Improvements in or relating to frequency selective surfaces


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The present invention is related to improvements in or relating to Frequency Selective Surfaces (FSSs), and in particular a frequency selective surface for separating or combining two channels of electromagnetic radiation; to a device incorporating the frequency selective surface, and for a method of the production for the frequency selective surface.

The channels of electromagnetic radiation can be linearly, elliptically or circularly polarised, and the invention is particularly applicable for beamsplitting devices that operate at millimetre and sub-millimetre wavelengths (i.e. with frequencies from around 100 GHz and upwards).

An FSS functions as shown in Figure 1. Figure 1a is a view showing incident, reflected and transmitted beams on a single FSS. An FSS is orientated at 45° to the incident beam. The incident beam 2, having spot frequencies F1 and F2, is separated into a reflected beam 3, having the spot frequency F1, and a transmitted beam 4, having the spot frequency F2. Figure 1b shows the bandpass frequency response of the FSS 1. The FSS 1 can be used in a reflector antenna, either as a dichroic substrate or as a waveguide beamsplitter to allow the antenna to operate at two separate frequency bands. Another option is to use the FSS beamsplitter in the quasi-optical feed train of a multi channel radiometer, to separate the energy by frequency and direct the energy to the spatial location of the individual detectors. The FSS 1 can be used singly or cascaded.

An FSS comprises at least one resonant element, the shape of which is designed to produce desired electrical characteristics. The resonant elements are generally formed by printing onto a substrate, to form patches or apertures. The formed resonant elements, or "slots", can take one of many shapes, for example a simple rectangle, a square, an annulus, or a Jerusalem cross shape.

In the case of an annular slot, it is known that splitting the annular slots modifies the electromagnetic behaviour of the resonant structure, so that the transmission response is very different for two waves which are orthogonally orientated (TE and TM plane polarised waves).

However, for slots which are formed on a substrate, there will always be dielectric losses, which detract from the beamsplitting efficiency of the device.

The paper by N. Misran et al.: "Concentric split ring element for dual frequency reflectarray antennas" ELECTRONICS LETTERS, IEE STEVENAGE, GB, vol. 39, no. 25, 11 December 2003 (2003-12-11), pages 1776-1777, discloses a concentric split ring element, i.e. the resonant surface of a first aperture element is increased significantly when compared to the case where the first aperture element is used on its own. This is because the second aperture element resonates in the same mode as the first aperture element, but at a higher frequency.

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nance aperture element formed therein.

[0025] The tiled structure may prevent propagation of cracks along more than one unit of the array. This increases the robustness and flexibility of the FSS device.

[0026] According to a third aspect of the present invention, there is provided a method of forming a freestanding FSS, comprising the steps of forming a stiffener layer, forming a polymer layer on a first surface thereof, etching a FSS shorted resonance aperture element shape through the stiffener layer and the polymer layer, etching from underneath the resultant FSS element shape to form a freestanding FSS and metallising the FSS.

[0027] Optionally, the method further comprises the step of forming a polymer layer on a second surface of the stiffener layer, and then etching an FSS shorted resonance aperture element shape through the stiffener layer and both polymer layers.

[0028] Optionally, the method further comprises the step of trenching the stiffener and/or the or each polymer layer to form tiles.

[0029] Optionally, the polymer of the or each polymer layer is polyimide or BCB.

[0030] Optionally, the stiffener layer is formed from a semiconductor material.

[0031] Embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figures 1a and 1b illustrate a known FSS and the operation thereof;

Figures 2a and 2b show a transmission response for a prior art FSS;

Figures 3a to 3f show the form and arrangement of resonant elements according to the present invention;

Figure 3g illustrates electric field vector combinations at normal incidence, where theta is the incident angle; 0° is shown;

Figure 4 shows the currents for the modes illustrated in Figure 3;

Figure 5 shows the transmission response of an FSS for a TE and TM 45° incident wave according to an embodiment of the invention;

Figure 6 shows the structure of an FSS layer according to an embodiment of the present invention;

Figure 7 illustrates a first fabrication technique according to an embodiment of the invention; and

Figure 8 illustrates a second fabrication technique according to another embodiment of the invention.

