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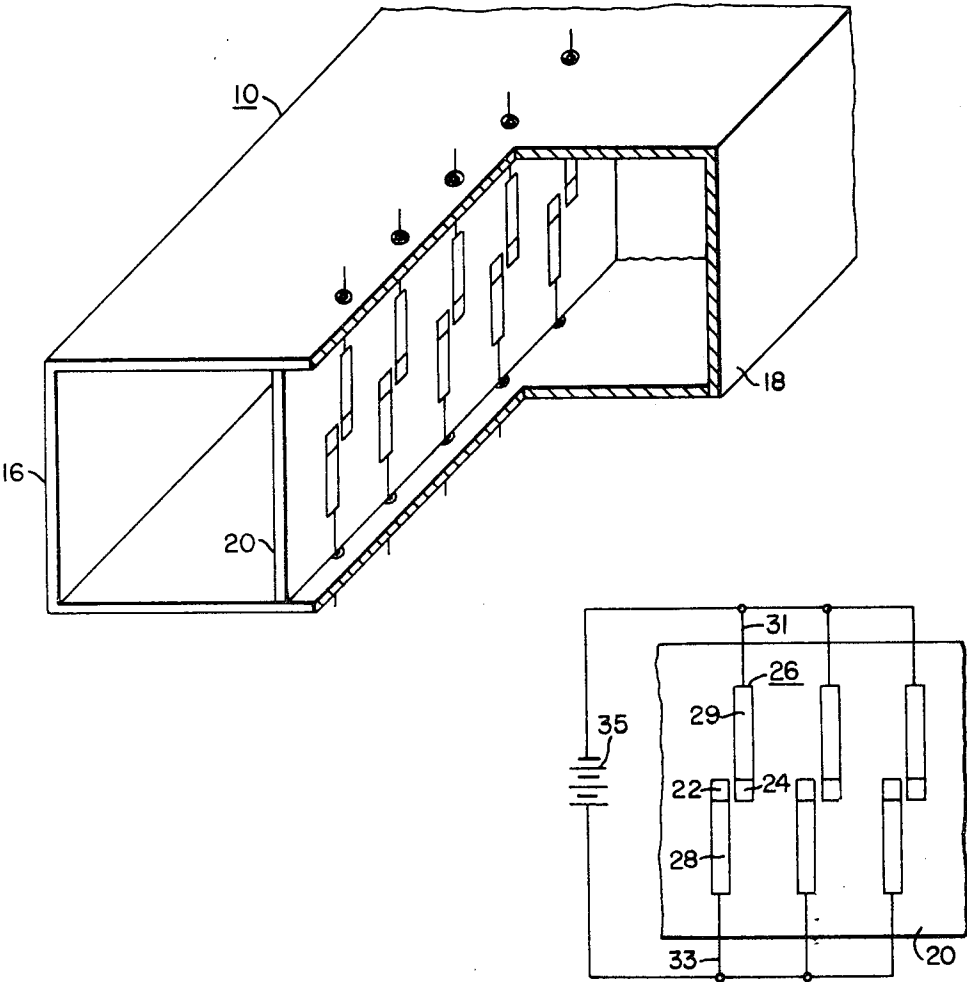
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[54] **SOLID-STATE TRANSFERRED ELECTRON EFFECT DEVICE**
4 Claims, 4 Drawing Figs.

[52] U.S. Cl..... 330/56,
330/61.5, 330/43
[51] Int. Cl..... H03f 3/60
[50] Field of Search..... 330/56, 43,
44, 61 A

ABSTRACT: This invention is directed to a microwave solid-state device incorporating semiconductor devices of the type which exhibit the transferred electron effect. A plurality of these devices provided within a transmission line may provide greater amplification or a larger oscillator output for microwave applications over that of a single device.



