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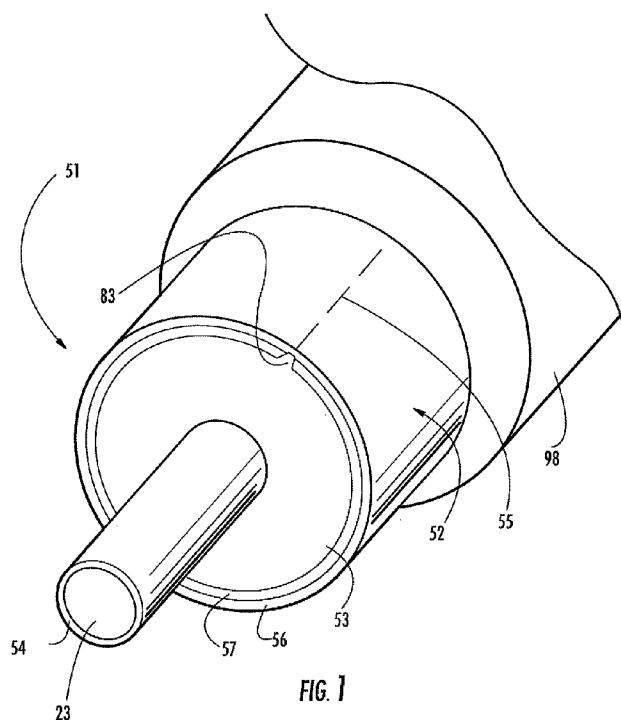
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(54) Title: COAXIAL CABLE INCLUDING TUBULAR BIMETALLIC OUTER LAYER WITH BEVELLED EDGE JOINT AND ASSOCIATED METHODS



(57) Abstract: A coaxial cable may include an inner conductor, an outer conductor, and a dielectric material layer therebetween. The outer conductor may include a tubular bimetallic layer having a pair of opposing longitudinal edges at a longitudinal seam. The tubular bimetallic layer may include an inner metal layer and an outer metal layer bonded thereto with the outer metal layer having a lower melting point than the inner layer. At least one of the opposing longitudinal edges of the tubular bimetallic layer may be at least partially bevelled. In addition, the longitudinal seam may include a welded joint between at least portions of the opposing longitudinal edges.



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European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI,
FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL,
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COAXIAL CABLE INCLUDING TUBULAR BIMETALLIC OUTER LAYER WITH BEVELLED EDGE JOINT AND ASSOCIATED METHODS

Field of the Invention

[0001] The present invention relates to the field of communications, and, more particularly, to coaxial cables and associated methods for making the coaxial cables.

Background of the Invention

[0002] Coaxial cables are widely used to carry high frequency electrical signals. Coaxial cables enjoy a relatively high bandwidth, low signal losses, are mechanically robust, and are relatively low cost. A coaxial cable typically includes an elongate inner conductor, a tubular outer conductor, and dielectric separating the inner and outer conductors. For example, the dielectric may be a plastic foam material. An outer insulating jacket may also be applied to surround the outer conductor.

[0003] One particularly advantageous use of coaxial cable is for connecting electronics at a cellular or wireless base station to an antenna mounted at the top of a nearby antenna tower. For example, the transmitter and receiver located in an equipment shelter may be coupled via coaxial cables to antennas carried by the antenna tower. A typical installation includes a relatively large diameter main coaxial cable extending between the equipment shelter and the top of the antenna tower to thereby reduce signal losses. For example, CommScope, Inc. of Hickory, N.C. offers its CellReach® coaxial cable for such applications.

[0004] In larger diameter coaxial cables, which are commonly used in cellular communication as described above, the elongate inner conductor can be tubular in shape. The tubular inner conductor may also surround an inner

dielectric material. The inner conductor is typically manufactured by forming a flat layer or sheet of conductive material into a tube with a longitudinal seam and welding the seam to form a continuous joint. The outer conductor is also similarly manufactured by forming a flat layer or metal sheet into a tube with a longitudinal seam that is welded to form a continuous joint.

[0005] The high frequency signals carried by the coaxial cable are concentrated in only a small portion, radially outermost, of the inner conductor, and a correspondingly small radially innermost portion of the outer conductor. This characteristic is attributed to the electromagnetic phenomenon called the skin effect. Therefore, only the thin outer radial portion of the tubular inner conductor carries the high frequency transmission. Conversely, the outer tubular conductor also carries the high frequency signals in the thin radially innermost portion.

