

NAME OF THE INVENTION

METHOD FOR MEASUREMENT OF STRAIGHTNESS OF METALLIC FINE WIRE AND MEASURING EQUIPMENT OF SAME

FIELD OF THE INVENTION

[0001]

The present invention relates to method for measurement of straightness of metallic fine wire and measuring equipment, wherein method for measurement of straightness of metallic fine wire drawn for use of bonding both ends of cut wire at a definite length, where the range of wire diameter is from 0.007 to 0.1 mm, especially from 0.015 to 0.025 mm such as in wire bonding.

STATE OF THE ART

[0002]

Conventionally metallic fine wire drawn has been treated in the shape of spool loaded; the wire is cut at a definite length for use. Metallic fine wire has been treated in such very conventional manner, such as in lead for electric parts, lead for sensor, bead wire for automobile tier, and bonding wire for semiconductor equipment such as bump wire and bonding wire for bonding of electric circuit device and electric circuit board.

According to the use, these metallic fine wires are made of metals such as Au, Ag, Pd, Pt, Al, Cu, Fe, Ni, Pb, Sn, W or are the chief ingredient of each element alloys, are drawn from thick wire to fine wire from these ingots, and if necessary, are heat treated before drawing or in or after.

Meander shape of these wires is used to be measured conventionally using naked eye method (Japanese Patent Application No. H11-190604), hanging down the wire under gravity. Consequently, it has been said that the greater width of meander shape is the worse straightness and is apt to form defective product.

[0003]

However, in the case of using naked eye method, there is dispersion of measured values by individuals and it has been hard to evaluate it quantitatively.

Hence, applicants of the present invention had proposed the evaluating equipment (Patent reference No.1: Japanese Patent Application No. 2002-124534) had been developed, which evaluate straightness of the fine wire, unloading out to definite length from the edge, illuminating this objective material, taking a photograph of this objective material and computer processing of this image.

This evaluating equipment projects 2-dimensional photographic image from 3-dimensional shape of metallic fine wire, preferably, since metallic fine wire is continuous wire, it is recognized connecting incomplete images as meander curve for correction. Comparing with case by naked eye method and with this evaluating equipment, it is possible to decrease dispersion of measured value of straightness. (Cf.

The same application: Embodiments of the invention; No. 5, 6, 10, - 12, and Compared example No.1, No.2 in the Table 1 on page 5.)

Moreover, in the Japanese Patent Application No. 2006—86174 (Patent Reference No.2), evaluation method and its equipment are disclosed that “the wire is floated on liquid in the state of one free end at least of metallic fine wire, on the surface of said liquid, straightness of said metallic fine wire is evaluated from the shape of said metallic fine wire (Patent reference No.2: No.5 paraphrase)” from the reason of “It is hard to keep form which metallic fine wire has meander shape (Omission) hanging down it because of its weight.”

Patent reference No.1: Japanese Patent Application No. 2002-124534

Patent reference No.2: Japanese Patent Application No. 2006—86174

[0004]

However, even these methods of straightness evaluating equipment have been remained the following issues.

First of all, it is explained on Patent reference No.1 here. Since the metallic fine wire is deformed 3 dimensionally, it is difficult to get homogeneous contrast image because of diffused reflection. Hence, unrecognized background portions are generated with unclear outline of wire, it is not able to distinguish at taking photograph on a metallic fine wire, many errors are occurred in forming a meander curve. Especially, in the case of metallic fine wire diameter is less than 0.1 mm, it is harder to recognize, and it generates the more errors in forming a meander curve.

Moreover, even in the case of homogeneous image taken under good lighting condition, a degree of plus minus 2 pixels error is generated between metallic fine wire and background in forming a meander curve. For instance, in the case of taking photograph of 30 cm length region using 4.75 millions pixel camera (vertical: 2,500 pixels, horizontal: 1,900 pixels.), though accuracy of camera is 120 micron-meters / pixel, it generates maximum 4 pixels error, it is converted to 480 micron-meters error.