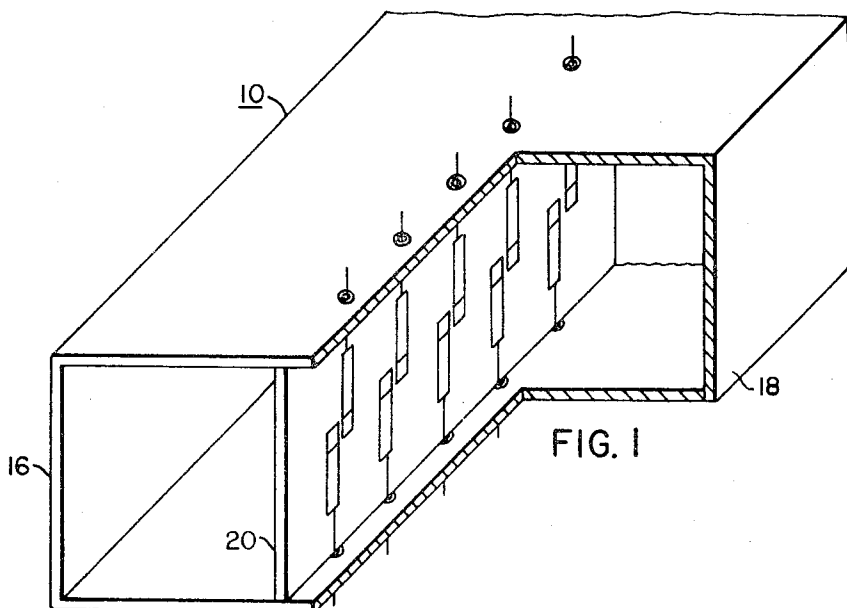


FIG. 1

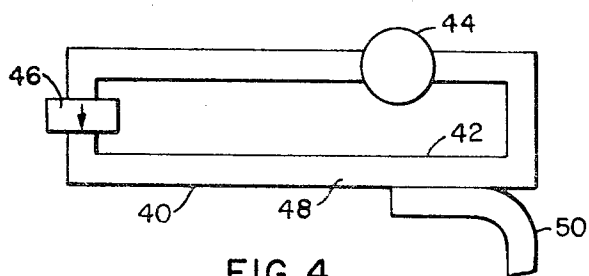


FIG. 4

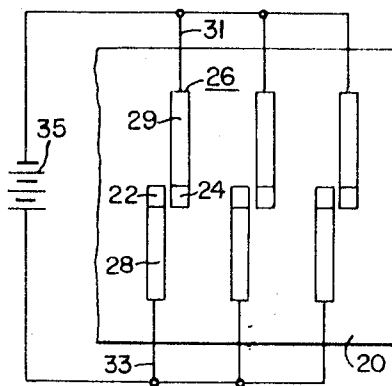


FIG. 3

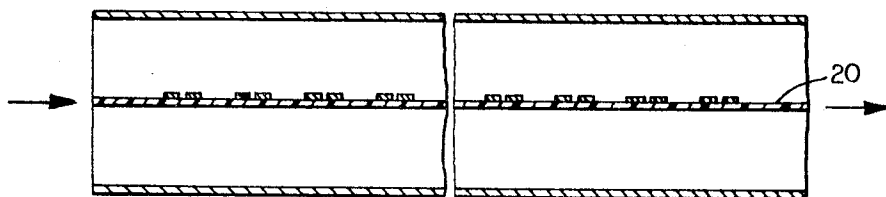


FIG. 2

WITNESSES

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SOLID-STATE TRANSFERRED ELECTRON EFFECT DEVICE

BACKGROUND OF THE INVENTION

It has been found in certain semiconductive materials, such as gallium arsenide, when subjected to electric fields of several kilovolts per centimeter exhibit coherent microwave oscillation at room temperatures. The mechanism responsible for this effect is the transfer of energetic electrons between conduction band "valleys" with electrons having different mobilities and the "valleys" separated in energy by a fraction of an electron volt. When these electrons are transferred to the higher valley, the mobility of the electrons is greatly reduced compared to those in the lower valley. When the rate of transfer of electrons between these two valleys exceeds a certain value, the material will exhibit a differential negative resistivity. In this region the field within the crystal becomes un-homogeneous, and abrupt domains or regions of high electric field are formed. These domains then travel through the crystal at some rate determined by the kinetics of the electron transfer. This effect or mode was reported by J. B. Gunn in an article entitled "Instabilities of Current in III-V Semiconductors" and published in the IBM Journal of Research and Development, page 141, Apr. 1964. Another effect or mode is the limited space-charge accumulation. This invention is directed to incorporating these transfer electron effect devices with some modifications into a transmission line thus, achieving amplification or oscillation over a wide frequency range.

It is accordingly an object of this invention to provide an improved solid-state semiconductor transferred electron effect device.

It is another object of this invention to provide an improved semiconductor microwave amplifier.

It is another object to provide a semiconductor microwave oscillator.

BRIEF SUMMARY OF THE INVENTION

This invention is directed to a microwave frequency device for providing amplification or oscillation over a wide frequency range. The microwave device provides a transmission line including semiconductor material with a plurality of transferred electron effect devices therein.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view partly in cross section of a microwave transmitting structure incorporating a semiconductor device in accordance with the teachings of this invention;

FIG. 2 is a cross-sectional view taken along the line II—II of FIG. 1;

FIG. 3 is a partial sectional view taken along line III—III of FIG. 1;

FIG. 4 is a schematic diagram of a portion of an oscillator incorporating the bulk semiconductor device illustrated in FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1, there is illustrated a semiconductor amplifier which includes a microwave transmitting means which is illustrated as a rectangular waveguide 10. The input microwave energy is directed into one end of the waveguide 10 and the output is derived from the opposite end in a well-known manner. The waveguide 10 consists of an upper wall 12 and a lower wall 14 with two sidewalls 16 and 18 of smaller dimensions. Typical dimensions of the top and bottom walls 12 and 14 would be 2.2 inches and the sidewalls 16 and 18 would be 0.99 inch with regard to an amplifier in the 3–5 GHz. frequency range.