[0006] Bimetallic layers have been used for the inner and/or outer tubular conductors in a coaxial cable where a higher conductivity and more expensive metal is used to provide the radially outermost portion of an inner conductor, and is used to provide the radially innermost portion of the outer conductor. For example, the outermost layer of the inner conductor may include a relatively costly and highly conductive metal such as copper, and the inner layer of the inner conductor may include a less costly and less conductive metal, such as aluminum. For example, U.S. Patent No. 6,717,493 B2 to Chopra et al. and U.S. Patent Application No. 2004/0118591 A1 to Bufanda et al. each discloses a coaxial cable with such bimetallic tubular inner conductors.

[0007] Notwithstanding the benefits of a bimetal tubular inner conductor, there may be some shortcomings. For example, the manufacture of a bimetal tubular inner conductor usually involves some form of heat based welding, such as for example, conventional induction welding, to weld the seam to form a welded joint. Unfortunately, the two metals that form the bimetal tubular inner conductor usually have different melting temperatures. For example, copper and aluminum are commonly used as the outer and inner layers of the

inner conductor, respectively. Copper has a melting point of 1100°C and a conductivity of $59.6 \times 10^6 \text{ S}\cdot\text{m}^{-1}$, while aluminum has a lower melting point of 660°C and a lower conductivity of $37.8 \times 10^6 \text{ S}\cdot\text{m}^{-1}$. This disparity in melting points makes welding of the joint relatively difficult.

[0008] In response to this particular shortcoming in manufacture of bimetal tubular inner conductors, coaxial cable manufacturers have developed a coaxial cable with a bimetal tubular inner conductor comprising an inlaid bimetallic layer, such as disclosed, for example, in U.S. Patent No. 6,342,677 to Lee. This coaxial cable is more easily welded since only the inner metal layer is welded during manufacture of the bimetal tubular inner conductor. Nonetheless, the inlaid bimetal inner conductor is relatively costly to manufacture. Of course, similar considerations apply to the outer conductor of a coaxial cable. That is a conventional bimetallic layer may be difficult to weld, and an inlaid bimetallic layer may be relatively expensive.

Summary of the Invention

[0009] In view of the foregoing background, it is therefore an object of the present invention to provide a coaxial cable including an outer conductor fabricated using a less expensive tubular bimetallic layer that is also readily welded at its longitudinal seam

[0010] This and other objects, features and advantages in accordance with the present invention are provided by a coaxial cable comprising an outer conductor including a tubular bimetallic layer having a pair of opposing longitudinal edges at a longitudinal seam. The tubular bimetallic layer may comprise an inner metal layer and an outer metal layer bonded thereto with the outer metal layer having a lower melting temperature than the inner metal layer. At least one of the opposing longitudinal edges of the tubular bimetallic layer may be at least partially bevelled. In addition, the longitudinal seam may comprise a welded joint between at least portions of the opposing longitudinal edges. Accordingly, a less expensive starting material may be used for the outer conductor, that is, a simple bimetallic strip with one or both edges bevelled, as compared to the more expensive inlaid bimetallic strip, for

example. The at least one bevelled edge may advantageously permit the lower melting temperature metal edges to be softened and pressed together to form the welded joint, while the higher melting temperature edges may remain solid, at least initially separated, and thereby not interfere with the welding of the lower temperature metal edges.

[0011] In some embodiments, each longitudinal edge of the tubular bimetallic layer may be at least partially bevelled to define a notch at the longitudinal seam. For example, the at least one opposing longitudinal edge may be at least partially bevelled at an angle from normal to an outer surface of the tubular bimetallic layer in a range of between 20 and 70 degrees.

[0012] The inner metal layer may have a greater electrical conductivity than the outer metal layer. For example, the outer metal layer may comprise aluminum, and the inner metal layer may comprise copper.

[0013] The tubular bimetallic layer may have a thickness in a range of about 0.005 to 0.050 inches. In addition, the inner metal layer may have a percentage thickness relative to an overall thickness of the tubular bimetallic layer in a range of about 1 to 30%.

[0014] The coaxial cable may further comprise another dielectric material layer filling the inner conductor. The cable may also further include an insulating jacket surrounding the outer conductor.

