

July 17, 1951

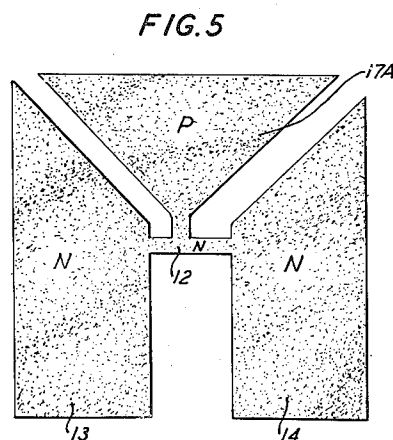
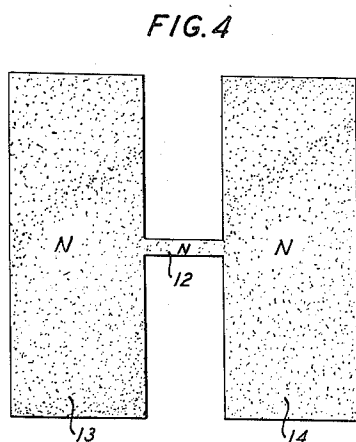
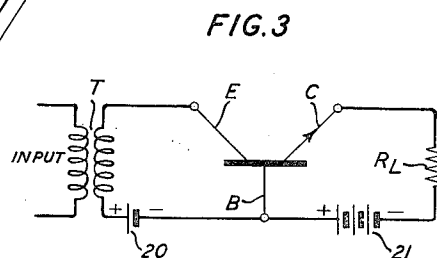
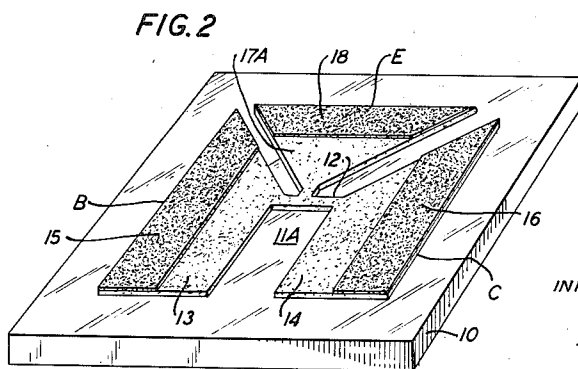
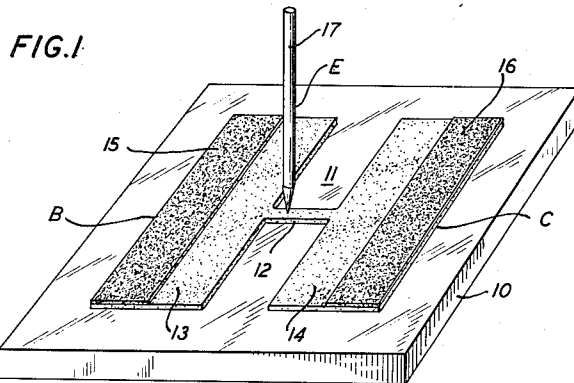
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2,560,594

