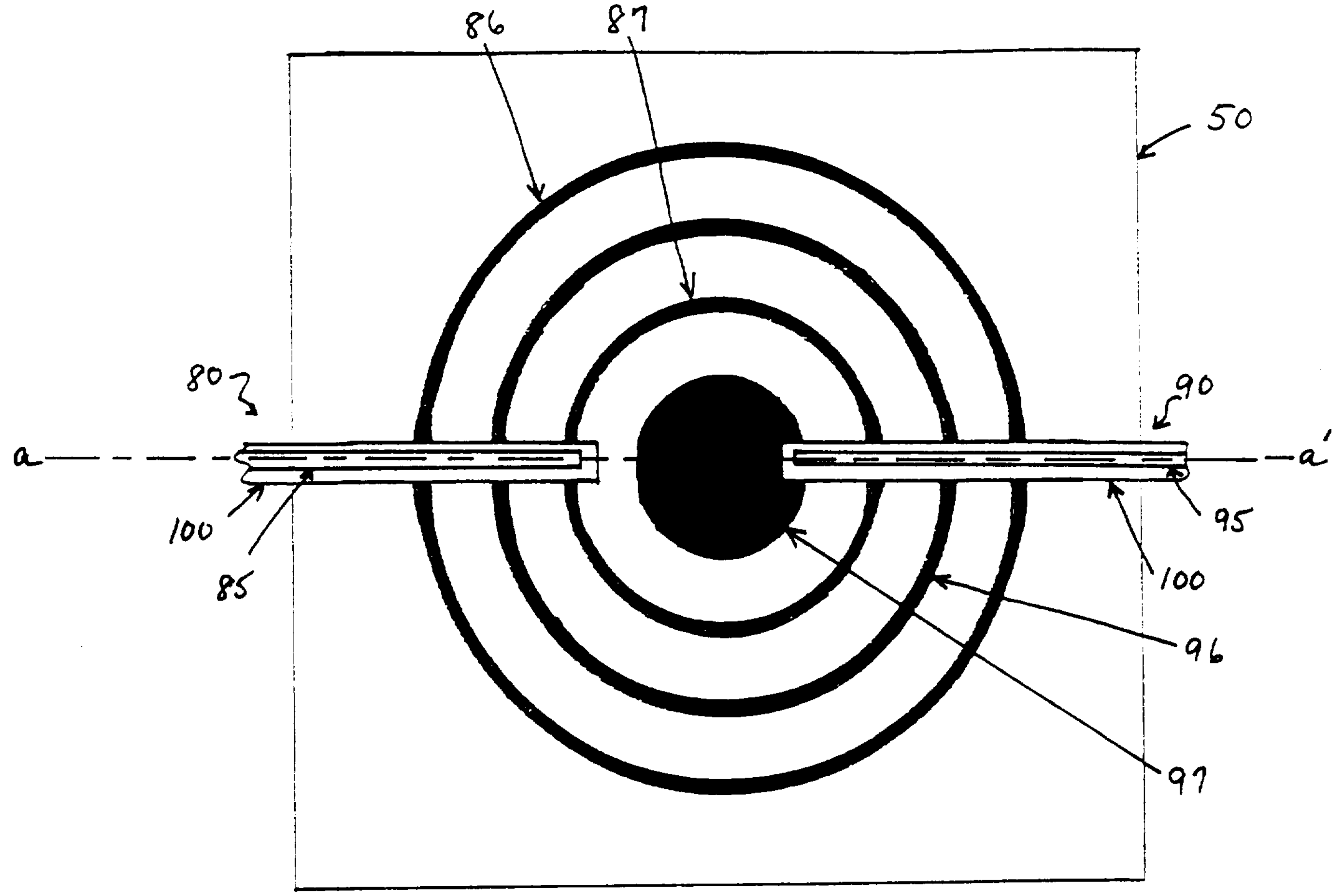
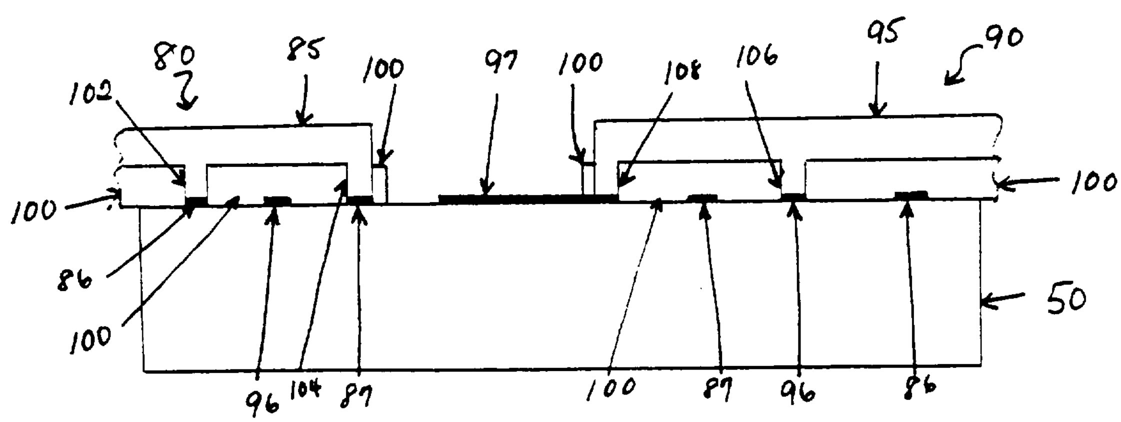


