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Coldren

[11] **3,831,115**

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[54] **ACOUSTIC SURFACE WAVEGUIDE WITH GRADED PROFILE CROSS SECTION**

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[21] Appl. No.: **381,054**

[52] **U.S. Cl.**..... **333/30 R,** 333/71, 333/72

[51] **Int. Cl.**..... **H03h 9/00,** H03h 9/30, H01v 7/00

[58] **Field of Search**.....333/30 R, 72, 71; 310/8, 310/9.8; 350/96 WG

[56] **References Cited**

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3,406,358 10/1968 Seidel et al. 333/71

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Stern, "Microsound Components, Circuits and Applications", in IEEE Transactions on Microwave Theory and Techniques, Vol. MTT-17, No. 11, Nov. 1969, pp. 835–840.

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Assistant Examiner—Marvin Nussbaum
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[57] **ABSTRACT**

The edges of an acoustic surface wave slot waveguide are formed with graded edge thickness of decreasing magnitude toward the center of the slot to create a similarly graded Rayleigh wave velocity profile across the waveguide. An acoustic wave delay system utilizing the invention is shown, and different thickness profiles are illustrated for several slot waveguides and a strip waveguide.

14 Claims, 6 Drawing Figures

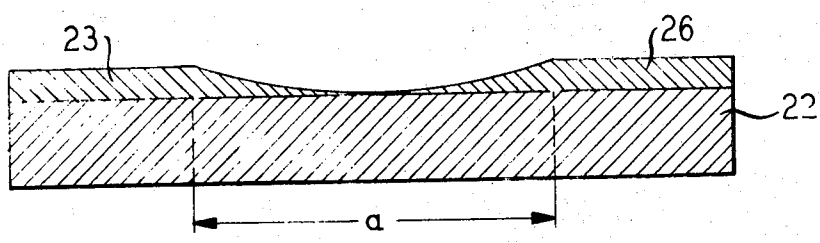


FIG. 1

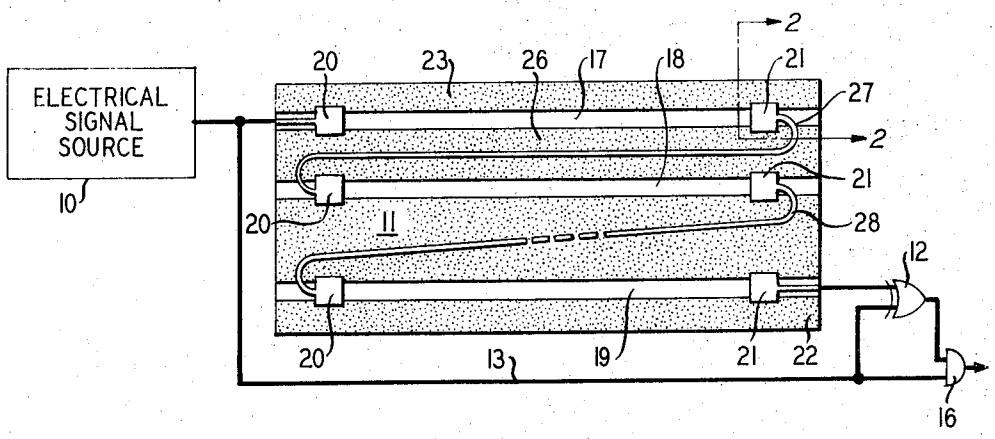


FIG. 2

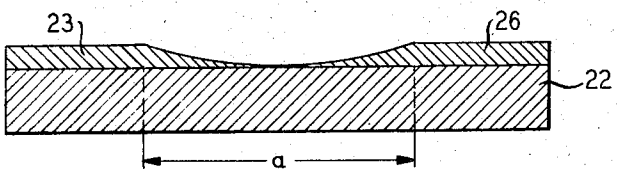


FIG. 3

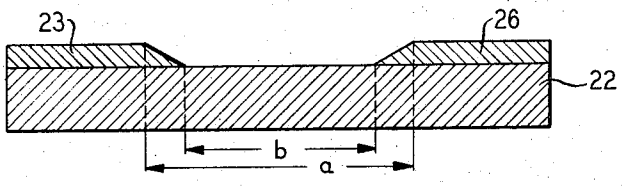


FIG. 4

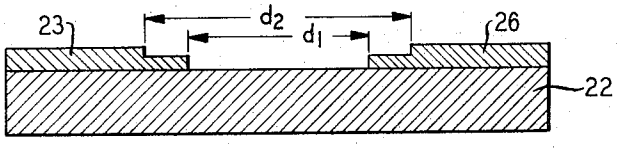


FIG. 5

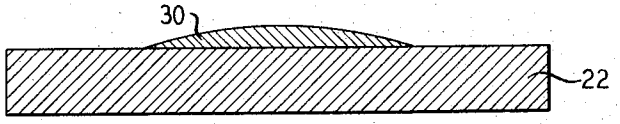
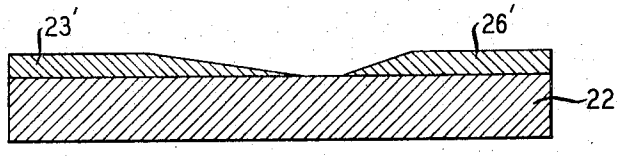


FIG. 6



ACOUSTIC SURFACE WAVEGUIDE WITH GRADED PROFILE CROSS SECTION

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to waveguides for use in the acoustic, or elastic, surface wave technology; and it relates more particularly to such waveguides of the mass loaded, or perturbed surface wave type.

2. Prior Art

Acoustic, or elastic, surface wave devices are those wherein energy is propagated across a surface of a substrate material by means of a mechanical flexure wave induced by an appropriate transducing device. The Rayleigh surface wave has found the most widespread application in the art of acoustic surface wave devices, and the Rayleigh wave is more fully discussed in an article "Acoustic Surface Waves" by G. S. Kino et al., *Scientific American*, October 1972, pages 50–68. In such devices, the principal propagated energy can be advantageously guided by structuring the device to have a predetermined perturbed Rayleigh wave velocity profile, i.e., a velocity profile