SEMICONDUCTOR TRANSLATOR AND METHOD OF MAKING IT

Filed Sept. 24, 1948

2 Sheets-Sheet 1



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SEMICONDUCTOR TRANSLATOR AND METHOD OF MAKING IT

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FIG. 6

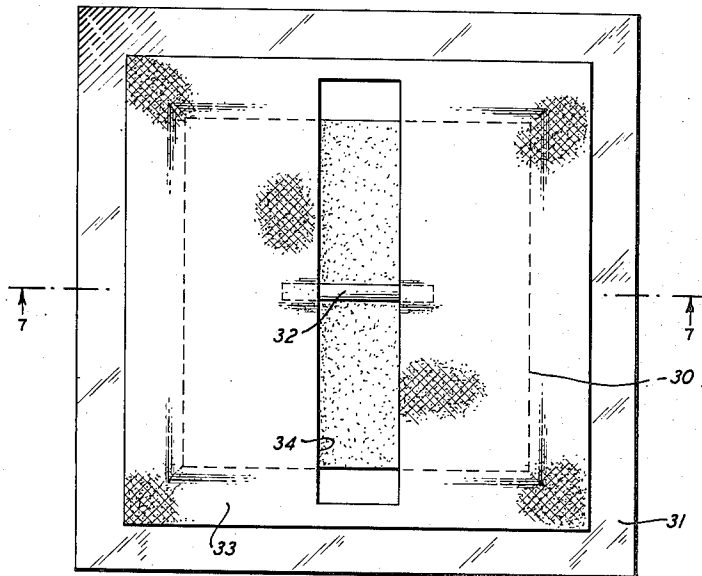


FIG. 7

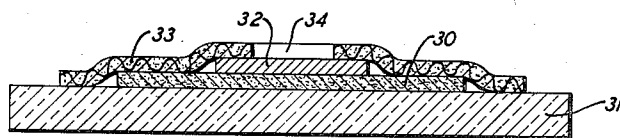


FIG. 8

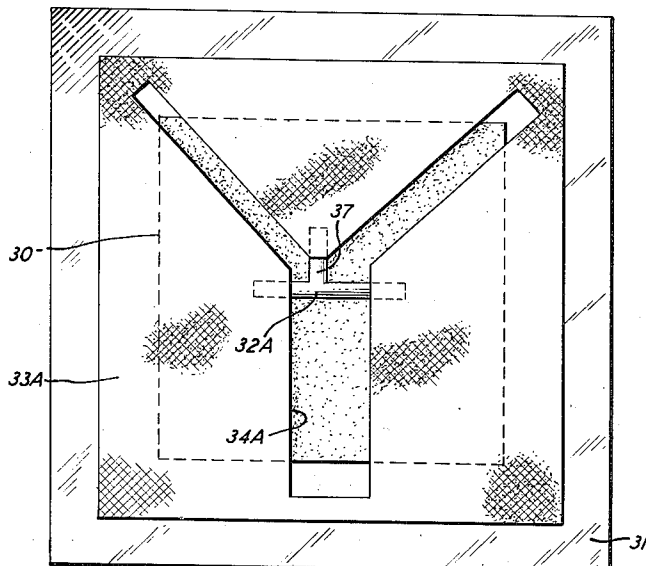
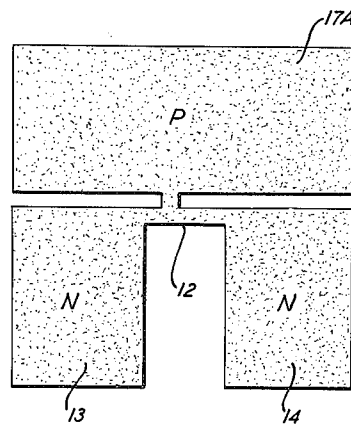


FIG. 9



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SEMICONDUCTOR TRANSLATOR AND
METHOD OF MAKING IT

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Application September 24, 1948, Serial No. 50,896

14 Claims. (Cl. 175—366)

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This invention relates to devices for translating or controlling electrical signals and to methods of making such devices, and more particularly to semiconductor circuit elements of the type disclosed in the application Serial No. 50,897, filed September 24, 1948, of G. L. Pearson and W. Shockley, now Patent No. 2,502,479, and methods of making such elements.

One general object of this invention is to improve semiconductor type translators suitable for translating or controlling, for example amplifying, generating or modulating, electric signals.

More specific objects of this invention are to simplify the construction of such translators, increase the ruggedness and stability thereof, enable and facilitate the fabrication of semiconductor circuit elements of small dimensions and expedite the manufacture of circuit elements of semiconductive material and including two or more portions of different electrical properties.

One feature of this invention involves a translating device comprising a body of insulating material having a thin semiconductor secured thereto, the semiconductor comprising a filament having at least one enlarged end section, means for making connections to opposite ends of the filament, and means for making a rectifying connection to the filament intermediate of the end connections.

Another feature of this invention includes fabricating steps by which a body of semiconductive material is shaped into a filament having one or more enlarged portions integral therewith.

Another feature of this invention pertains to methods of making semiconductive circuit elements of prescribed configurations and having portions of small and preassigned dimensions.