[0015] A method aspect is for making a coaxial cable comprising an inner conductor, an outer conductor and a dielectric material layer therebetween. The method may include forming the inner conductor, forming the dielectric layer surrounding the inner conductor and forming the outer conductor surrounding the dielectric layer. Forming the outer conductor may include forming at least forming a bimetallic strip into a tubular bimetallic layer having a pair of opposing longitudinal edges at a longitudinal seam with the tubular bimetallic layer comprising an inner metal layer and an outer metal layer bonded thereto and with the outer metal layer having a lower melting temperature than the inner metal layer, and at least one of the opposing longitudinal edges of the tubular bimetallic layer being at least partially

bevelled. Forming the outer conductor may further include welding the longitudinal seam to form a welded joint between at least portions of the opposing longitudinal edges.

Brief Description of the Drawings

[0016] FIG. 1 is a perspective end view of a coaxial cable in accordance with the present invention.

[0017] FIG. 2 is an enlarged cross-sectional view of a portion of a tubular bimetallic outer conductor of the coaxial cable of FIG. 2 shown prior to welding.

[0018] FIG. 3 is a cross-sectional view of the portion of the tubular bimetallic outer conductor of FIG. 2 shown after welding.

[0019] FIG. 4 is an enlarged cross-sectional view of a portion of a tubular bimetallic outer conductor of a coaxial cable of another embodiment shown prior to welding.

[0020] FIG. 5 is a cross-sectional view of the portion of the tubular bimetallic outer conductor of FIG. 4 shown after welding.

[0021] FIG. 6 is a schematic diagram of a portion of yet another embodiment of an apparatus for making the coaxial cable in accordance with the present invention.

Detailed Description of the Preferred Embodiments

[0022] The present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which preferred embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like numbers refer to like elements throughout, and prime notation is used to indicate similar elements in alternative embodiments.

[0023] Referring initially to FIGS. 1-3, an embodiment of a cable **51** is described. The coaxial cable **51** illustratively includes an outer conductor **52**

comprising a tubular bimetallic layer **84**. The coaxial cable **51** illustratively includes an inner conductor **54** and an outer conductor **52** with a dielectric material layer **53** between the conductors. A dielectric rod or filling **23** is illustratively within the tubular inner conductor **54**, although in other embodiments, the tubular inner conductor may be hollow or solid as will be appreciated by those skilled in the art. The outer conductor **52** illustratively includes a tubular bimetallic layer **84** having a pair of opposing longitudinal edges **81, 82** at a longitudinal seam **55**.

[0024] The tubular bimetallic layer **84** illustratively comprises an inner metal layer **57** and an outer metal layer **56** bonded thereto. The metal comprising the outer metal layer **56** may have a lower melting point, lower electrical conductivity, and lower cost, for example, than the metal comprising the inner metal layer **57**. The lower melting temperature of the outer metal layer **56** facilitates welding, for example, as described in detail below. The outer metal layer **56** may comprise aluminum or any other suitable metal as will be appreciated by one skilled in the art. The inner metal layer **57** may comprise copper or any other suitable metal as will be appreciated by one skilled in the art. The inner metal layer **57** may have a higher electrical conductivity than the outer metal layer **56** to facilitate signal carrying ability at the skin depth, for example.

[0025] In the illustrated embodiment, both of the opposing longitudinal edges **81, 82** of the tubular bimetallic layer **84** are bevelled at least prior to welding, and the longitudinal seam **55** illustratively includes a welded joint **91** (FIGS. 1 and 3) between at least portions of the outer metal layer **56**. Prior to welding, as illustrated in FIG. 2, the edges of the outer metal layer **56** may be touching or more closely spaced than the edges of the inner metal layer **57**. Furthermore, when both of the opposing longitudinal edges of the tubular bimetallic layer **84** are bevelled, the bevelled opposing longitudinal edges may define an inverted V-shaped notch **83** at the longitudinal seam **55**. The opposing longitudinal edges **81, 82** may be bevelled at an angle from normal

to an outer surface of the tubular bimetallic layer **84** in a range of between 20 and 70 degrees.

[0026] The welding of the opposing longitudinal edges **81**, **82** of the tubular bimetallic layer **84** results in a welded joint **91**. The welding can be accomplished through induction welding or any other suitable method as will be appreciated by one skilled in the art. Alternatively, the opposing longitudinal edges **81**, **82** of the tubular bimetallic layer **84** may define a flush meeting joint, an inwardly protruding outer metal layer portion, or an inwardly protruding outer metal layer portion that is subsequently trimmed in other embodiments.

[0027] The bevelled edges may advantageously permit the lower melting temperature metal edges to be softened and pressed together to form the welded joint **91**, while the higher melting temperature edges may remain solid, at least initially separated, and thereby not interfere with the welding of the lower temperature metal edges. Advantageously, the welding process can be matched to the characteristics of only the outer metal layer **56**, which is typically more easily welded due to the lower melting temperature. The coaxial cable illustratively includes an insulating jacket **98** surrounding the outer conductor **52**.