Moreover, continuously drawn metallic fine wire has originally small difference of straightness, in order to comparing with meander width to be evaluated is almost less than 10 pixels, the higher straightness becomes the harder to confirm whether large or small of meandering on the monitor screen.

[0005]

Secondly, it is explained on Patent reference No. 2 here. In the example of Patent reference No.2, it is difficult to float the wire on the 2-dimensional horizontal surface of water because of naturally 3-dimensionally meandering metallic fine wire, which are taken out from a spool, when Au wire with 18 micron meters diameter and 350 mm length would be floated on the surface of pure water container.

Even if such metallic fine wire could be floated, the Au wire was suck to sidewall of the container by surface tension, it was difficult to keep right position and right direction to the image pickup apparatus, and it was not practical to apply manufacturing site.

Moreover, since the wire is cut at both ends, stress of cutting comes out some bent at Au

wire edge (Cf. No. 21 paraphrase of Patent reference No.2), it is hard to evaluate whether measured value of bent by cutting or measured straightness of Au wire itself. Thus, by method for measurement or method for evaluation in the Patent reference No.1 and No. 2, errors generated under photograph taking conditions for measurement has not been avoided.

[0006]

Moreover, even metallic fine wire with narrow meandering width defined in Japanese Patent Application No.2002-124534 (Patent reference No.1), it has been used to be a defective product deformed to unexpected shape during such multiple operations as bonding cut wire at a definite length after unloading out from a spool.

Especially, in the case of bonding wire for use of semiconductor device, it has been become a fatal defect that one point defect makes all other bondings unusable among several hundreds to several thousands of bondings in one semiconductor device. Such defect is so called bent of wire or leaning defect, even in the case of narrow width of meandering, it occurs, by the conventional method for measurement or evaluation method, it is not available to judge quality before bonding after cutting metallic fine wire.

Concretely, leaning defect is abnormal incline near at root of the first bond, after forming the first bond by bonding a molten ball of bonding wire to an Al pad of semiconductor chip, when the wire fed by a capillary to form a loop. This leaning defect occurs since the neighbouring wire interval is narrow and becomes too close.

In recent years, pitch space has been changed finer rapidly from 100 to 35 microns, as the finer pitch has been progressed, the space between wire and wire has become narrower. Hence, slight incline had not been judged as leaning defect when space between wire and wire is broad, consequence of narrower space has been increased as leaning defect judgments.

However, degree of integration of semiconductor device has become higher, finer pitch and finer wire diameter has been promoted simultaneously in recent years.

Pitch space has been changed finer rapidly from 100 to 35 microns, wire diameter has been changed finer from 30 micron-meters to 15 micron-meters. After all, means for leaning defect become very important issue in the case of ultra fine wire.

DISCLOSURE OF INVENTION

ISSUES TO BE SOLVED BY THE PRESENT INNVENTION

[0007]

The present invention has been done to solve above-mentioned issues and aims to provide a practical and effective method of measurement of straightness for using bonding cut wire at definite length of metallic fine wire in such as wire bonding.

The present invention provides an effective method for measurement of straightness to be able to judge surely distinguishing difference between degree of meandering deformed 3-dimensionally of metallic fine wire and degree of meandering, which does not cause of leaning defect, and aims to solve what accuracy of optical apparatus for imaging getting an image is not sufficient, in the case of very small absolute value of diameter of metallic fine wire and meander width, with good accuracy of measurement 2-dimensionally for degree of meandering 3-dimensionally of metallic fine wire.

Moreover, the present invention provides more practical, economical and higher accurate measuring equipment than conventional one, and attainment of the above issues.