[0032] A resonant FSS element that comprises a continuous annular slot resonates when the circumference of the slot is approximately equal to the wavelength λ of incident radiation, and also to harmonics of λ. A typical frequency response is shown in Figure 2. At the resonant frequency, the element transmits and the passband width is dependent on the incident angle, separation between the elements, the number of layers, the slot width and depth of each array.

[0033] Figure 2a shows the transmission response at normal incidence. It can be seen that in this case, the filter response of the annular slot is independent of the polarisation of the incident radiation. It can be seen that the two plots for transverse electric (TE) and transverse magnetic (TM) radiation coincide.

[0034] However, at oblique incidence the filter response of the annular slot is dependent on the polarisation of the incident radiation. It can be seen that the two plots for transverse electric (TE) and transverse magnetic (TM) radiation coincide.

[0035] A continuous annular slot element shape is suitable for existing substrate based technology but cannot be formed into a freestanding FSS, since the inner disk is not supported.

[0036] However, by splitting the slot, different magnetic current modes can be excited in the element and the mode depends on the orientation of the electric vector in relation to the slot short and the size of the element in relation to the resonant wavelength. This polarization selectivity enables the frequency selective beamsplitting properties of the device to be controlled independently in orthogonal planes of incidence (TE and TM plane), see Figure 4, which shows a typical transmission response for nested shorted annular slots for TE and TM 45° incident waves. In addition, this permits the combination or separation of circularly polarized waves or closely spaced channel demultiplexing of linearly polarized waves.

[0037] The short also provides support for the inner disk allowing the annular slot shape to be used in the freestanding FSS, as shown in Figures 3d, 3e, and 3f.

[0038] Figures 3a to 3f show the form and arrangement of FSS resonant elements according to the present invention.

[0039] In Figures 3a and 3b, the conditions necessary to excite a slot 12, half-wavelength) modes are shown. The currents for the different modes are shown in Figure 4, wherein Figure 4a shows a comparison of currents on a λ mode linear slot (insert) and shorted annular slot, and Figure 4b shows currents on a λ/2 linear mode linear slot which can be similarly mapped onto a λ/2 annular slot. At higher frequencies further modes can be generated such as nλ (where n is 1, 2, 4,...) and nλ/2 (where n is 1, 3, 5,...). A "direction" of the shorted gap in the slot can be considered as a direction tangential to the annular slot taken from a central point of the gap. The λ or nλ mode is excited when the electric vector (E) is orientated parallel to the
metal short, and when the electric vector is orientated perpendicular to the shorted gap, the $\lambda/2$ or $n\lambda/2$ mode is excited. Therefore for a given ring diameter the ratio of the resonant frequencies for $\lambda/2$ TE and $\lambda/2$ TM radiation is 2:1.

[0040] By nesting two similarly orientated rings 16, 18 as shown for example in Figure 3e and reducing the physical size of the inner slot 18 (approximately 50% reduction in the circumference relative to the outer ring at normal incidence), it is possible to excite resonances at the same frequency in both rings. In Figure 3e, the TE electric field vector excites the outer wavelength ring 16, and the TM electric field vector excites the inner half-wavelength ring 18. This means the filter response in the two orthogonal planes (i.e. TE and TM incident radiation) can be independently controlled by varying the relative diameter and short length of the two annular slots 16, 18.

[0041] The transition between the transmission band and reflection band is very much faster for an annular slot operating in the $\lambda/2$ mode compared to a $\lambda$ mode annular slot. However when the two annular slots are nested the roll-off response of the $\lambda$ mode annular slot is increased significantly because the inner ring resonates in the $\lambda$ mode also but at a higher frequency. This is because the reflection band (F1 in Figure 1b) of $\lambda$ ring is sandwiched between the transmission peaks which are generated by the inner and outer rings.

[0042] Another way to achieve this property is to use nested annular slots 20, 22 which both resonate in the $\lambda$ mode, as shown in Figure 3d. Here, TE operates the outer $\lambda$ ring 20 while TM operates inner $\lambda$ ring 22.

[0043] Figure 3g illustrates electric field vector combinations at normal incidence ($\theta = 0^\circ$). The incident angle ($\theta$) can be any angle from $+90^\circ$ to $-90^\circ$.