[0028] The exemplary dimensions of the tubular bimetallic layer **84** are as follows. The tubular bimetallic layer **84** may have a thickness in a range of about 0.005 to 0.050 inches. In addition, the inner metal layer **57** may have a percentage thickness relative to an overall thickness of the tubular bimetallic layer **84** in a range of about 1 to 30%.

[0029] Referring now additionally to FIGS. 4 and 5, another embodiment is now described. In this embodiment of the coaxial cable **51'**, those elements already discussed above with respect to FIGS. 1-3 are given prime notation and most require no further discussion herein. This embodiment differs from the previous embodiment in that only one of the longitudinal edges **81'**, **82'** of the tubular bimetallic layer **84'** is bevelled.

[0030] Referring now additionally to FIG. 6, another apparatus and method aspect is directed to making the coaxial cable **51** including an outer conductor **52** comprising tubular bimetallic layer **84**, and with at least one bevelled edge. The supply reel **142** of bimetallic strip, which can be provided with at least one longitudinal edge being bevelled, and inner conductor **144** are fed into the tube former **143**. The tube former **143** illustratively forms the bimetallic strip into an outer conductor having tubular bimetallic layer having a pair of opposing longitudinal edges at a longitudinal seam. The method can be modified to provide a supply reel of bimetallic strip and a beveller **145**, shown with phantom lines, to illustratively bevel at least one longitudinal edge of the bimetallic strip.

[0031] Many modifications and other embodiments of the invention will come to the mind of one skilled in the art having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is understood that the invention is not to be limited to the specific embodiments disclosed, and that modifications and embodiments are intended to be included within the scope of the appended claims.

THAT WHICH IS CLAIMED IS:

1. A coaxial cable comprising:
an inner conductor, an outer conductor and a dielectric material layer therebetween;
said outer conductor comprising a tubular bimetallic layer having a pair of opposing longitudinal edges at a longitudinal seam;
said tubular bimetallic layer comprising an inner metal layer and an outer metal layer bonded thereto with said outer metal layer having a lower melting temperature than said inner metal layer;
at least one of said opposing longitudinal edges of said tubular bimetallic layer being at least partially bevelled;
the longitudinal seam comprising a welded joint between at least portions of said opposing longitudinal edges.
2. A coaxial cable according to Claim 1 wherein each longitudinal edge of said tubular bimetallic layer is at least partially bevelled to define a notch at the longitudinal seam.
3. A coaxial cable according to Claim 1 wherein the at least one opposing longitudinal edge is at least partially bevelled at an angle from normal to an outer surface of said tubular bimetallic layer in a range of between 20 and 70 degrees.
4. A coaxial cable according to Claim 1 wherein said inner metal layer has a greater electrical conductivity than said outer metal layer.
5. A coaxial cable according to Claim 1 wherein said outer metal layer comprises aluminum.
6. A coaxial cable according to Claim 1 wherein said inner metal layer comprises copper.
7. A coaxial cable according to Claim 1 wherein said tubular bimetallic layer has a thickness in a range of about 0.005 to 0.050 inches.

8. A coaxial cable according to Claim 1 wherein said inner metal layer has a percentage thickness relative to an overall thickness of said tubular bimetallic layer in a range of about 1 to 30%.

9. A coaxial cable according to Claim 1 further comprising another dielectric material layer filling said inner conductor.

10. A coaxial cable according to Claim 1 further comprising an insulating jacket surrounding said outer conductor.

11. A coaxial cable comprising:
an inner conductor, an outer conductor and a dielectric material layer therebetween;
said outer conductor comprising a tubular bimetallic layer having a pair of opposing longitudinal edges at a longitudinal seam;
said tubular bimetallic layer comprising an inner copper layer and an outer aluminum layer bonded thereto;
each of said opposing longitudinal edges of said tubular bimetallic layer being at least partially bevelled at the longitudinal seam;
the longitudinal seam comprising a welded joint between at least portions of said outer aluminum layer.

12. A coaxial cable according to Claim 11 wherein each opposing longitudinal edge is at least partially bevelled at an angle from normal to an outer surface of said tubular bimetallic layer in a range of between 20 and 70 degrees.

13. A coaxial cable according to Claim 11 wherein said wherein said tubular bimetallic layer has a thickness in a range of about 0.005 to 0.050 inches.