A further feature of this invention relates to methods of readily altering the electrical characteristics of prescribed limited portions of a body of semiconductive material to produce rectifying junctions between contiguous parts of the body.

Other objects and features of this invention will appear more fully and clearly from the following description of illustrative embodiments thereof taken in connection with the appended drawings in which:

Fig. 1 is a diagrammatic view of one illustrative embodiment of the invention;

Fig. 2 is a diagrammatic view of another illustrative embodiment of the invention;

Fig. 3 is a circuit diagram illustrating one way in which the devices of Figs. 1 and 2 may be employed;

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Fig. 4 is a plan view of a semiconductor element, such as is used in the device of Fig. 1;

Fig. 5 is a plan view of a semiconductive element, such as is used in the device of Fig. 2;

Fig. 6 is a plan view of apparatus which may be used in making a semiconductor element as shown in Figs. 1 and 4;

Fig. 7 is a sectional view on line 7—7 of Fig. 6;

Fig. 8 is a plan view of apparatus which may be used in making a semiconductor element as shown in Figs. 2 and 5; and

Fig. 9 is a plan view of a semiconductive element similar to the one shown in Fig. 5.

As an aid to a better understanding of the description of specific embodiments of this invention, a brief discussion of pertinent principles and phenomena, and an explanation of certain terms employed in the description, are in order.

As is known, see for example "Crystal Rectifiers" by H. C. Torrey and C. A. Whitmer, volume 15 of the M. I. T. Radiation Laboratories series, there are two kinds of semiconduction, referred to as intrinsic and extrinsic. Although some of the semiconductive materials contemplated within the purview of this invention may exhibit both kinds of semiconduction, the kind referred to as extrinsic is of principal import.

Semiconduction may be classified also as of two types, one known as conduction by electrons or by the excess process of conduction and the other known as conduction by holes or the defect process of semiconduction. The term "holes," which refers to carriers of positive electric charges as distinguished from carriers, such as electrons, of negative charges, is more fully explained in the application of W. Shockley, Serial No. 35,423 filed June 26, 1948.

Semiconductors which have been found suitable for use in devices of this invention include germanium and like materials containing minute quantities of significant impurities which comprise one way of determining the conductivity type (either N or P-type) of the semiconductive material. The conductivity type may also be determined by energy relations within the semiconductor. For a more detailed explanation, reference is made to the application of J. Bardeen and W. H. Brattain Serial No. 33,466 filed June 17, 1948, now Patent No. 2,524,035.

The terms N-type and P-type are applied to semiconductive materials which tend to pass current easily when the material is respectively negative or positive with respect to a conductive connection thereto and with difficulty when the

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reverse is true, and which also have consistent Hall and thermoelectric effects.

The expression "significant impurities" is here used to denote those impurities which affect the electrical characteristics of the material such as its resistivity, photosensitivity, rectification and the like, as distinguished from other impurities which have no apparent effect on these characteristics. The term "impurities" is intended to include intentionally added constituents as well as any which may be included in the basic material as found in nature or as commercially available.

The term "barrier" or "electrical barrier" used in the description and discussion of devices in accordance with this invention is applied to a high resistance interfacial condition between contacting semiconductors of respectively opposite conductivity types or between a semiconductor and a metallic conductor whereby current passes with relative ease in one direction and with relative difficulty in the other.

For a further discussion of devices of this character, reference is made to the applications of W. Shockley and of G. L. Pearson and W. Shockley previously noted.

Semiconductive material suitable for use in devices in accordance with this invention are germanium material prepared in accordance with methods disclosed in the application of J. H. Scaff and H. C. Theuerer Serial No. 638,351 filed December 29, 1945, and silicon material prepared in accordance with United States Patents 2,402,661 and 2,402,662 to R. S. Ohl, and the application of J. H. Scaff and H. C. Theuerer Serial No. 793,744 filed December 24, 1947.

The devices to be described are relatively small which has necessitated some exaggeration of proportions in the interest of clarity in the illustrations.