Positioned vertically within the waveguide 10 is a sheet 20 of a suitable semiconductive material which exhibits the transferred electron effect. A suitable material for an amplifier would be N-type gallium arsenide with a resistivity of about 5

to 100 ohm-centimeters. The thickness of the sheet 20 could be about 0.01 inch and the width would be about 0.99 inch. The length could be of any suitable dimensions so as to provide a desired number of transferred electron effect devices along the waveguide 10. The sheet of semiconductive material 20 may be secured within the waveguide by sealing the edges of the sheet 20 to the upper and lower walls 12 and 14 with a suitable adhesive material such as hysol.

Referring now to FIGS. 2 and 3 for the details of the ohmic contacts provided on the surface of the sheet 20, a plurality of transferred electron effect devices 26 are provided along the sheet 20 and each of these transferred electron devices 26 consist of a pair of surface ohmic contacts 22 and 24. The ohmic contacts 22 and 24 are provided by evaporating a suitable electrically conductive material such as tin onto the surface of the sheet 20. The spacing between the contacts 22 and 24 of each device 26 should be about 0.001 inch in the case of the Gunn-effect mode. The thickness of the conductive element 22 and 24 should be approximately 0.007 inch and the dimensions may be 0.005 by 0.005 inch. The spacing between the electron transfer devices 26 is not critical in the case of an amplifier but should be about one-half wavelength in the case of an oscillator. Other suitable surface ohmic contacts may be utilized.

Suitable electrical conductive coatings 28 and 29 of a material such as gold are plated or evaporated onto the sheet or slab 20 for providing electrical conductivity from the ohmic contacts 22 and 24, respectively to the edge of the slab 20. A suitable electrical lead-in member 31 extends from the conductive coating 29 through the sidewall 16 and the lead-in 33 is provided from the conductive coating 28 through the sidewall 18. Similar connections are made to each of the elements 26. A suitable direct current potential source illustrated as battery 35 is provided for applying a direct current potential to each of the transferred electron effect devices 26. A suitable potential for this specific application would be about 20–40 volts which would provide an electric field within the semiconductive material of about 3,000 cm. for each device 26.

In the operation of the device, input microwave energy of a frequency of about 3–5 GHz. would be fed into the input end of the waveguide 10 and this energy would interact with the microwave energy generated by each of the transferred electron effect devices 26 so as to increase the amount of energy arriving at the output end of the waveguide 10.

In FIG. 4 an oscillator system is illustrated which includes a microwave device 40 similar to that illustrated in FIG. 1. The semiconductive material would have a resistivity of 2 to 10 ohms-centimeter and the spacing between the electron transfer devices 26 should have the relationship so that about one-half wavelength in distance is between each of the transferred electron devices 26. The system includes in addition to the oscillator device 40, a directional coupler 48 and a waveguide 42 connected from the directional coupler 48 to a cavity resonator 44. The resonator is designed for operation at a frequency of about 4 GHz. The energy is then fed through the cavity resonator 44 back into an oscillator 40 through an insulator 46. The directional coupler 48 is provided so that a portion of the energy is fed through the cavity resonator 44 and back into the oscillator 40 while the majority of the energy is coupled to a load through a waveguide 50 from the directional coupler 48.

Other suitable materials and a more complete description of the transferred electron effect device may be found in the IEEE Transactions on Electron Devices, volume ED-13, Number 1, Jan. 1966. Various other modifications of the embodiments may be made.

I claim as my invention:

1. A microwave energy device comprising a waveguide transmission line having an axis of wave propagation and conductors spaced transversely of said axis between which electric and magnetic wave fields are established,

3

a plurality of differential negative resistance devices arranged in spaced relation along said axis of propagation, said devices comprising a sheet of semiconductor material and a plurality of pairs of ohmic contacts on said sheet, a pair of said ohmic contacts and the intervening portion of said sheet constituting one of said devices, means for applying a DC potential across said pairs of ohmic contacts to thereby produce electric currents through the intervening portions of said semiconductor sheet between the ohmic contacts of the respective pairs, to thereby amplify propagated microwave energy incident upon said devices.

2. A device as defined in claim 1 in which all of the ohmic

4

contacts on said sheet of semiconductor material are on one surface of said sheet.

3. The device defined in claim 2 in which said waveguide transmission line is a rectangular waveguide and said semiconductor sheet is perpendicular to the broad sides of said waveguide.

4. The device defined in claim 3 in which electrically conductive means is provided on the same surface of said sheet as said ohmic contacts for providing electrical connection to said ohmic contacts and lead-ins extending through the walls of said waveguide.

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