14. A coaxial cable according to Claim 11 wherein said outer aluminum layer has a percentage thickness relative to an overall thickness of said tubular bimetallic layer in a range of about 1 to 30%.

15. A coaxial cable according to Claim 11 further comprising another dielectric material layer filling said inner conductor.

16. A coaxial cable according to Claim 11 further comprising an insulating jacket surrounding said outer conductor.

17. A method for making a coaxial cable comprising an inner conductor, an outer conductor and a dielectric material layer therebetween, the method comprising:

forming the inner conductor;

forming the dielectric layer surrounding the inner conductor; and

forming the conductor surrounding the dielectric layer by at least

forming a bimetallic strip into a tubular bimetallic

layer having a pair of opposing longitudinal edges at a

longitudinal seam, the tubular bimetallic layer comprising an

inner metal layer and an outer metal layer bonded thereto with

the outer metal layer having a lower melting temperature than

the inner metal layer, and at least one of the opposing

longitudinal edges of the tubular bimetallic layer being at least

partially bevelled,

welding the longitudinal seam to form a welded

joint between at least portions of the opposing longitudinal

edges.

18. A method according to Claim 17 wherein each longitudinal edge of the tubular bimetallic layer is bevelled to define a V-shaped notch at the longitudinal seam prior to welding.

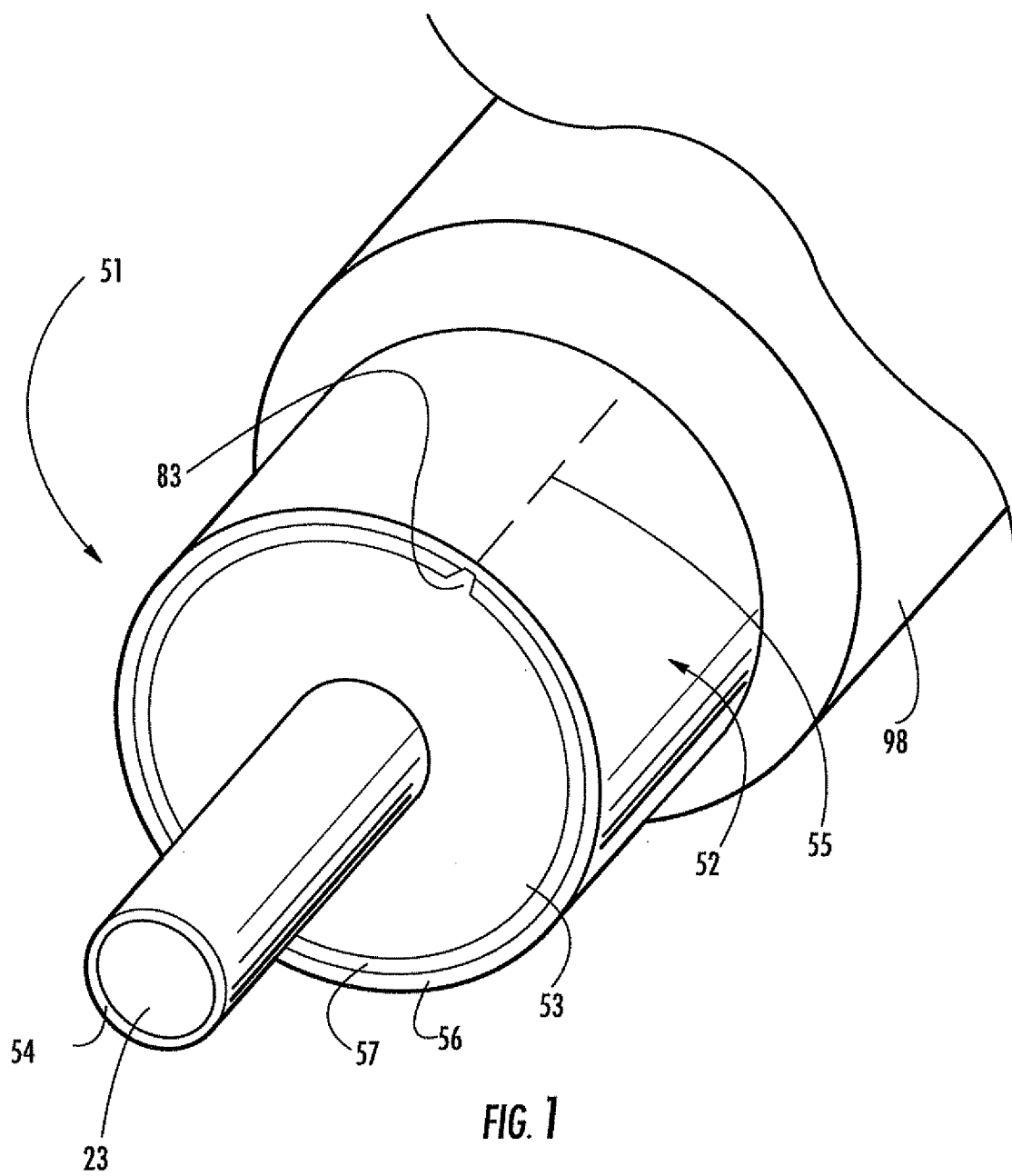
19. A method according to Claim 17 wherein the at least one opposing longitudinal edge is bevelled at an angle from normal to an outer surface of the tubular bimetallic layer in a range of between 20 and 70 degrees.