The device shown in Fig. 1 comprises a slab 10 of glass or other suitable insulating material on which the semiconductor element 11 is mounted centrally of one face by an adhesive, such as sealing wax or the like. Germanium containing significant impurities, such as used for point contact rectifiers or other suitable semiconductive material having similar characteristics, may be used for the element 11. This element has an attenuated or filamentary portion 12 and large area end portions 13 and 14. These end portions are provided with electrodes 15 and 16, respectively, which may be metallic films of solder, electroplated metal or the like. A typical device may be .005 inch thick throughout with a filamentary section .005 inch wide and .025 inch long, the end portions being .050 inch by .125 inch, the proportions being as shown in Fig. 4.

A pointed metal electrode 17 of tungsten, phosphor bronze or like suitable metal makes rectifying contact to the filament 12. This electrode may be like the "whisker" used in point contact rectifiers and may be similarly mounted if so desired.

The device illustrated in Fig. 2 comprises a slab 10 of insulating material, such as glass or other suitable material, on which is mounted a semiconductor element 11A. The adhesive used for mounting may be sealing wax or the like or, where a high temperature adhesive is required, may be of sodium silicate and finely divided aluminum oxide, or other suitable high temperature adhesive.

This element has an attenuated or filamentary portion 12 and large area end portions 13 and 14

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provided with electrodes 15 and 16 as in the device of Fig. 1.

In place of the metallic point electrode 17 of Fig. 1, this embodiment employs an extension 17A on the side of the filament 12. This extension is of semiconductive material of opposite conductivity type to that of the filament 12. For example, if the filament is of N-type material the extension is of P-type material. The extension 17A may be provided with an electrode 18 like the electrodes 15 and 16.

In Fig. 3 there is shown a circuit in which the devices of Figs. 1 and 2 may be used. In order to correlate Figs. 1, 2 and 3 the corresponding electrodes of each have been labeled E, B and C, respectively, to denote them as emitter, base and collector connections in accordance with nomenclature used with respect to devices of this type. The emitter E is connected through the secondary 20 of transformer T and battery 20 to the base B. The collector C is connected through a load resistor R_L and battery 21 to the base B. With a relatively small bias (0.1 to 1 volt) on E and a relatively large bias of the order of 10 to 100 volts on C, a signal introduced through the transformer T appears considerably amplified across the load resistor R_L . With semiconductor units as shown in Figs. 4 and 5 comprising primarily N-type material, the biases are as shown in Fig. 3, i. e., positive on the emitter and negative on the collector. If P-type material is used, the biases will be reversed and the stub or projection on the filament as in Figs. 2 and 5 will be of N-type material.

To make an element as shown in Fig. 4 for a device such as the one illustrated in Fig. 1, a thin slab of semiconductor, such as high back voltage, rectifier germanium, may be used. An illustrative size is a 0.125 inch square somewhat more than 0.005 inch thick.

One side of the slab is ground smooth and this side may be now etched with a suitable etchant such as the one subsequently indicated, and cemented to a flat plate of glass using sealing wax or another suitable adhesive. The etching of this part of the device may also be done later as will be subsequently indicated. After mounting the slab is then grounded to a uniform thickness, for example of the order of 0.005 inch.

Metallic films which are to serve as electrodes may now be applied or may be applied later. These films may be electroplated rhodium, copper or other suitable metal, or films of solder or other conductive material that may be suitably applied without damage to the semiconductor. If solder is used, a high temperature adhesive between the element and the backing plate must be used or the element removed from the plate for soldering.

If the slab is removed for soldering, after the electrodes are applied, they are covered with a mask such as a polystyrene film and the back of the slab is etched, if this has not been done previously as indicated above.

The etchant may be one used for preparing crystal rectifier surfaces and may comprise 10 cubic centimeters of nitric acid, 5 cubic centimeters of hydrofluoric acid and 200 milligrams of copper nitrate in 10 cubic centimeters of water applied for one to four minutes. The etchant is then washed from the slab and the slab is then dried.

The semiconductive slab is then remounted on the glass plate for subsequent processing. If a high temperature adhesive is used or the elec-

trodes are applied by a "cold" method, e. g., electroplating, the back of the slab will be etched after the first grinding and no removal and subsequent mounting is required.