ISSUES TO BE SOLVED BY THE PRESENT INNVENTION

[0008]

The present invention is relate to a method for measurement of straightness of metallic fine wire, the method is featured hanging down vertically a metallic fine wire, taking a photograph of the said metallic fine wire from vertical direction to hanging down direction, acquiring digital data from the photograph, calculating virtual centerline from the image of wire, transforming it to 2-dimensional continuous meander curve, dividing it into plural sections from 2 to 25 times of loop length of wire-bonding as the measurement range of said 2-dimensional curve, evaluating straightness of the said curve for each divided section of the 2-dimensional curve, and above-mentioned section number is more than 5, measuring width of meander curve for each section, evaluating straightness of the said curve using acquired values, which are sorted by size and using only values selected from a half number of sections to one tenth of number of sections, and evaluating above-mentioned straightness of metallic fine wire, which is performed by using distance of parallel lines putting above-mentioned sectioned curve of metallic fine wire between said parallel lines, and when above-mentioned image of photograph is calculated into digital data and transformed into 2-dimensional curve, using expanded image, which is expanded along width direction in order to decrease error in transformation, and diameter of the above-mentioned metallic fine wire is featured from 0.015 to 0.025 mm, each section divided of the above-mentioned 2-dimensional curve, is overlapped with neighboring sections in order to keep continuity of the curve and to improve measurement accuracy.

[0009]

Moreover, the present invention is related to a measuring equipment to measure straightness of metallic fine wire for wire bonding drawn, comprising;

a) Guide ring with a through hole for positioning of metallic fine wire hanged down

- from a spool
- b) Means of taking photographs in vertical direction to metallic fine wire hanged down direction, and
 - c) Processor to acquire distance data between said parallel lines, which are putting each divided section of 2-dimensional curve, expanding 2-dimensional meander image shot only width direction, 2-dimensional curve from calculated centerline of the image is divided into sections to from 2 times of loop length of wire bonding to 25 times of loop length of wire bonding.

And back light illumination features this measurement equipment as lighting for said metallic fine wire in order to decrease effect of diffused reflection.

EFFECTS OF THE PRESENT INNVENTION

[0010]

The present invention is enable to use metallic fine wire with a gradual curvature radius, which does not cause leaning defect, and to exclude surely metallic fine wire, which will be a cause of leaning defect, by evaluating small curvature radius with accuracy for wire bonding.

Therefore, it is enabling to meet to requirement of improvement on straightness at higher level, which is imposed to metallic fine wire for wire bonding under outstanding trend of finer diameter and finer pitch.

Moreover, it is enable to line up to higher accuracy required for measurement, to decrease expense for an imaging apparatus and analyzing image, to use inexpensive imaging apparatus, and consequently to decrease expense for facility and to make it easy for operation of it.

DESCRIPTION OF THE MOST PREFERRED EMBODIMENT

[0011]

In the present invention, evaluation of straightness of metallic fine wire is done by measuring degree of meandering, dividing length of 2 to 25 times of 2-dimensional curve gotten from image of the wire as the base of loop length in wire bonding same as cut length.

From inventor's research, meandering affect to leaning defect as straightness of metallic fine wire is not caused large span or gentle curvature radius, bend of small curvature radius.

This relationship is shown in Fig. 2.

Bending shapes of metallic fine wire of examples for length of measuring range are generally shown in Fig. 2(a) to (d).

(a) is an ideal shape of small meandering width. (b) is a gentle bend like "wave" or small curvature radius, (c) is a generated as meandering as comparably large curvature radius, and (d) is a small curvature radius like "bump"-shaped bend with "wave" and "loop".

When meandering width on these curves are measured in the case of Fig. 2(b) to (d), the difference of these shapes do not generally reflect to value of measurement, any one becomes same value as the maximum meandering width.

[0012]

However, in the case of bonding, where bonding length is at longest less than 10 mm loop length like bonding wire, it has been turned out that meandering existing for general and relatively longer section of such “wave” and “loop” like these (b) and (c) to be measured to the range of several tens cm, does not almost affect to straightness of such leaning defect.

On the other hand, in the case of bend of “bump”- shape as in small curvature radius seen in (d), since, so to speak, the rate of change of bend is large, using the wire in these short section, its effect comes out outstandingly, especially if there is such a bend at bonding portion in bonding wire, even meandering width is small, and its region is narrow, leaning defect appears on the instant, its effect is big.

Namely, for measurement of straightness small curvature radius shown in (d) these meandering curves, or large degree of bend, or “bump”-shaped bend is important. However, taking long distance as measurement length like the past, by measuring method of degree of meandering from overall length, as it becomes maximum wave and meandering by large curvature radius within the range, it is detected as maximum meandering width.