that is perturbed with respect to the uniform velocity of an unguided plane Rayleigh wave on the same substrate. Hence, the device is sometimes called a perturbed surface wave device. A Rayleigh wave has an intrinsic velocity on the plane surface of a semi-infinite substrate, and the value of that velocity depends upon the material used for the substrate. The velocity can be perturbed by various mechanisms. A velocity profile can be used to describe an acoustic surface wave device; and in that case, one ascribes to each point on the surface cross section perpendicular to the direction of wave propagation the velocity a perturbed Rayleigh wave would possess if the perturbation at that point were uniformly distributed over the surface.

Acoustic surface waveguides, sometimes also called elastic surface waveguides, of various types are known in the art. Those of the mass loaded, or perturbed surface wave type employ a thin film deposited on a substrate for defining the waveguide by loading the substrate to effect the aforementioned guiding velocity profile. The film and substrate have different mechanical material parameters which are selected so that the velocity of the perturbed surface wave is either increased or decreased. Guides of the so-called fast-on-slow type employ an overlay film, which increases the propagation velocity, deposited on the proper regions of the substrate. An upper limit on the upward velocity perturbation is the bulk shear wave velocity of the substrate, for beyond that level energy leakage into the bulk of the substrate becomes excessive. The film is formed in two spaced portions which define therebetween a slot which comprises the waveguide propagation path across the substrate surface. Similarly, waveguides of the slow-on-fast type employ a film strip which decreases the velocity in the region where energy is to be guided. In both cases, as the velocity difference between the slower guide region and the faster surrounding region is increased, the energy is bound more tightly to the guide, and the unwanted frequency dispersion becomes larger. Frequency dispersion results from the different velocities of energy propagation that may exist over the spectrum of the transmitted signal. Discussions of different types of acoustic surface waveguides, including the mass loaded type of waveguide, are found in various publications. Illustrative examples are: "Elastic Surface Waves Guided by Thin Films," by H. F. Tiersten, *Journal of Applied Physics*, Vol. 40, No. 2, February 1969, pages 770–789; and "Microsound Surface Waveguides," E. A. Ash et al., *IEEE Transactions on Microwave Theory and Techniques*, Vol. MTT-17, No. 11, November 1969, pages 882–892.