The mounted or remounted slab is then masked to protect certain parts from the subsequent abrading.

As shown in Figs. 6 and 7, the semiconductive slab 30, mounted on the glass plate 31, is covered with a mask comprising a metal member 32 which, in a specific case, may be of 0.005 inch nickel wire, and an adhesive coated fabric 33. The material commonly called "adhesive tape" will serve. The fabric part of the mask is provided with an opening 34 which is of the same width as the required length of the filamentary portion 12 (Figs. 1 and 4) of the semiconductor element, which is .025 inch in the case illustrated. The opening 34 is long enough to extend beyond the semiconductive slab on both sides.

The unmasked semiconductive material is then completely removed. This may be done by abrading with a blast of grit such as 180 mesh silicon carbide at from 10 to 15 pounds air pressure. A blasting for four or five minutes will usually remove all of the material necessary. The abrading may be carried slightly into the glass plate to assure "clean" bottom edges on the semiconductor.

The adhesive on the mask may then be made non-adhesive by suitable means and the mask removed. If a rubber base adhesive tape is used, immersion in toluene will serve.

Other masking means may be used. For example, a complete metallic mask having a recess for receiving the slab may be clamped onto the glass plate.

After the element is completely shaped and the mask removed, any blasting grit and other debris may be cleaned off and the front of the element then etched with a suitable etchant such as the one previously noted.

The element and its backing may be mounted in a suitable holder (not shown) and a point contact as 17 in Fig. 1 may be applied thereto to complete the unit.

To make a semiconductor element as shown in Figs. 2 and 5, certain variations in the previously described process are required. Since the configuration of the element is different in the two cases the masking means may be as shown in Fig. 8. The fabric portion 33A of this mask has a Y-shaped slot 34A and the metal member 32A is provided with a stub 37. If nickel wire is used as indicated in the previously described process, the stub 37 may be welded to the side of the member 32A.

Since in this device the portion 17A of the semiconductor element must be of opposite conductivity type material to the rest of the body, provision must be made for obtaining this material. One way of doing this is to start with a slab of one type material and to convert the material in the desired area to the other type. This may be done with N-type germanium by heating to a dull red heat the portion to be converted to P-type in the presence of a P-type significant impurity such as aluminum or a compound thereof or by relying entirely upon activation of P-type impurities in the germanium which are inactive in the N-type material.

The portion 17A (Figs. 2 and 5) of the semiconductor element may be electrically heated by connecting it in circuit with a source of current. One connection may be made to the edge

of 17A remote from the filament 12 and the other made by a movable contact placed at the junction of 17A and 12.

Enough current is passed through this area to heat it to a dull red color which may be maintained momentarily before the element is cooled. The current may be applied from a controllable source and increased until the dull red color is obtained.

Since this operation takes place with the semiconductor on its backing, a high temperature adhesive must be used as previously indicated in connection with soldering. Due to the relatively thin section of material involved, the heating is sufficiently controllable to insure a relatively sharp line of demarcation between the two types of material with the barrier at the edge of the area that appears red during the heating.

The conductivity type conversion may also be made on the slab of semiconductor before it is shaped, by localized heating in a flame. For example, one edge of the slab may be heated in a Bunsen flame until the edge of the dull red area spreading therefrom reaches the location at which the P-N barrier is desired. The slab is then marked in accordance with the location of this barrier and shaped by the method previously described.

Since with this type of heating it may be difficult or inexpedient to confine the conversion to an area of the shape of 17A in Fig. 5, the mask of Fig. 8 may be altered so that the abrading will isolate all of the P-type material from the N-type material except at the barrier between 17A and 12. For example, if the flame heating has converted substantially half of the slab from N to P-type material, the mask may be made with a T slot in place of a Y slot. With this arrangement the large area part of 17A will be rectangular and the portions 13 and 14 will project beyond the filament 12 on one side only as shown in Fig. 9.

If the N to P conversion is by heating, the surfaces of the semiconductors should be etched after this treatment.