FIG. 2


86
87
50
80
90
a
a'
100
85
95
100
96
97

(a)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85
100
97
100
108
106
95
90
102
100
100
86
100
50
96
104
87
100
87
96
86

(b)

FIG. 4

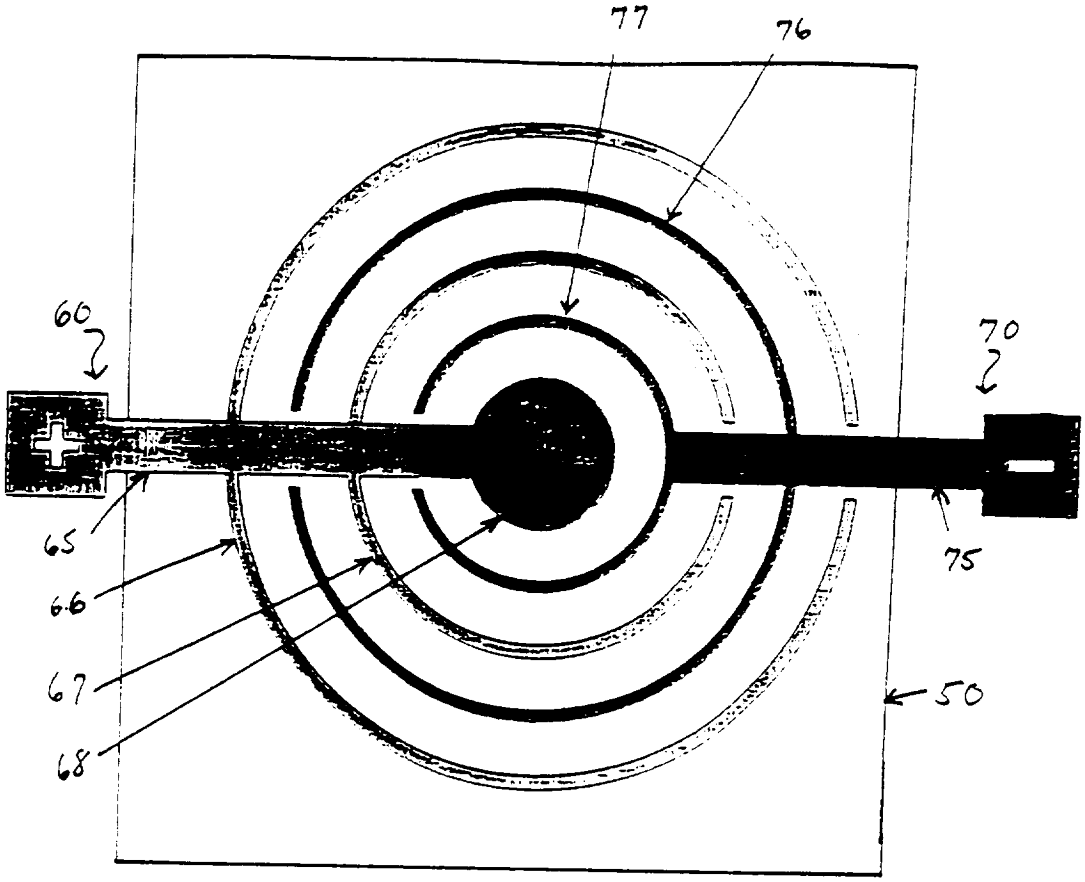

FIG. 3