[0044] It is well known that the resonant frequency of a ring FSS which is orientated at oblique incidence is dependent upon the orientation of the incident wave, and the difference in the resonant frequency is determined by the physical spacing between the elements. Therefore, by increasing the periodicity of an array of ring FSSs, it is possible to reduce the resonant frequency for one orientation of the electric field. Further in this plane the size of the element can be reduced, in cause to make it resonate at the same frequency as the orthogonally polarised wave.

[0045] Then, as shown in Figure 3d, by shorting the individual slots and orientating these at $90^\circ$, it is possible to independently tune the response of the rings elements which are excited in the $\lambda$ mode. It is to be noted that the ring also operates for the other polarised wave in the $\lambda/2$ modes.

[0046] Also by further nesting $\lambda/2$ rings to form a four ring structure, as shown in Figure 3f, it is possible to adjust the roll-off for both outer ring polarisations.

[0047] An FSS device according to the present invention uses one, two or more spaced layers of resonant elements. Each layer consists of a thin laminate composite comprising a conductively coated polymer membrane which covers or encapsulates a stiffening portion. The stiffener material used to form the stiffening portion may be silicon or another suitable semiconductor material. Each layer of resonant elements is perforated with an array of apertures, which function as the slots of the FSSs in the array. Examples of possible aperture shapes are shown in Figure 3.

[0048] When the surface of the layers is surrounded by air, i.e. freestanding FSS, dielectric losses are removed and the highest possible beamsplitting efficiency is obtained.

[0049] For sub millimetre applications the thickness of the individual layers is typically $10\mu$m and therefore a prior art solid metal perforated foil structure may not be robust enough to survive situations where the FSS device is subject to large forces, for example, typical launch forces of a space vehicle.

[0050] The incorporation of silicon stiffener into a polymer membrane gives the aperture elements good structural rigidity, and, as the polymer membrane prevents cantilever droop of the metal inner part of the slot due to the rigidity of the silicon layer. The polymer membrane is flexible and provides a taut drumskinn, and when combined with the rigid stiffener layer gives reduced aperture stretch and distortion when under tensile stress.

[0051] The polymer is formed on one or both sides of the silicon tiles, and the slot pattern etched through the laminate. Metal encapsulation then covers the laminate to provide the outer skin on which the resonant currents are formed. The high conductivity electroplated metal on the outer surface, combined with the freestanding FSS provides very efficient frequency filtering.

[0052] The polymer used is most preferably polyimide or BCB, although other polymer materials could be used, so long as the choice of material allows deformation under high g force without breaking, and returns to its original shape with little or no deformation.

[0053] Silicon is a preferred material as it has sufficient rigidity to support for the inner disk, and also because it can be easily machined to give good dimensional accuracy for the apertures, and also because it has a low coefficient of thermal expansion for good dimensional stability under thermal variation. However, the invention is not limited to the use of silicon, and any other material with similar physical properties could be used, for example, quartz or glass.

[0054] As the silicon is brittle, the silicon wafer can optionally be diced forming an array of tiles. A single tile 24 is shown in Figure 6, which contains ether one slot, multiple slots or more than one nested slots. A layer of polyimide 26 surrounds the tiled silicon wafer 28. The top view of Figure 6 shows nested aperture rings in a unit cell on the embedded silicon tile, while the lower views show sectional views of two different embodiments - a two layer laminate and a three layer laminate version.

[0055] Should a crack form in the silicon during the device’s operation life, it will be contained to the silicon tile 24 where it developed, thereby enhancing the robust-
ness of the array and increasing the elasticity of the FSS device.

Figure 7 illustrates one possible manufacturing technique for creating an FSS device according to one embodiment. In step 1, a silicon on insulator (SOI) wafer 30 is purchased or fabricated. This may have any suitable depth, for example a depth from 5 to 10 micrometers. The silicon layer is then trenched to form tiles 32. This trenching step gives the abovementioned advantages relating to the prevention of crack propagation, but it is an optional step, as the FSS device could be constructed without tiles.

