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(54) IMPROVEMENTS IN OR RELATING TO ACOUSTIC SURFACE WAVE DEVICES

(71) We, MULLARD LIMITED, of Abacus House, 33 Gutter Lane, London, E.C.2, a British Company, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to acoustic surface wave devices.

The use of acoustic surface waves has enabled devices such as delay devices or frequency selective filters, to be manufactured which are small, robust and are moreover compatible with integrated circuit manufacturing techniques. Such devices also enable difficulties, such as the bulk and the manufacturing cost associated with the provision of inductors, to be avoided.

An acoustic surface wave device is commonly formed by a thin wafer of piezoelectric material on one surface of which a launching and a receiving transducer are arranged respectively to launch and to receive an acoustic surface wave propagating over the surface. Each transducer normally comprises an interdigital electrode array formed, for example by a photolithographic process, from a layer of suitable metal, such as gold deposited on the surface of the wafer.

In practice this kind of transducer array can have an inconveniently large capacitance with piezoelectric materials of large dielectric constant. The acoustic surface wave device can be employed as a frequency selective filter in which case the amplitude-frequency and phase-frequency responses thereof are determined by the number, spacing and dimensional configuration of strip electrode elements making up each transducer array. Each pair of adjacently located strip electrode elements which are fed with a signal of opposite polarity, can be regarded as a discrete source of acoustic surface waves. However, for convenience of computation, a mathematical model of the array is considered in which each electrode element is regarded

as representing an individual effective acoustic surface wave source and the results obtained from this model are found to be satisfactory in practice for design purposes. By employing techniques for Fourier synthesis and computer optimisation which are mathematically analogous to diffraction theory, on this mathematical model, a suitable relative distribution of magnitude and spacing of such sources in the launching and receiving transducer arrays can be determined which can provide a good approximation to a desired bandpass response.

In order to provide a desired response it is often necessary to provide within either or both transducer arrays, one or more sources whose magnitude is small compared with the largest source magnitude. Normally the strength of each discrete source of acoustic surface waves is determined by such parameters as the width of the corresponding parallel strip electrode elements and the length in a direction perpendicular to the acoustic surface wave propagation direction, of the overlap of adjacent electrode elements in the propagation direction. The provision of relatively small sources in a transducer array of this kind thus requires either that the overlap length should be small, causing problems from diffraction and end effects, or that the electrode elements should be made very narrow leading to difficulties in maintaining dimensional accuracy during manufacture.

It is an object of the invention to provide an improved acoustic surface wave device in which one or more of the aforementioned difficulties are reduced or overcome.

According to the invention there is provided an acoustic surface wave device including a body of piezoelectric material having at least a respective launching and receiving transducer arranged on an acoustic surface wave propagation surface of said body so that acoustic surface waves launched by said launching transducer in response to an electrical signal applied thereto are converted by said receiving transducer into a related

[Price 25p]

Price 75p

electrical signal after propagation over said surface, at least one of said transducers comprising an interdigital electrode array including at least two comb-shaped electrodes arranged respectively along the acoustic surface wave propagation path and connected electrically in series, two further comb-shaped electrodes being provided which are respectively connected to a pair of terminal connections, and interdigitated with two of the first mentioned comb-shaped electrodes.

According to a preferred feature of the invention there is provided an acoustic surface wave filter comprising a said acoustic surface wave device in which said launching and receiving transducers are arranged to provide a predetermined overall frequency response and in which the said two further comb-shaped electrodes of at least one of said interdigital electrode arrays are in part mutually interdigitated to form a first interdigital electrode portion located in the acoustic surface wave propagation path between second and third interdigital electrode portions, each comprising a further part of one of said two further comb-shaped electrodes interdigitated with one of the first mentioned comb-shaped electrodes, said portions being arranged respectively along the acoustic surface wave propagation path, said second and third portions forming relatively weak acoustic surface wave sources at the extremities of the transducer.

In order that the invention may be clearly understood and readily carried into effect embodiments thereof will now be described by way of example, with reference to the accompanying drawings of which:

Figure 1 shows a low capacitance acoustic surface wave transducer embodying the invention, and

Figure 2 shows an embodiment in which the weak sources of a filter transducer array are formed by the series connection of portions of the array.

Referring to Figure 1 which shows, in plan view, an acoustic surface wave delay device having transducer arrays embodying the invention, a body 1 in the form of a wafer of piezoelectric material, suitably a piezoceramic, has applied to the upper surface thereof an acoustic surface wave launching transducer comprising an interdigital electrode array 2 and a corresponding receiving transducer comprising an interdigital electrode array 3. The respective interdigital electrode arrays 2, 3 are formed on the surface of the body 1 by photolithography from a vapour deposited layer of gold.

The launching transducer array 2 comprises two portions each formed by a respective pair of comb-shaped electrodes 5, 6 and 7, 8 arranged in order of succession along the propagation direction 9 for acoustic surface waves propagating towards the receiving

transducer array 3. Each of the comb-shaped electrodes 5, 6, 7, 8 comprise a plurality of parallel strip electrode elements 10 connected to a respective common connection 11, 12, 13, 14. The electrodes 5 and 8 are respectively connected to corresponding terminal feed connections 15, 16 and the common connections 12, and 13 of the electrodes 6 and 7 are connected together via a connecting link 17. In this way the two portions of the interdigital electrode array 2 formed by the pairs of electrodes 5, 6 and 7, 8, are connected in series across a high frequency supply source connected to the terminals 15, 16 and the capacitance load presented to the source is approximately one quarter of the capacitance of a conventional interdigital electrode array having a similar number of strip electrode elements. In this way a transducer array having a large number of strip electrode elements 10 can be produced having a loading capacitance which is within the capabilities of normal amplifiers.