The foregoing mass loaded acoustic surface waveguides are to be distinguished from other types of acoustic surface waveguides such as, for example, guides of the topographical, or raised ridge, type. Practical guides of the latter type utilize a surface structure which extends a distance of a wavelength or more above the plane of the substrate to create a region where the material is less restrained, and thus energy is guided along this region. There is also a so-called $\Delta v/v$ type of waveguide which employs a flat metallic strip overlay on a piezoelectric substrate for short-circuiting a portion of the electric field accompanying the acoustic wave and thereby creating the velocity reduction which defines the preferred wave propagation path.

A number of design considerations are involved in the manufacture of the mass loaded acoustic surface waveguides. Briefly, two of the considerations are the confining of propagation energy within the propagation path of the waveguide and the securing of a low level of frequency dispersion, i.e., the change in delay as a function of frequency, so that the waveguide will be useful over a relatively broad bandwidth. Other considerations involve the ease of manufacture of the waveguide and the ease of excitation of signal energy in the waveguide. For example, some topographical waveguides are known to have good energy confinement characteristics and theoretically low frequency dispersion; but they are difficult to manufacture in their ideal form, and it is difficult to excite the desired propagation mode. They are also subject to manufacturing surface defects which result in increased dispersion, propagation loss, and spurious reflections, especially in the VHF range of the frequency spectrum. On the other hand, mass loaded acoustic surface waveguides are comparatively easy to manufacture, since they are simply formed by a relatively thin film, e.g., much less than one wavelength in thickness, deposited on a planar substrate.

Frequency dispersion in the aforementioned strip guide tends to be high because most of the energy propagates in the dispersive overlay region. The frequency dispersion can be made small for the aforementioned slot waveguide by utilizing only a small velocity increase in the surrounding media. However, in this latter slot guide case, much of the energy propagating in the mode is stored in the evanescent fields outside of the slot cross section, thereby producing crosstalk problems if there are adjacent propagation channels on the same substrate. On the other hand, if the energy is bound more tightly by using a larger velocity difference between the slot guide and surrounding regions, waveguide dispersion increases.

It is also known that improved energy confinement results if the slot waveguide is formed along a low diffraction loss orientation of an anisotropic substrate.

In self-focusing optical fiber systems, it is known that the frequency dispersion within a frequency band can be reduced by grading the index of refraction of the fiber material radially outward from the longitudinal

center of the fiber. However, such an index grading technique has not heretofore been available for dispersion reduction in acoustic surface wave devices. A discussion of the mentioned optical technique is included in a D. Gloge article entitled "Optical Waveguide Transmission," *Proceedings of the IEEE*, Vol. 58, No. 10, pages 1513–1522, October 1970.

STATEMENT OF THE INVENTION

The foregoing difficulties encountered in reducing frequency dispersion while maintaining strong energy confinement in mass loaded acoustic surface waveguides are alleviated in accordance with the present invention by forming a waveguide propagation path with a graded thickness cross section. It has been found that slot waveguides so configured, i.e., with film thickness decreasing in the direction toward the center of the slot have substantially reduced dispersion but retain the desirable relatively strong guiding influence on acoustic surface waves.

It is a feature of the invention that an advantageous signal propagation mode is relatively easily excited in such a mass loaded acoustic surface waveguide by well-known transducing techniques implemented by familiar integrated circuit manufacturing procedures on planar surfaces. In addition, the waveguide propagation path width is advantageously at least several wave lengths of the lowest frequency to be propagated so that surface defects in the slot across the surface of the substrate, or on the graded edges of the film, or at the film edge interface with the substrate do not seriously adversely affect propagation.