20. A method according to Claim 17 wherein the outer metal layer comprises aluminum, and wherein the inner metal layer comprises copper.

21. A method according to Claim 17 wherein the wherein the tubular bimetallic layer has a thickness in a range of about 0.005 to 0.050 inches.

22. A method according to Claim 17 wherein the inner metal layer has a percentage thickness relative to an overall thickness of the tubular bimetallic layer in a range of about 1 to 30%.

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2/4

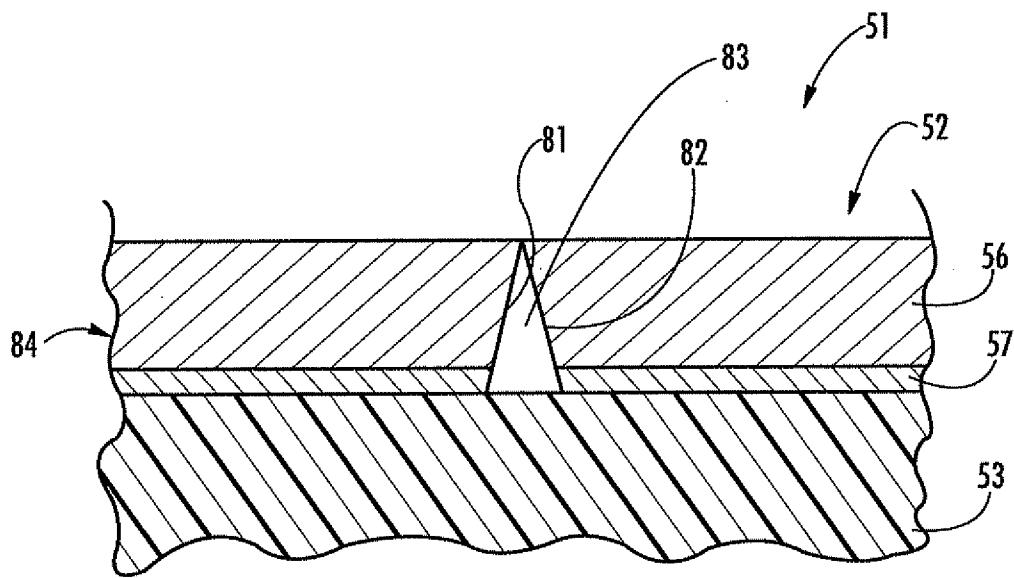


FIG. 2

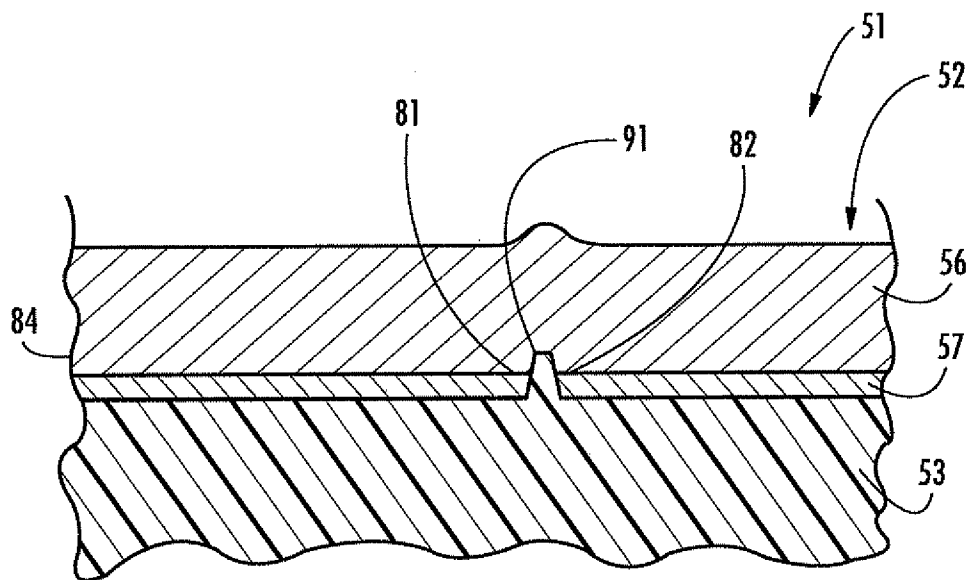


FIG. 3

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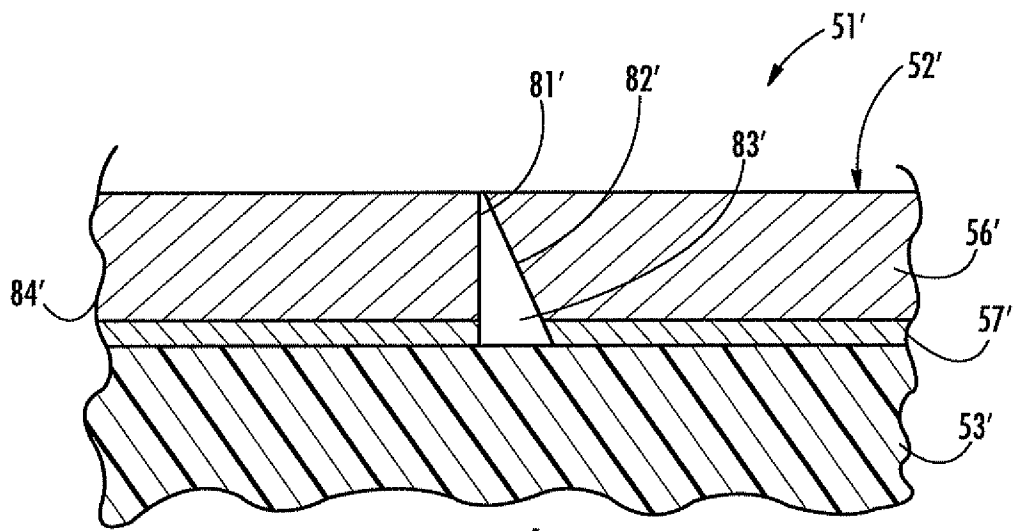