A polymer layer 34, most suitably polyimide or BCB, is then spun on (it could be deposited by another suitable process), suitably having a thickness of five to fifteen micrometers. The FSS element shape is then etched through the polyimide 34 and trenched silicon layers. The array is then etched from underneath to form the freestanding FSS, before a metallization step is performed. The metallization uses a metal chosen for its conductivity characteristics, for example silver, copper, gold or aluminium or some combination of these. Figure 8 illustrates one possible manufacturing technique for creating an FSS device according to another embodiment.

A layer of oxide 36 is grown or deposited onto a substrate 38. In a preferred embodiment, the substrate 38 is silicon and the oxide 36 is silicon oxide. An example of a suitable thickness of a layer to be deposited is two micrometers. A polymer layer 40, most suitably polyimide or BCB, is then deposited, following which a silicon wafer 42 is bonded thereto. The silicon wafer 42 is then thinned to a suitable depth, for example a depth from 5 to 10 micrometers. This is achieved for example using Deep Reactive Ion Etching (DRIE).

The silicon layer 42 is then trenched to form tiles 44. This trenching step gives the above-mentioned advantages relating to the prevention of crack propagation, but it is an optional step, as the FSS device could be constructed without tiles 44.

A further layer of polyimide 46 is then deposited, suitably having a thickness of eight micrometers. The FSS element shape is then etched through the top polyimide layer 46, the silicon layer 42, and the bottom polyimide layer 40. The array is then etched from underneath to form the freestanding FSS, before a metallization step is performed. The metallization uses a metal chosen for its conductivity characteristics, for example silver, copper, gold or aluminium or some combination of these. The methods illustrated in Figures 7 and 8 show that very accurate and complex aperture shapes can be manufactured using existing semiconductor processing techniques.

The FSS of the present invention therefore allows a FSS device to be constructed that has many useful advantages over known FSS technology. The FSS device of the present invention can separate or combine two electromagnetic waves over a defined frequency band, with an efficiency factor which is largely independent of the orientation of the impinging linearly polarised waves.

The FSS device can separate or combine an impinging circularly polarised electromagnetic wave, or two linearly polarised orthogonally orientated electromagnetic waves at two different frequencies; and it can generate a circularly polarised wave from a linearly polarised wave which is oriented at either +/- 45 degrees to the incident plane.

The metallization of the array, together with the fact that the resonance aperture elements are freestanding, means that the FSS device has very low losses.

Various improvements and modifications may be made to the above without departing from the scope of the invention. For example, while the above embodiments refer to a shorted annular slot, it will be apparent that the invention is equally applicable to other slot shapes, such as rectangular or cross-shaped slots, or squares which may be shorted and therefore form a freestanding FSS according to the invention.

Claims

1. A freestanding frequency selective surface (FSS) comprising a plurality of nested resonance aperture elements having at least a first shorted resonance aperture element and a second shorted resonance aperture element nested within the first shorted resonance aperture element, wherein the first shorted resonance aperture element provides a sensitivity to polarisation of TE plane polarised incident radiation, and the second shorted resonance aperture element provides a sensitivity to polarisation of TM plane polarised incident radiation, the TE and TM incident radiation have substantially the same frequency.

2. A FSS according to claim 1 in which the sensitivity of the first shorted resonance aperture element to the polarisation of the TE plane polarised incident radiation causes excitation of a resonance in the first shorted resonance aperture element and transmission of the TE plane polarised incident radiation, and the sensitivity of the second shorted resonance aperture element to the polarisation of the TM plane polarised incident radiation causes excitation of a resonance in the second shorted resonance aperture element and transmission of the TM plane polarised incident radiation.

3. A FSS according to claim 1 or claim 2 in which the first and second shorted resonance aperture elements have relative sizes which provide the polarisation sensitivity of the first shorted resonance aperture element to the polarisation of the TE plane polarised incident radiation and the polarisation sen-
sitivity of the second shorted resonance aperture element to the polarisation of the TM plane polarised incident radiation when the TE and TM incident radiation have substantially the same frequency.

4. A FSS according to claim 3 in which the relative size of the first shorted resonance aperture element to the second shorted resonance aperture element is substantially 2:1.