BRIEF DESCRIPTION OF THE DRAWING

A more complete understanding of the invention and the various features, objects and advantages thereof may be obtained from the following detailed description when taken in connection with the appended claims and the attached drawing in which:

FIG. **1** is a functional diagram of a signal transmission system employing a slot waveguide delay line in accordance with the invention;

FIG. **2** is a cross section of a segment of the waveguide in FIG. **1** and showing a concave parabolic taper of film overlay edges;

FIG. **3** is a modified cross section showing a linear taper of the film edges;

FIG. **4** is a modified cross section showing a stepped approximation of tapered edges of the overlay film;

FIG. **5** is a similar cross section depicting a strip waveguide with parabolic film edge tapers; and

FIG. **6** is a slot waveguide cross section showing the employment of differential edge thickness grading on each side of the waveguide to facilitate surface wave propagation along a curved waveguide path.

DETAILED DESCRIPTION

FIG. **1** illustrates in functional form an application of the invention as a picture frame store in a video system. In this system an electric signal source **10** comprises, for example, a video camera with optical input and electric signal output. The latter output is advantageously in the form of a serial digital bit stream in which successive groups of pulses represent pulse code modulated characters defining successively scanned picture elements which make up a total video signal frame. The electrical output of source **10** is applied to a frame store **11** which comprises an acoustic surface waveguide delay line in accordance with one aspect of the present invention. An output of the store **11** is coupled to one input of an EXCLUSIVE OR gate **12** which is also provided, by way of a circuit **13**, with an additional input from the aforementioned output of source **10.** Signals received by the gate **12** from the store **11** are delayed by one frame time with respect to signals received by the gate from circuit **13.** Consequently, the EXCLUSIVE OR gate **12** produces an output in any bit time when the output of source **10** and the output of store **11** are different. This gate output is applied to one input of a coincidence gate **16** for enabling that gate to be actuated in response to signals on the circuit **13.** The output of gate **16** thus corresponds to signal information during each bit time of a frame in the output of source **10** when that source output is different from the signal in the corresponding bit time of the preceding signal frame from source **10.**

Store **11** is advantageously made up of a plurality of series connected, acoustic surface wave, delay lines such as the lines **17, 18** and **19.** Each of these delay lines is an acoustic surface wave, mass loaded, slot waveguide which is provided with a wide band input signal transducer **20** for converting electric input signals into corresponding acoustic surface waves for propagation along the waveguide. Each delay line further includes an output signal transducer **21** for similarly converting such acoustic surface waves into corresponding electrical signals. Slot waveguides of this type are illustrated, for example, in the A. H. Meitzler et al., U.S. Pat. No. 3,409,848. Briefly, such a waveguide comprises a slow acoustic surface wave propagation substrate **22** on which there are deposited two portions, such as the portions **23** and **26** in FIG. **1,** of a faster acoustic surface wave propagating overlayer film. The two portions are spaced apart to define the slot waveguide propagation path, e.g., line **17,** across the surface of substrate **22.** A variety of materials are known in the art for producing thin film, mass loaded, waveguides of the aforementioned type. Those illustrated in FIG. **1** advantageously employ a monocrystalline piezoelectric substrate of bismuth germanium oxide ($Bi_{12}GeO_{20}$) with a film of evaporated silicon monoxide (commonly designated SiO_x) for the overlayer portions such as **23** and **26.** A piezoelectric substrate is not essential to the invention, but its use facilitates the transducing function for coupling energy into and out of the waveguide. Transducers **20** and **21** are advantageously of the known metal electrode interdigital pattern type on the mentioned piezoelectric substrate. For such a transducer, the interdigital portion of the electrode pattern is used only within the waveguide.

The delay lines **17, 18,** and **19** are connected in electrical series between source **10** and an input of EXCLUSIVE OR gate **12.** In the series connection, outputs of transducers **21** are typically coupled through respective signal repeaters (not shown) to the following transducer **20** or gate **12.** Thus, the input transducer **20** of delay line **17** receives signals from source **10.** The output transducer **21** of the same delay line is coupled by means of a metallic circuit **27** to the input transducer **20** of line **18,** and such circuit is deposited on portions of the substrate **22** outside of a delay line propagation path and over the top of the film portion **26.** However, where the aforementioned repeaters are employed on a separate integrated circuit chip, circuits

such as **27** may be more conveniently located off the substrate **22.** Other delay line sections are similarly connected in the series combination as schematically represented by the broken circuit **28.**