FIG. 4

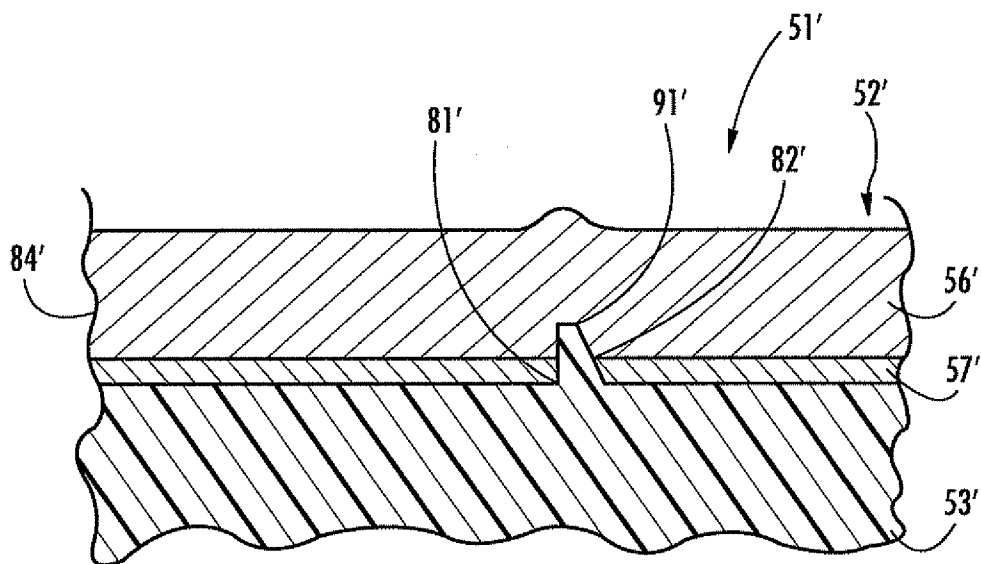


FIG. 5

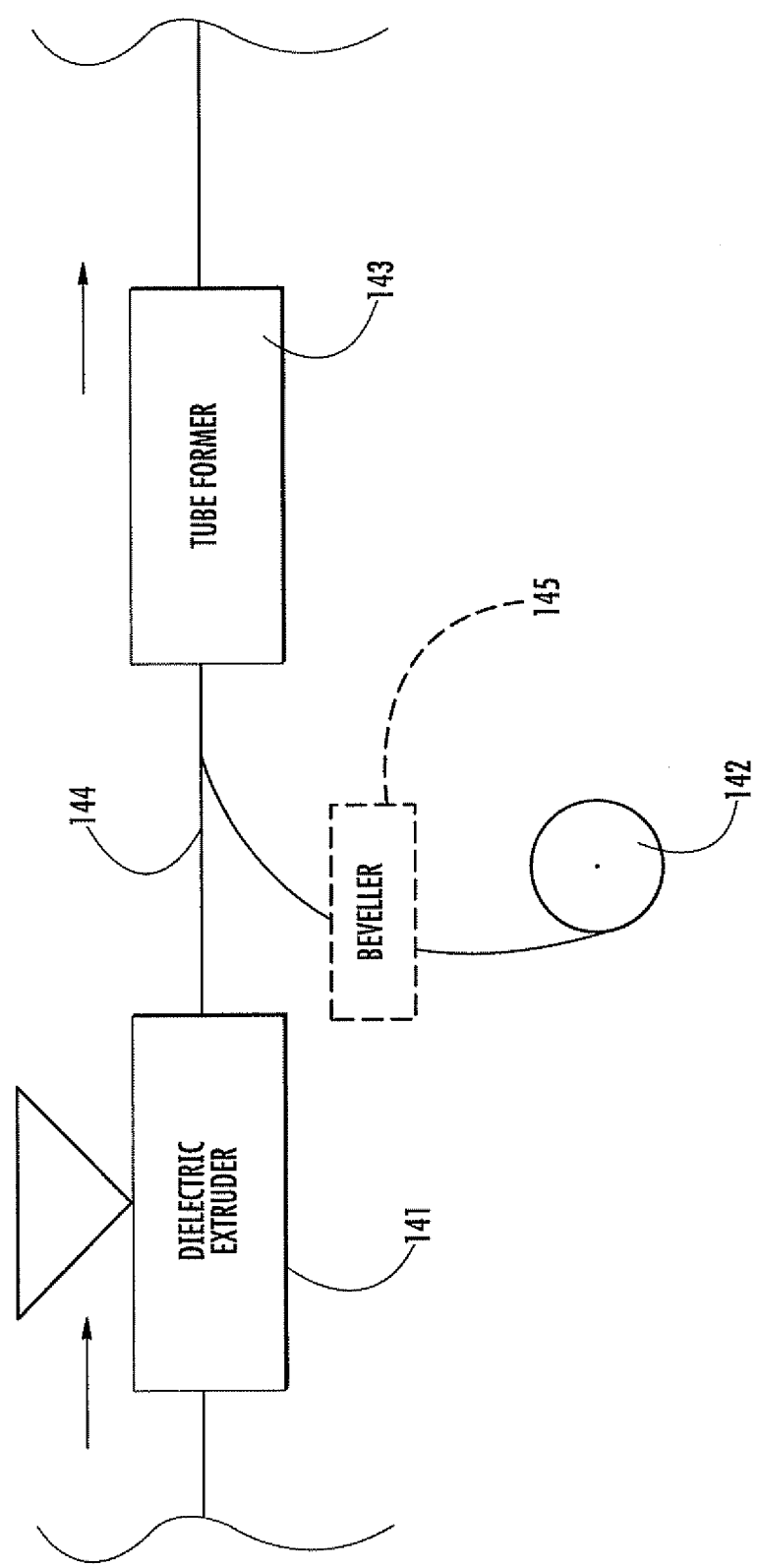


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No
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A. CLASSIFICATION OF SUBJECT MATTER

INV. H01B11/18 H01B13/26 B23K9/025

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H01B B23K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 1 469 486 A (COPPERWELD BIMETALLIC PRODUCTS [US] DOFASCO TUBULAR PRODUCTS CORP [US]) 20 October 2004 (2004-10-20) paragraph [0017] - paragraph [0020]; figures 3-6	1-22
A	US 3 940 049 A (RICHTER ULF ET AL) 24 February 1976 (1976-02-24) column 6, line 47 - line 54; figure 5	1,11,17

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:

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Date of the actual completion of the international search

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2008/086223

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