Hence, small curvature radius bend most affected leaning defect characteristics like above-mentioned, is not detected.

In order to detect small curvature radius affecting leaning defect, measurement by dividing section length corresponding to curvature radius to be evaluated, bigger cycle curvature radius or some curvature radius is neglected by abstraction, the curvature radius corresponds to these small curvature of radius is to be detected.

[0013]

About these relationships, conceptual diagram of method for degree of meandering to 2-dimensional meandering curves is shown in Fig. 3, which follows meandering shapes in Fig. 2. In this figure, each 2-dimensional curve is divided to sections of a1 to a3, ---; d1 to d3, and these divided ranges are overlapped partly.

Good straightness fine wire with small “wave” and small “loop”, as shown in (a), each meandering width measured is small in sectioned range.

Moreover, meandering with longer span, as shown in (b) and (c) curve, is measured as erasing the width of “wave” and “loop” corresponding to the length divided like in the figure. The cycle of “wave” and/or “loop”, or the shorter length of divided section than curvature radius, the value becomes smaller. On the contrary, shorter meandering of the smaller curvature radius like short cycle of bend in (d) is measured as larger value according with approaching to cycle or curvature radius of the divided length.

[0014]

Appropriate length of divided section or number of divided sections, depends on diameter of metallic fine wire, or loop length of bonding (where it means overall length unloaded out from spool. Namely, in the case of bonding wire observation from vertical direction, though the length as a plane is same, loop length becomes longer when loop height becomes higher. Hereinafter it's same.), depends on making a loop such as loop height, and length of examples, but in generally for defect like leaning defect, it was

found that small and short values of these curvature radius are measured value as a maximum meander width, when the length of each divided section using metallic fine wire is equal to length of 2 to 25 times length for the above-mentioned loop length. Moreover, it is more desirable to make the length 2 to 25 times, because it can be directly compared with practical condition

[0015]

Moreover, measuring method of the present invention is to evaluate straightness by measuring meander width dividing the 2-dimensional curve corresponding to the length of loop length in wire bonding, as a 2-dimensional curve digitized by computer processing captured image, dividing the 2-dimensional curve, it is able to line up requisite accuracy corresponding to performance of image processing apparatus of photography equipment, getting required high-definition image for meander width measurement by dividing photograph section of metallic fine wire.

As mentioned before, it is required that expanded high-definition image for capturing a small bend of almost straight line, in photographic imaging of ultra fine wire of less than several tens micron-meters diameter as an object of the present invention. However, it is hard to prepare such photography equipment of the number of pixels corresponding to that. And the expense is large.

Hence, thus capturing the image, which partitioned and took an image suitably and processing, it makes possible to acquire high-definition image and an equipment burden can be reduced substantially.

[0016]

Next, the image taken is expanded into width direction.

As an effect of lens aberration near at optic axis is small and it appears along radius direction, on the image of metallic fine wire taken along radius direction through the optic axis neighborhood of the lens, even if only width direction expands, the influence is small. Moreover, the meander width of 2-dimensional curve is magnified with that only width direction, and it becomes easier to measure.

Capturing obtained image in this way, then digitizing as 2-dimensional curve, in ultra fine wire as object of the present invention, the outline of photographic image tends to become indistinct by diffraction of light and a diffused reflection, when digitizing just as it is, at unclear outline of the line, the image becomes discrete by the influence, and it has been able to decrease ratio of error on transforming into 2 dimensional curve by expanding diameter of wire beyond definite value to width direction.

[0017]

Since 3-dimensional deformation of metallic fine wire causes to various histories on working process like drawing and heat treatment, is generated complicatedly with complex mixture of these causes, it can only grasp a part at short and discontinuous section. However, observing the wire along one definite length, these deformations appear almost all combination of various deformations along length direction with changing direction.

Therefore, it is possible to grasp almost all these characteristics of meander generated

on metallic fine wire by using length of these conditions to meet to divided sections of photographic image.