The extensive delay line capacity which is necessary for a video frame store makes it advantageous to employ the aforementioned plural delay line sections. However, in order to achieve reasonable store size, it is desirable that the delay line waveguides be arranged as closely as possible to one another; and, thus, it is desirable that the film thickness, and hence the velocity difference between film and substrate, be relatively large in order to retain a strong waveguide effect. However, for a slot of rectangular cross section, a velocity difference larger than only one or two percent at the highest frequency in the band of interest will yield levels of dispersion that will necessitate pulse regeneration after a delay much less than is needed in a viable video frame store. For such a store, about a 17-millisecond delay is needed. With a one or two percent velocity difference, a large portion of the energy would be stored outside of the rectangular guide necessitating a large separation between adjacent channels. For example, a 175-micrometer wide rectangular slot formed in a 4,000 A. thick evaporated silicon monoxide film along the (**110**) direction on a (**001**) cut bismuth germanium oxide substrate would not allow delay lines closer than 2 millimeters apart without significant crosstalk at 50 megahertz over a 1-millisecond delay path. For closer spacing a thicker film must be used, but, of course, this results in still larger levels of dispersion. Thus, the described rectangular guide would be inconvenient as a frame store because more than 17 repeaters would be required, one after each submillisecond delay section of the frame store.

Dispersion can be measured as the relative change in time delay per unit frequency increase, $1/\tau\ (d\tau/df)$, where τ is delay at frequency f in the transmitted signal pulse frequency spectrum. For a given bandwidth Δf and time delay τ, the difference in delay between high and low frequency components is $1/\tau\ (d\tau/df)\ \Delta f\tau$. For the 175 micrometer wide by 4,000 A. deep evaporated silicon monoxide rectangular waveguide on bismuth germanium oxide, $|1/\tau(d\tau/df)| \sim 10^{-11}$ second in the vicinity of 50 megahertz. For the time delay and bandwidth required on a video store this amount of dispersion is usually considered excessive. In addition, the energy is confined too poorly for video frame storage. As an example of the improvement that can be obtained by edge tapering, it has been found that a similar guide using a 6,000 A. thick evaporated silicon monoxide film with linearly tapered edges, as will be described, yields less than half the time delay change per unit frequency increase and a tighter energy confinement near 50 megahertz. In other words, the edge taper allowed a film of 50 percent greater thickness but produced lower dispersion, a result that is contrary to experience with prior art slot waveguides.

A taper of the type in the mentioned waveguide extends with decreasing thickness from the main body of the film portion toward the longitudinal axis of the slot waveguide in a direction which is perpendicular to that axis. The thickness cross section, or profile, so provided is essentially symmetrical about that axis for a straight waveguide section; and it produces a perturbed Rayleigh wave velocity profile which is similarly symmetrical about that longitudinal axis with the lowest velocity at the center of the slot waveguide and increasing velocities at increasingly greater distances on either side of the axis. The aforementioned graded thickness profiles can be achieved in different forms. Several different illustrative configurations are hereinafter considered. In all cases it is assumed that the velocity perturbation is directly proportional to the film thickness since layers much thinner than a wavelength of the highest frequency in the propagation band of interest are being considered.

FIG. **2** is a partial cross section of the store **11** at the section line **2—2** in FIG. **1.** In FIG. **2,** a parabolic thickness profile is shown with the tip of the parabola on the substrate surface at the center of the slot waveguide, the directrix of the parabola either within or below the substrate **22,** and the focus of the parabola above the film bearing surface of the substrate. The same profile is utilized along the full length of a delay line. A parabolic profile is presently believed to offer the closest approach to the ideal case of zero dispersion.