5. A FSS according to any preceding claim in which the short of each of the first and second shorted resonance aperture elements is orientated to provide the polarisation sensitivity of the first shorted resonance aperture element to the polarisation of the TE plane polarised incident radiation and the polarisation sensitivity of the second shorted resonance aperture element to the polarisation of the TM plane polarised incident radiation when the TE and TM incident radiation have substantially the same frequency.

6. A FSS according to any preceding claim in which the shorted resonance aperture elements comprise at least one short.

7. A FSS according to claim 6 in which the at least one short enables the FSS to be freestanding.

8. A FSS according to any preceding claim in which the plurality of nested resonance aperture elements separate or combine two channels of incident radiation which are very closely spaced in the frequency domain.

9. A FSS according to any preceding claim in which at least some of the shorted resonance aperture elements are substantially circular.

10. A FSS according to claim 9 in which at least some of the circular shorted resonance aperture elements comprise a single short in the circle.

11. A FSS according to any of claims 1 to 8 in which at least some of the shorted resonance aperture elements are substantially rectangular.

12. A FSS according to any preceding claim in which at least some of the shorted resonance aperture elements have a composite structure, and comprise a stiffener layer bounded on at least one surface thereof by a polymer layer.

13. A FSS according to claim 12 in which the stiffener layer and the polymer layer are encapsulated by a metallization layer.

14. A FSS according to claim 12 or claim 13 in which the stiffener layer is formed from a semiconductor material.

15. A FSS according to claim 14 in which the stiffener layer comprises silicon.

16. A FSS according to any of claims 12 to 15 in which the stiffener layer is bounded on both a first surface and a second surface thereof by a polymer layer.

17. A FSS according to any of claim 12 to 16 in which the or each polymer layer comprises polyimide or B-staged bisbenzocyclobutene (BCB).

18. An FSS device comprising at least one array of freestanding frequency selective surfaces according to any of claims 1 to 17.

19. An FSS device according to claim 18 in which a plurality of arrays is provided as one or more spaced layers.

20. An FSS device according to claim 18 or claim 19 which comprises a tiled structure having a plurality of isolated silicon tiles, at least some of the tiles having at least one FSS shorted resonance aperture element formed therein.

21. An FSS device according to claim 20 in which the tiled structure prevents propagation of cracks along more than one unit of the array.

22. A method of forming a freestanding FSS according to any of claims 1 to 21, comprising the steps of forming a stiffener layer, forming a polymer layer on a first surface thereof, etching a FSS shorted resonance aperture element shape through the stiffener layer and the polymer layer, etching from underneath the resultant FSS element shape to form a freestanding FSS and metallising the FSS.

23. A method according to claim 22 which further comprises the step of forming a polymer layer on a second surface of the stiffener layer, and then etching the FSS shorted resonance aperture element shape through the stiffener layer and both polymer layers.

24. A method according to claim 22 or claim 23 which further comprises the step of trenching the stiffener and/or the or each polymer layer to form tiles.

25. A method according to any of claims 22 to 24 in which the polymer of the or each polymer layer is polyimide or BCB.

26. A method according to any of claims 22 to 25 in which the stiffener layer is formed from a semiconductor material.
Patentansprüche

1. Eine freistehende frequenzselektive Oberfläche (FSS), die eine Vielzahl von ineinander geschachtelten Resonanzaperturelementen beinhaltet, welche mindestens ein erstes kurzgeschlossenes Resonanzaperturelement und ein zweites kurzgeschlossenes Resonanzaperturelement, das innerhalb des ersten kurzgeschlossenen Resonanzaperturelementes verschachtelt ist, aufweist, wobei das erste kurzgeschlossene Resonanzaperturelement eine Empfindlichkeit gegenüber der Polarisation einer in der TE-Ebene polarisierten einfallenden Strahlung bereitstellt, und das zweite kurzgeschlossene Resonanzaperturelement eine Empfindlichkeit gegenüber der Polarisation einer in der TM-Ebene polarisierten einfallenden Strahlung bereitstellt, wobei die einfallende TE- und TM-Strahlung im Wesentlichen die gleiche Frequenz aufweisen.