If it is desired to have those portions of the device other than the filament thicker than the filament, a semiconductive block having the thickness desired for these portions may be used. In such a situation, those portions of the block from which the filament is to be made may be ground or otherwise reduced to filament thickness before masking and abrading.

Although this invention has been disclosed by means of illustrative embodiments thereof, such embodiments are not intended as limitations on the scope of the invention.

What is claimed is:

1. The method of making a semiconductor translator having an attenuated portion that comprises shaping a block of semiconductive material by thinning at least a central portion thereof, reducing the width of the thinned portion to substantially the same dimensions as its thickness to provide a semiconductive body including a filament and at least one portion of greater cross-section than the filament, and making at least three spaced connections to said body including one to each enlarged portion.

2. The method of making a semiconductive circuit element that comprises producing a plane surface on one face of a slab of semiconductive material, mounting the slab on an insulating backing with this plane face towards the back-

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ing, applying masking means to the free surface of the slab, said masking means including a portion of substantially the same width as the slab thickness, and a portion considerably wider than this dimension and abrading away the exposed portions of the slab leaving a semiconductive body having a filamentary portion and a portion of greater cross-section than the filamentary portion.

3. The method of making a semiconductive circuit element including a filamentary portion and a portion having a greater cross-section than the filamentary portion that comprises reducing the thickness of at least a portion of a slab of semiconductive material to that required for the filamentary portion, mounting the slab, protecting the portions of the slab which are to form the element and removing the remainder thereof by abrasive blasting.

4. A translating device comprising a block of insulating material, a thin body of semiconductive material secured to a face of the block, said body comprising a filament having enlarged end sections, means for making a connection respectively to each end section, and means for making a rectifying connection to the filament intermediate of the end sections.

5. A translating device as defined in claim 4 in which the means for making rectifying connection comprises a metallic point making contact to the filament.

6. A translating device as defined in claim 4 in which the means for making rectifying connection comprises an integral portion of the semiconductive body extending from the filament but of opposite conductivity type.

7. The method of making a translating device comprising a block of insulating material having a thin body of semiconductive material including a filamentary portion and enlarged end portions secured to one face thereof, that comprises smoothing and etching one surface of a slab of semiconductive material, mounting the slab on the block of the insulating material, reducing the slab to the required thickness of the filamentary portion, applying to the slab a mask defining the filamentary and enlarged portions, removing the unmasked semiconductive material by abrasive blasting, etching the surface of the remaining semiconductive material, applying metallic film electrodes to a surface of the end portions respectively, and making a rectifying connection to the filamentary portion.

8. The method of making a translating device as defined in claim 7 in which the rectifying con-

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nection is made by applying a metallic point contact to the surface of the filamentary portion.

9. The method of making a translating device as defined in claim 7 in which the rectifying connection is made by providing an integral portion of semiconductive material like that of the filamentary portion and projecting from a side thereof, and converting said integral portion to material of opposite conductivity type to that of the filament.

10. In a method of making a semiconductor circuit element comprising a body of N-type germanium material having a filamentary portion with a rectifying connection thereto, the steps of making the rectifying connection that comprise providing the filamentary portion with an integral projection of N-type germanium material and converting the projection to P-type material by heating only the projection to a dull red color and cooling it.

11. The method of making a circuit element that comprises reducing a portion of a semiconductor to filamentary dimensions, providing electrical connections respectively at opposite ends of the filamentary portion, providing at least one intermediate connection to the filamentary portion between the end connections, and conditioning each intermediate connection to provide an electrical barrier between it and the filamentary portion.

12. The method of producing a barrier at a preassigned region in a body of semiconductive material initially of one conductivity type which comprises heating a limited portion of said body extending from said region to a temperature sufficient to change the conductivity type of said portion.

13. The method of producing a barrier at a prescribed region in a body of semiconductive material initially of one conductivity type which comprises passing a flash of current through a limited portion of said body immediately adjacent said region.

14. A translating device comprising a block of insulating material, a thin body of semiconductive material secured to a face of the block, said body comprising a filament having an enlarged end section, connections to each end of said filament including a connection to said enlarged section, and an electrical barrier connection to the filament intermediate said first-mentioned connections.

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No references cited.