The length of sample to meet to criterion like these characteristics of meander should be determined by degree of wave of metallic fine wire unwound from the spool concretely, empirically, the length is sufficient that if the length is almost 30 to 50 cm, though it depends on the wire diameter.

Thus divided section is preferable to overlap with each other. Because it is possible to interconnect each section each other at overlapped section. It is practical that overlapped range is 20 to 70 %.

It is preferable that metallic fine wire as an object of measurement has 0.007 to 0.1 mm diameter, especially 0.015 to 0.025 mm diameter.

Because the wire has stiffness in itself, when bonding, in which the flaw of wire inhere is hidden by the stiffness when the wire diameter becomes thicker than 0.1mm. On the contrary, it's because handling of the ultra fine wire becomes difficult when it becomes too fine than 0.007mm.

EMBODIMENT OF THE PRESENT INVENTION

[0018]

Hereinafter, measurement method and measuring equipment of the present invention are explained more concretely by referencing figures.

Fig. 1 shows one example of embodiment of the present invention, in the figure, 7 shows hanged down example metallic fine wire, 12 shows photography equipment, 13 shows image processing apparatus, 14 shows a monitor, 10 shows a housing of wind shield to prevent influence of air flow, 11 shows an observation window, 3 shows spool wound metallic fine wire and 18 shows a guide ring.

[0019]

(Mean to hold metallic fine wire)

Spool 3, which is wound a metallic fine wire, is supported to be able to rotate at the upper part of housing, and it keeps to be hanged down the metallic fine wire at a definite length of wire after unloading it.

In this situation, as a metallic fine wire with such ultra fine diameter waves by influence of the air flow, a photograph is taken through the observation window of the wind shield housing, the metallic fine wire is hanged down inside it in order to prevent waving of the wire and to be able to keep position accurately in the center of the photographic equipment, by hanging down the metallic fine wire through a guide ring with a small hole.

It is preferable to set up in the shape of double or triple coil after coating with such Chromium Oxide, Titanium Nitride or Wolfram Carbide in order to enhance sliding characteristics for a guide ring.

I

[0020]

(Mean of lighting)

Conditions for taking photographic image; in order to capture a clear photographic image of metallic fine wire, a panel such as black board with high contrast as back ground is located, the image is taken as a 2-dimensional image in parallel plane to the panel.

Where, it is required that illumination should be done directly to metallic fine wire from multi directions to avoid discontinuous image because of shadow or reflection.

Since it is observed reflection light from metallic fine wire 7 which is illuminated by the illumination source in conventional lighting, it is difficult to capture a homogeneous image about all over of metallic fine wire, there are dispersion of brightness of metallic fine wire 7 by diffused reflection from metallic fine wire 7.

The other way, when taking photograph by using backlight illumination, it is observed only metallic fine wire 7 as a dark silhouette to shut direct light by metallic fine wire 7. Therefore, even there are some small curvature radius bends in the metallic fine wire 7, there is no diffused light though there is some influence of deflection light from backlight, the metallic fine wire 7 is observed as dark contrast almost homogeneously.

[0021]

(Image capturing apparatus)

It is possible to use an over-the-counter digital camera as a 2-dimensional image capturing apparatus 12. As a digital camera, there are, for instance, "Three-dimensional digital fine scope VC4500" made by Omron Corp., "Digital HD microscope VH-7000" made by Keyence Corp., "Penguin 600CL" made by Pixera company, "5.0RTV" made by Micro Publisher company, or "EOS" series (EOS Kiss) made by Canon company). It is preferable to take a photograph at a position apart from a definite distance from terminal end of metallic fine wire 7 because of deformation by cutting.

[0022]

The range to be measured; depending on accuracy of an image capturing apparatus explained before, the image is taken a photograph of section, which is divided all over hung down metallic fine wire into plural sections. Each divided section is overlapped each other, it is possible to keep continuity combining each section at the overlapped portion. The overlapped range is practical at 20 to 70 %.