3. FSS gemäß Anspruch 1 oder Anspruch 2, wobei das erste und zweite kurzgeschlossene Resonanzaperturelemente relative Größen aufweisen, die die Polarisationsempfindlichkeit des ersten kurzgeschlossenen Resonanzaperturelementes gegenüber der Polarisation der in der TE-Ebene polarisierten einfallenden Strahlung und die Polarisationsempfindlichkeit des zweiten kurzgeschlossenen Resonanzaperturelementes gegenüber der Polarisation der in der TM-Ebene polarisierten einfallenden Strahlung beeinträchtigen, wenn die einfallende TE- und TM-Strahlung im Wesentlichen die gleiche Frequenz aufweisen.

4. FSS gemäß Anspruch 3, wobei die relative Größe des ersten kurzgeschlossenen Resonanzaperturelementes im Verhältnis zu dem zweiten kurzgeschlossenen Resonanzaperturelement im Wesentlichen 2:1 beträgt.

5. FSS gemäß einem der vorhergehenden Ansprüche, wobei der Kurzschluss jedes der ersten und zweiten kurzgeschlossenen Resonanzaperturelemente ausgerichtet ist, um die Polarisationsempfindlichkeit des ersten kurzgeschlossenen Resonanzaperturelementes gegenüber der Polarisation der in der TE-Ebene polarisierten einfallenden Strahlung und die Polarisationsempfindlichkeit des zweiten kurzgeschlossenen Resonanzaperturelementes gegenüber der Polarisation der in der TM-Ebene polarisierten einfallenden Strahlung bereitzustellen, wenn die einfallende TE- und TM-Strahlung im Wesentlichen die gleiche Frequenz aufweisen.

6. FSS gemäß einem der vorhergehenden Ansprüche, wobei die kurzgeschlossenen Resonanzaperturelemente mindestens einen Kurzschluss beinhalten.

7. FSS gemäß Anspruch 6, wobei der mindestens eine Kurzschluss ermöglicht, dass die FSS freistehend ist.

8. FSS gemäß einem der vorhergehenden Ansprüche, wobei die Vielzahl ineinander geschachtelter Resonanzaperturelemente zwei Kanäle einfallender Strahlung, die in dem Frequenzbereich sehr eng bei- einander liegen, trennt oder kombiniert.

9. FSS gemäß einem der vorhergehenden Ansprüche, wobei mindestens einige der kurzgeschlossenen Resonanzaperturelemente im Wesentlichen kreisförmig sind.

10. FSS gemäß Anspruch 9, wobei mindestens einige der kreisförmigen kurzgeschlossenen Resonanzaperturelemente einen einzelnen Kurzschluss im Kreis beinhalten.

11. FSS gemäß einem der Ansprüche 1 bis 8, wobei mindestens einige der kurzgeschlossenen Resonanzaperturelemente im Wesentlichen rechteckig sind.

12. FSS gemäß einem der vorhergehenden Ansprüche, wobei mindestens einige der kurzgeschlossenen Resonanzaperturelemente eine Verbundstruktur aufweisen und eine Versteifungsschicht, die an mindestens einer Oberfläche davon durch eine Polymerschicht begrenzt ist, beinhalten.

13. FSS gemäß Anspruch 12, wobei die Versteifungsschicht und die Polymerschicht durch eine Metallisierungsschicht eingekapselt sind.

14. FSS gemäß Anspruch 12 oder Anspruch 13, wobei die Versteifungsschicht aus einem Halbleitermaterial gebildet ist.

15. FSS gemäß Anspruch 14, wobei die Versteifungsschicht Silizium beinhaltet.
16. FSS gemäß einem der Ansprüche 12 bis 15, wobei die Versteifungsschicht an sowohl einer ersten Oberfläche als auch einer zweiten Oberfläche davon durch eine Polymerschicht begrenzt wird.

17. FSS gemäß einem der Ansprüche 12 bis 16, wobei die oder jede Polymerschicht Polyimid oder Bisbenzocyclobuten (BCB) im B-Zustand beinhaltet.

18. Eine FSS-Vorrichtung, die mindestens eine Anordnung von freistehenden frequenzselektiven Oberflächen gemäß einem der Ansprüche 1 bis 17 beinhaltet.