The receiving transducer array 3 can be formed as shown in a manner similar to that of the launching transducer array 2. By employing the series connection described, the receiving transducer array 3 will present a lower capacitance to the input circuit of an amplifier connected thereto than would a conventional receiving transducer of similar size, thus allowing a relatively large and therefore selective transducer to be connected to a conventional amplifier.

The division of each transducer array into two series connected portions is facilitated by the longitudinal symmetry of a normal transducer about the centre. However, the capacitance of each transducer can be further reduced by division of the interdigital electrode array into a greater number of portions all of which are connected in series. In this case care must be taken in design to make the impedance of each portion of electrode array of suitable value, preferably equal to each other, over the working frequency band.

It should be noted that, in the embodiment shown in Figure 1, the electrode elements 10' and 10'' which are components of the electrodes 5 and 8 respectively connected to the supply terminals 15 and 16 are situated side by side in the array and subjected to twice the voltage difference experienced by other pairs of adjacent electrode elements 10. In order that the equivalent acoustic surface wave component generated by the electrode elements 10' and 10'' should conform to the desired magnitude it will be realised that appropriate adjustments in electrode size or overlap must be carried out in accordance with normal design technique.

A further embodiment, illustrated in Figure 2 to which reference will now be made, comprises an acoustic surface wave filter formed

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on the upper surface of a wafer 21 of piezo-electric material, suitably a piezoceramic. An acoustic surface wave launched by a launching transducer comprising an interdigital electrode array 22, propagates over the surface of the wafer as a substantially parallel beam and is picked up by a receiving transducer array 23. The launching interdigital electrode array 22 comprises three portions 26, 27 and 28 arranged in order of succession along the acoustic surface wave propagation direction 29. The interdigital electrode portion 27 is formed by a part of each of comb-shaped electrodes 30, 31 which are connected respectively to terminal connections 35, 36. The comb-shaped electrodes 30, 31 are formed with parallel strip electrode elements 40 which in the portion 27 of the array 22, alternately form part of the respective electrodes 30 and 31 and are arranged transverse to the acoustic surface wave propagation direction 29.

The interdigital electrode portions 26 and 28 of the array 22 comprise respectively and in similar manner a comb-shaped electrode 33 and a further part 32 of the electrode 30, and a comb-shaped electrode 34 and a further part 38 of the electrode 31, again including parallel strip electrodes 40 arranged in a manner similar to that hereinbefore described. The interdigital electrode array portions 26 and 28 straddle the array portion 27, the comb-shaped electrodes 33 and 34 being conductively connected together in series via the connection 37. Thus only half the signal voltage applied across the array portion 27 is fed to each of the array portions 26 and 28.

The launching transducer array 22 is designed to provide, in combination with the receiving transducer array 23, which latter can be of the same form as that of the array 22, a predetermined band-pass filter effect. This involves varying over the length of the array, the effective strengths of equivalent acoustic surface wave sources which are assumed to correspond to the respective electrode elements 10 of the array. In normal filter designs the equivalent sources have to be strongest near the centre of the array and to decrease in strength, becoming relatively weak towards each end. This is commonly achieved by reducing the width of the electrode element 10 or the length of overlap of one electrode element 10 with an adjacent electrode element. However, it is difficult to manufacture very narrow strip electrode elements with accuracy, and a short overlap produces diffraction effects such as for example a wide lobed beam instead of a parallel beam. By reducing the effective drive voltage applied to each of the array portions 26 and 28 by the series connection 37, it is now possible to provide relatively weak equivalent sources at or near the ends of the array 22 without having to make the electrode elements

10 very narrow or, alternatively, to employ an unsatisfactorily short overlap of adjacent electrode elements 10. It will be readily apparent that further improvement can be effected, if desired, by arranging four series connected comb-shaped electrodes, two at each end of the array or more if especially weak sources are required, however, in this case also care will have to be exercised during design to ensure that those portions of the array containing comb-shaped electrodes connected in series, each have an appropriate, preferably mutually equal, impedance over the working frequency range.

The receiving transducer 22 can be arranged in the same way as the launching transducer 23 or, alternatively the band-pass filter effect can be obtained by suitable design of one transducer array while the other array is arranged to have a uniform electrode structure.

The transducers 22 and 23 can be formed by photolithography from a vapour deposited layer of gold as in the embodiment described with reference to Figure 1.

WHAT WE CLAIM IS:—

1. An acoustic surface wave device including a body of piezoelectric material having at least a respective launching and receiving transducer arranged on an acoustic surface wave propagation surface of said body so that acoustic surface waves launched by said launching transducer in response to an electrical signal applied thereto are converted by said receiving transducer into a related electrical signal after propagation over said surface, at least one of said transducers comprising an interdigital electrode array including at least two comb-shaped electrodes arranged respectively along the acoustic surface wave propagation path and connected electrically in series, two further comb-shaped electrodes being provided which are respectively connected to a pair of terminal connections, and interdigitated with two of the first mentioned comb-shaped electrodes.

2. An acoustic surface wave filter comprising an acoustic surface wave device as claimed in Claim 1 in which said launching and receiving transducers are arranged to provide a predetermined overall frequency response and in which the said two further comb-shaped electrodes of at least one of said interdigital electrode arrays are in part mutually interdigitated to form a first interdigital electrode portion located in the acoustic surface wave propagation path between second and third interdigital electrode portions, each comprising a further part of one of said two further comb-shaped electrodes interdigitated with one of the first mentioned comb-shaped electrodes, said portions being arranged respectively along the acoustic surface wave propagation path, said second and third por-



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tions forming relatively weak acoustic surface wave sources at the extremities of the transducer.

- 5 3. An acoustic surface wave device substantially as herein described with reference to Figure 1 or Figure 2 of the accompanying drawings.

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