[0023]

(Image processing apparatus)

Image by an image capturing apparatus 12 is expanded preferably to 3 to 30 times, for example 10 times along horizontal direction, keeping the magnification of length direction of metallic fine wire 7 as is by image processing apparatus 13. The expanding range and magnification of metallic fine wire 7 are able to select preferably in the range of 5 mm to 50 mm of metallic fine wire drawn out, for example, 300 mm to 1,000 mm length while watching monitor 14.

[0024]

Expanded image is digitized. Method of digitizing only contrast between metallic fine wire and background, so eliminating what is under threshold discontinuous image causing of such as diffraction light and defused light, it becomes to enable to measure metallic fine wire, which is such 7 micron-meters diameter. Moreover, when continuous digital data can not be obtained because of unclear borderline between metallic fine wire and background, complimenting and combining such blank with a straight line or a regression curved line, error in digitizing was reduced to the utmost. The method to obtain these continuous curve, it is well known as so called digital image processing, since it can be available to choose appropriately an over-the-counter application software, explanation on the method is eliminated here.

[0025]

Next, a virtual centerline is led by computer process from digitized image. Though to unclear borderline between profile of metallic fine wire and background, as an expanded image magnified to horizontal direction of metallic fine wire is expressed by thick curve, without influence of the outline (discontinuity of such zigzags), it was obtainable a centerline with high accuracy and smoothness. This curve is defined as a virtual meander curve. On the contrary, when magnification is not expanded to horizontal direction, it does not eliminate errors in digitizing because of big influence of discontinuity influence of the outline to meander curve. For this reason, it is required to

use an expensive lens with deeper focusing depth and expensive application software available complex processing.

[0026]

From a virtual meander curve obtained, it is possible to measure by using such expanded curvature radius of meander and number, expanded width of meander and expanded meander width as parameters, by these digitized data, defect of bonded metallic fine wire in practical bonding, for instance, it could compare with defect caused straightness of metallic fine wire like leaning defect and fine bend of wire in bonding wire for semiconductor device.

[0027]

Metallic fine wire 7 with about 100 cm length and 0.015 to 0.025 diameter were chosen as measurement objects. Appropriate length as a measurement object depends on diameter, in order to measure above-mentioned 3-dimensional change with high accuracy, in the case of large diameter; it is preferable to select such length said before. Moreover, in the case of thin diameter, even in the case of measurement length of metallic fine wire 7 is 30 cm, aspect ratio to wire diameter becomes large like 3×10^4 to 3×10^5 , it is possible to grasp meander characteristics sufficiently above-mentioned.

[0028]

Fig. 4 shows a schema to obtain meander width for each section divided into definite length of measurement range on the 2-dimensional curve, which is made from captured image of metallic fine wire drawn. These divided sections C1 to C16 keep continuity are overlapped each other in order to enhance measurement accuracy. Measurement methods of these meander width had been proposed variously, for example, it is generally shown in Fig. 5(a), (b).

(a) First of all, a centerline is drawn, a line combined with upper and lower edges of wire for each divided position of divided section, then 2 straight parallel lines to a said centerline are drawn and hold between meander curve, it is calculated the distance of them.

(b) Or, a centerline is calculated from meander curve of the divided section at divided section by using the method of least squares, 2 of parallel lines around a meander curve can be drawn in equal manner hereinafter.

Then, repeating these operations for each divided section, the maximum value can be found comparing with these data each other.

[Example]

[0029]

Au bonding wire, which diameter is 25 micron-meters, its purity is more than 99.99 mass %, as for example, the measurement range is 30 cm length, on the 2-demensinal curve given by the above-mentioned manner, divided into 0.5 cm, 2 cm, 5 cm and 15 cm as meander measurement range, has been investigated relationship between degree

of meander measured for each divided section and leaning defect (where loop shape is 2.56 mm.), data of Table 1 was gotten.

Where, degree of meander, a centerline was obtained by the method of least squares in each divided section, drawing the smallest width of parallel 2 straight lines around this centerline, distance of this parallel lines, or meander width is defined as degree of meander. The unit is mm.