19. FSS-Vorrichtung gemäß Anspruch 18, wobei eine Vielzahl von Anordnungen in einer oder mehreren mit Abstand angeordneten Schichten bereitgestellt ist.

20. FSS-Vorrichtung gemäß Anspruch 18 oder Anspruch 19, die eine fliesenartige Struktur mit einer Vielzahl von isolierten Siliziumfliesen beinhaltet, wobei mindestens einige der Fliesen mindestens ein darin gebildetes kurzgeschlossenes FSS-Resonanzaperturelement aufweisen.

21. FSS-Vorrichtung gemäß Anspruch 20, wobei die fliesenartige Struktur eine Ausbreitung von Rissen entlang mehr als einer Einheit der Anordnung verhindert.

22. Ein Verfahren zum Bilden einer freistehenden FSS gemäß einem der Ansprüche 1 bis 21, das die Schritte des Bildens einer Versteifungsschicht, des Bildens einer Polymerschicht auf einer ersten Oberfläche davon, des Ätzens einer Form eines kurzgeschlossenen FSS-Resonanzaperturelements durch die Versteifungsschicht und die Polymerschicht, des Ätzens von unterhalb der resultierenden FSS-Elementform, um eine freistehende FSS zu bilden, und des Metallisierens der FSS beinhaltet.


25. Verfahren gemäß einem der Ansprüche 22 bis 24, bei dem das Polymer der oder jeder Polymerschicht Polyimid oder BCB ist.

26. Verfahren gemäß einem der Ansprüche 22 bis 25, wobei die Versteifungsschicht aus einem Halbleitermaterial gebildet ist.

Revendications

1. Une surface sélective de fréquences (SSF) autonome comprenant une pluralité d’éléments formant ouvertures à résonance emboîtées ayant au moins un premier élément formant ouverture à résonance court-circuitée et un deuxième élément formant ouverture à résonance court-circuitée emboîté au sein du premier élément formant ouverture à résonance court-circuitée, où le premier élément formant ouverture à résonance court-circuitée fournit une sensibilité à une polarisation de rayonnement incident polarisé sur plan TE, et le deuxième élément formant ouverture à résonance court-circuitée fournit une sensibilité à une polarisation de rayonnement incident polarisé sur plan TM, le rayonnement incident sur TE et le rayonnement incident sur TM ont substantiellement la même fréquence.

2. Une SSF selon la revendication 1 dans laquelle la sensibilité du premier élément formant ouverture à résonance court-circuitée à la polarisation du rayonnement incident polarisé sur plan TE amène une excitation d’une résonance dans le premier élément formant ouverture à résonance court-circuitée et une transmission du rayonnement incident polarisé sur plan TM amène une excitation d’une résonance dans le deuxième élément formant ouverture à résonance court-circuitée à la polarisation du rayonnement incident polarisé sur plan TM.

3. Une SSF selon la revendication 1 ou la revendication 2 dans laquelle les premier et deuxième éléments formant ouvertures à résonance court-circuitées présentent des tailles relatives qui fournissent la sensibilité à la polarisation du premier élément formant ouverture à résonance court-circuitée à la polarisation du rayonnement incident polarisé sur plan TE et la sensibilité à la polarisation du deuxième élément formant ouverture à résonance court-circuitée à la polarisation du rayonnement incident polarisé sur plan TM lorsque le rayonnement incident sur TE et le rayonnement incident sur TM ont substantiellement la même fréquence.

4. Une SSF selon la revendication 3 dans laquelle la taille relative du premier élément formant ouverture à résonance court-circuitée par rapport au deuxième élément formant ouverture à résonance court-circuitée est substantiellement de 2/1.
5. Une SSF selon n’importe quelle revendication précédente dans laquelle le court-circuit de chacun des premier et deuxième éléments formant ouvertures à résonance court-circuitées est orienté pour fournir la sensibilité à la polarisation du premier élément formant ouverture à résonance court-circuitée à la polarisation du rayonnement incident polarisé sur plan TE et la sensibilité à la polarisation du deuxième élément formant ouverture à résonance court-circuitée à la polarisation du rayonnement incident polarisé sur plan TM lorsque le rayonnement incident sur TE et le rayonnement incident sur TM ont substantiellement la même fréquence.