Which particular parabola is utilized for the edge thickness grading profile will depend upon the particular signal bandwidth which is to be propagated through the slot waveguide. At high frequencies, where the energy is contained substantially within the region of the parabolic profile, the mode has a gaussian energy distribution profile and has a width

$$x_o = (v_o/2f)^{3/4}\ (1/\pi^2\alpha\gamma)^{1/4}$$

The velocity is written as $v(x) = v_o + \gamma\alpha f x^2$, x being the horizontal distance measured transversely from the center of the guide, and

γ is the mass loading coefficient representing the perturbation of substrate velocity due to the thickness and material properties of the film,

α is the parabolic shape factor in a parabola defining the film thickness profile, i.e., $y = \alpha x^2$, y being the film thickness at the distance x,

f is the frequency, and

v_o is the substrate Rayleigh wave velocity.

The lowest useful frequency of operation is approximately that where the mode width x_o is equal to a, the width of the slot at the upper surface of the film, i.e., where the parabola is truncated.

The upper frequency of the propagation band of interest is for practical purposes determined by the frequency at which significant propagation of spurious surface propagation modes can occur. Slot guides are overmoded over much of their useful frequency range. That is, they are capable of simultaneously supporting multiple modes of propagation; but the high dispersion usually present in portions of the band between such modes generally presents utilization of the entire spectrum of the propagation band. The use of a parabolic velocity profile vastly reduces the dispersion between the various modes that may propagate at the higher frequencies. This effect suggests that the parabolically profiled guide may be useful in an overmoded region while the rectangularly profiled guide is not. The highest frequency of operation thus will be decided on the basis of loss to higher order modes, that are subject to different delays or are separated from the principal band by a band of dispersive frequencies, over the length of a specified delay path.

FIG. **3** is a corresponding section of the store **11** and depicts a slot waveguide which is useful in approximately the same band as the guide of FIG. **2.** However, in the embodiment of FIG. **3** the slot waveguide is

formed by tapering the overlayer film edges with a substantially linear taper which extends from each extreme of the slot width toward the center of the slot a distance that is about 7 percent of the slot width at the widest point. The waveguide of FIG. 3 affords signal propagation with somewhat higher frequency dispersion in the band of interest than is produced by the waveguide of FIG. 2. Nevertheless, the improvement over the rectangular cross-sectioned slot is significant. Different degrees of taper give different degress of improvement.

FIG. 4 again depicts a slot waveguide cross section, but in this case the graded edge thicknesses of the film portions 23 and 26 defining the waveguide are graded in accordance with a stepped approximation of a taper. For the illustrated embodiment, two steps, i.e., a single intermediate step, are utilized for each grading, and the intermediate step extends from the waveguide width extreme toward the center of the waveguide a distance which is approximately 15 percent of the maximum slot width. The step thickness is approximately one-half of the maximum film thickness. This is believed to be the best two-step approximation of a parabola.

For all of the FIGS. 2–4, the useful frequency band for pulse transmission extends from the lowest frequency where single mode dispersion is tolerable to the point where dispersion due to higher order modes results in intolerable pulse broadening, i.e., intersymbol interference, as discussed above for the truncated parabola of FIG. 2.

First order propagation modes in FIGS. 2–4 have a number of similarities to the symmetric mode illustrated in the aforementioned Meitzler et al. patent. That is, all have at the central portion of the slot a positive-going lobe in the energy distribution; and the distribution is exponential in form outside the slot. That positive-going lobe follows a cosine function in FIGS. 3 and 4 and in Meitzler et al.; and in FIG. 2 herein, it has a gaussian form. The different embodiments presented herein have different types of transitions between the lobe in the center of the slot and the exponential distribution outside the slot. The next higher mode in the present invention is antisymmetric with a positive-going and a negative-going lobe in the energy distribution within the slot, the two lobes being connected at a zero energy point in the center of the slot. Going still higher in frequency, the next mode is again symmetric with two positive-going lobes separated by a single negative-going lobe in the center of the slot.

A slot waveguide of the form illustrated in FIG. 4 is readily manufactured by well-known integrated circuit techniques. Thus, for example, a first mask is deposited to define the smaller slot width d_1; and then the overlayer film is deposited to the thickness of the intermediate film step within the waveguide, i.e., one-half of the maximum thickness for the illustrative embodiment. Next a further mask is deposited for defining the maximum slot width d_2, and then the remainder of the film overlayer is then deposited. Finally the masking material is removed to leave the stepped slot waveguide. Metal films for transducers 20 and 21 are somewhat more difficult to deposit for the embodiment of FIG. 4 than for the embodiments of FIGS. 2 and 3 because of the vertical (as illustrated) side walls in the two slot portions of FIG. 4.