6. Une SSF selon n’importe quelle revendication précédente dans laquelle les éléments formant ouvertures à résonance court-circuitées comprennent au moins un court-circuit.

7. Une SSF selon la revendication 6 dans laquelle cet au moins un court-circuit permet à la SSF d’être autonome.

8. Une SSF selon n’importe quelle revendication précédente dans laquelle la pluralité d’éléments formant ouvertures à résonance emboîtées séparent ou combinent deux canaux de rayonnement incident qui sont séparés par un espace très étroit dans le domaine des fréquences.

9. Une SSF selon n’importe quelle revendication précédente dans laquelle au moins certains des éléments formant ouvertures à résonance court-circuitées sont substantiellement circulaires.

10. Une SSF selon la revendication 9 dans laquelle au moins certains des éléments formant ouvertures à résonance court-circuitées comprennent un court-circuit unique dans le cercle.

11. Une SSF selon les revendications 1 à 8 dans laquelle au moins certains des éléments formant ouvertures à résonance court-circuitées sont substantiellement rectangulaires.

12. Une SSF selon n’importe quelle revendication précédente dans laquelle le couche de raidisseur comprise du silicium.

13. Une SSF selon n’importe lesquelles des revendications 12 à 15 dans laquelle la couche de raidisseur est liée à la fois sur une première surface et sur une deuxième surface de celle-ci par une couche en polymère.


15. Un dispositif à SSF comprenant au moins une matrice de surfaces sélectives de fréquences autonomes selon n’importe lesquelles des revendications 1 à 17.

16. Un dispositif à SSF selon la revendication 18 dans lequel une pluralité de matrices sont fournies sous la forme d’une ou de plusieurs couches espacées.

17. Un dispositif à SSF selon la revendication 18 ou la revendication 19 qui comprend une structure en mosaïques présentant une pluralité de mosaïques en silicium isolées, au moins certaines des mosaïques présentant au moins un élément formant ouverture à résonance court-circuitée de SSF formé dans celui-ci.

18. Un dispositif à SSF selon la revendication 20 dans lequel la structure en mosaïques empêche la propagation de fissures le long de plus d’une unité de la matrice.

19. Une méthode pour former une SSF autonome selon n’importe lesquelles des revendications 1 à 21, comprenant les étapes de former une couche de raidisseur, former une couche en polymère sur une première surface de celle-ci, graver une forme d’élément formant ouverture à résonance court-circuitée de SSF à travers la couche de raidisseur et la couche en polymère, graver depuis le dessous la forme d’élément de SSF résultante pour former une SSF autonome et métalliser la SSF.
dication 23 qui comprend de plus l’étape de trancher la couche de raidisseur et / ou la ou chaque couche en polymère pour former des mosaïques.

25. Une méthode selon n’importe lesquelles des revendications 22 à 24 dans laquelle le polymère de la ou de chaque couche en polymère est du polyimide ou du BCB.

26. Une méthode selon n’importe lesquelles des revendications 22 à 25 dans laquelle la couche de raidisseur est formée à partir d’un matériau semi-conducteur.
Fig. 2a

Fig. 2b
Currents mapping of shorted annular slot

max current

λ mode currents on linear slot

min current

Fig. 4a

max

min

Fig. 4b
Fig. 6
Fabrication Approach 1
1. Fabricate or purchase the 5 - 10μm SOI wafer

2. Trench the silicon to form tiles

3. Spin on 8μm of polyimide

4. Etch the FSS element shape through polyimide and silicon

5. Etch underneath the array to form the freestanding FSS

6. Metallise the array

Fig. 7
Fabrication Approach 2
1. Deposit 2μm of oxide
2. Deposit 8μm of polyimide
3. Bond a silicon wafer to the polyimide, thin the silicon to 5 - 10μm using DRIE
4. Trench the silicon to form tiles
5. Deposit another 8μm of polyimide
6. DRIE out the FSS element shapes through the laminated tiles
7. DRIE out the back to form the freestanding FSS
8. Metallise the FSS using high conductivity metal

Fig. 8
REFERENCES CITED IN THE DESCRIPTION

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Non-patent literature cited in the description