FIG. 5 depicts a store section (not used in FIG. 1) including a modified waveguide in the form of a strip guide, or slow-on-fast acoustic surface waveguide. A film strip 30 is deposited on the substrate 22 to define the waveguide propagation path. Assuming a bismuth germanium oxide substrate, strip 30 is advantageously formed of known materials such as gold or one of the heavy glasses.

As in the previously discussed embodiments, the film overlayer has a thickness which is advantageously a fraction of a wavelength of the highest frequency which is to be propagated. Edges of the strip 30 are tapered to have a decreasing thickness profile from the center of the waveguide propagation path toward the edges of that path in a direction which is perpendicular to the longitudinal axis of the path.

In the embodiment of FIG. 5 the thickness profile is advantageously in the form of a parabola centered on the longitudinal axis of the propagation path. Such a strip waveguide reduces frequency dispersion due to waveguide width limitations in a manner which is analogous to the frequency dispersion reduction for the slot waveguides already described. However, the waveguide of FIG. 5 does not significantly affect frequency dispersion which is due to thickness limitations of the thin film in the surface wave propagation path. In addition, the strip waveguide is normally considered less advantageous than the slot waveguide for many applications because the thin film 30 employed to define the propagation path is usually relatively lossy for the surface propagation wave. The loss factor due to this effect is not significant in the conventional rectangular slot waveguide because the principal propagated energy is transmitted across a portion of the substrate on which there is little or no thin film deposit. In slot waveguides having tapered edges in accordance with the present invention there is, of course, a greater amount of loss than for rectangular slot waveguides because the thin film taper extends into the propagation path. Nevertheless, the loss effect is negligible as compared to the strip waveguide because, even in the slot waveguides with tapered film edges, it has been found that the principal propagated energy is concentrated in the central portion of the waveguide propagation path where there is little or no film deposit and thus relatively minor surface wave attentuation.

In FIG. 6 there is shown a waveguide cross section of the type depicted in prior embodiments but representing a waveguide cross section that is advantageously employed at a point in a slot waveguide propagation path where the path is to turn away from a straight line path. (No such turn is shown in FIG. 1.) In this situation, it is desirable that the portion of an acoustic surface wave front along the outer edge of the curve in the path should propagate somewhat faster than the wave front portion at the inner edge of the curve in order to avoid significant disturbance of the propagation mode. To this end, the tapered edges of the film portions 23′ and 26′ are tapered in a nonsymmetrical fashion about the longitudinal axis of the propagation path. Thus in FIG. 6, wherein linear tapers are illustrated for convenience, the taper on the film portion 23′ includes a larger volume of thin film material than does the taper on film portion 26′. This is achieved by extending the taper on the portion 23′ to approximately the center of the waveguide propagation path while the taper on the film portion 26′ extends to only about one-half of the distance, along a radius of the guide curve, from the edge of the propagation path to the center thereof.

It should perhaps be observed at this point that in the embodiments of FIGS. 2 through 6 the exact dimensions of the film edge grading are not critical. That is, almost any substantial, but relatively gradual, edge thickness grading produces substantial reduction in frequency dispersion as compared to a conventional slot waveguide of rectangular cross section.

The tapered profiles suggested in FIGS. 2 and 3 can be conveniently fabricated by shadow masking the substrate with a wire and then rocking the structure about an axis parallel to and adjacent to the wire during film deposition. The shape of the profile can be varied from parabolic to linear to any of a variety of forms by adjusting the nature of the rocking cycle. If a cycle with a relatively long dwell near normal incidence of film vapor on the substrate is used, the film profile will be a concave slot. If the rocking cycle gives a uniform dwell at all angles, a linear edge taper will result. The maximum angles that the substrate reaches determine the relative width of the edge tapers. If the rocking cycle is made nonsymmetric about the angle of normal film vapor incidence a nonsymmetric slot as in FIG. 6 can be fabricated.

Although the present invention has been described in connection with particular embodiments thereof, it is to be understood that additional embodiments, applications, and modifications thereof which will be apparent to those skilled in the art are included within the spirit and scope of the invention.

What is claimed is:

1. A mass loaded acoustic surface waveguiding structure comprising
- a substrate body capable of propagating elastic surface waves,
- a thin film which perturbs the velocity of said surface waves on the substrate body, said film being deposited on a surface of said body for defining a waveguide region bounded by edge portions of said film, and
- said edge portions having a predetermined graded thickness profile.

2. A mechanically impeded elastic surface waveguiding structure comprising
- a layer of substrate material capable of propagating elastic surface waves at a first velocity,
- a thin overlayer material on said substrate, said overlayer being configured for guiding a multifrequency elastic surface wave at a second velocity, and
- means for reducing waveguide frequency dispersion in said wave, said reducing means including the edges of said overlayer material configured to have the thickness thereof graded in accordance with a predetermined thickness profile.

3. An elastic surface waveguiding structure comprising
- a layer of substrate material capable of propagating elastic surface waves at a first velocity,
- a thin overlayer material on said substrate, said overlayer being configured for guiding an elastic surface wave at a second velocity and including at least two film portions spaced apart across a surface of said substrate material to define a surface wave propagation path between such portions, and
- edges of said overlayer material adjacent to said path having the edge thickness thereof graded in accordance with a predetermined thickness profile.

4. The guiding structure in accordance with claim 2 in which
- said overlayer material includes at least one film strip defining a surface wave propagation path across a surface of said substrate material, and
- edges of said strip along said path being said graded thickness edges.

5. An acoustic surface waveguide comprising
- a substrate layer of material,
- an overlayer on the surface of the said substrate and comprising two portions spaced apart across said surface to define a surface wave propagation path therebetween said surface wave being subject to frequency component dispersion due to differences in energy velocity of different frequency components of such wave along said path, and
- edges of said portions defining said path having graded thickness cross sections, taken in a direction perpendicular to the length of said path, along substantially the full extent of said path.

6. The waveguide in accordance with claim 5 in which
- said substrate material has a relatively slow elastic wave propagation velocity and said overlayer is chosen so the perturbed elastic wave velocity is larger in regions covered by the film than in other regions.

7. The waveguide in accordance with claim 5 in which
- the thickness of said overlayer in a direction perpendicular to said surface of said substrate is less than the thickness of said substrate in the same direction.

8. The waveguide in accordance with claim 5 in which
- said substrate is monocrystalline bismuth germanium oxide, and
- said overlayer is a film of evaporated silicon monoxide.

9. The waveguide in accordance with claim 5 in which
- said graded thickness edges of said overlayer portions are configured to have cross sections forming a substantially linear taper decreasing to zero thickness within said propagation path.

10. The waveguide in accordance with claim 5 in which
- said graded thickness edges are configured to form a slot cross-section profile in the shape of a substantially concave parabola.

11. The waveguide in accordance with claim 5 in which
- said graded thickness edges each includes at least two steps to form overlayer edges of increasing thickness extending laterally away from the center line of said propagation path.

12. The waveguide in accordance with claim 5 in which
- said graded thickness edges have nonsymmetrical grading along at least a portion of said path.

13. The waveguide in accordance with claim 12 in which
- one of said edges in said nonsymmetrical edge portion of said path includes a greater volume of over-

layer material than does the opposite edge in the same portion of said path for turning the wave front of an acoustic surface wave propagated along said path.

14. An elastic surface waveguiding structure comprising

a layer of substrate material capable of propagating elastic surface waves at a first velocity,

a thin overlayer of material on said substrate, said overlayer having mechanical properties chosen in relation to mechanical properties of said substrate material for perturbing the velocity of the elastic surface wave to a different value, and

means for defining a guided wave path for said wave, said defining means including plural edges of said overlayer material having the edge thickness thereof graded in accordance with a predetermined thickness profile extending perpendicularly to said path for defining such path between said plural edges.

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