[0030]

Meander measurement for a whole 2-dimensional curve, to avoid the error by cutting of wire, measurement range was fixed 30 cm from 10 cm apart from bottom end of the wire, and overlapped section was 50 %. Degree of meander in this measurement range, determining optional divided section length, was attained by such values of means of meander width obtained of plural sections. However, if divided sections were set shorter, number of data as a whole will increase, when there were several large meanders though the number was small, it will do not stand out any more by mean value processing. Hence, based on the following equations, from whole data, by the mean value using only 1/3 of data sorting by large value order of meander width, degree of meander will be found out. Besides this, methods of mean value processing, are considered plural others tempering such dispersions, it should be adopted suitably as the need arises.

Namely, measurement region (cm): divided section (cm): to K,

Where overlapped length is x, number of overlap is n-1 at measurement region L,

$$L = nK - (n-1)x$$

Here, overlapped length is 50 %,

$$L = nK - (n-1)0.5K = K/2(n+1)$$

To solve this, as number of measurement region,

$$\text{Whole data number (piece): } n = (L/K) + ((L-K)/K)$$

When dominance 1/3 is adopted from these data, it becomes as follows,

The number of effective data (piece): The meander width is high, in turn $\{(L/K) + ((L-K)/K)\} / 3(\text{piece})$

(Example) Therefore when it depends on example above-mentioned, from L = 30 cm, K = 0.5 cm,

$$\text{Whole number of data (piece): } = (30/0.5) + ((30-0.5)/0.5) = 119(\text{piece})$$

The number of effective data: 40(piece) in the order of higher meander width

In this example case, this measurement were repeated 10 times, large 5 values in the order of higher meander width were selected, mean values are shown in Table 1.

[Table 1]

Table 1 Relationship between meander width and leaning defect by divided section width

No.	Number of Leaning *	Meander width of divided section width 0.5 cm (mm)	Meander width of divided section width 2 cm (mm)	Meander width of divided section width 5 cm (mm)	Meander width of divided section width 15 cm (mm)
1	0	0.03	0.03	0.06	0.41
2	1	0.02	0.03	0.15	0.76
3	1	0.02	0.04	0.12	0.44
4	0	0.03	0.04	0.11	0.37
5	3	0.06	0.15	0.31	1.09
6	0	0.04	0.05	0.11	0.51
7	1	0.03	0.06	0.12	0.66
8	4	0.05	0.06	0.22	0.98
9	2	0.03	0.07	0.21	0.81
10	4	0.06	0.09	0.29	1.13
11	5	0.04	0.08	0.15	0.63
12	3	0.03	0.08	0.20	0.87
13	1	0.03	0.10	0.24	0.74
14	10	0.03	0.09	0.18	0.55
15	9	0.03	0.09	0.26	1.02
16	3	0.05	0.13	0.31	1.00
17	16	0.03	0.10	0.24	0.74
18	7	0.03	0.11	0.22	0.75
19	15	0.06	0.11	0.27	0.83
20	12	0.06	0.12	0.30	0.95
21	15	0.05	0.12	0.27	0.87
22	10	0.05	0.12	0.33	1.03
23	24	0.05	0.13	0.27	0.91
24	2	0.05	0.13	0.32	1.27
25	14	0.06	0.14	0.32	1.13
26	10	0.05	0.14	0.38	1.40
27	27	0.06	0.15	0.30	1.03
28	24	0.06	0.15	0.31	1.10
29	18	0.04	0.14	0.31	0.97
30	15	0.07	0.16	0.46	1.79
31	22	0.07	0.17	0.38	1.28
32	26	0.07	0.17	0.37	1.39

* Using Bonder "UTC-400" made by Shinkawa, pitch distance is 53 micron-meters, after 1.500 cycles of wire bonding; numbers of wire contacted with neighbouring wire were counted.

[0031]

Relationship of Table 1 is shown in Fig. 6-1, Fig. 6-2 by divided section length as meander width and leaning contact number / number of wire.

Namely, there is a definite relationship between meander width and number of leaning defect, at any range of 0.5, 2, 5, and 15 cm of meander measurement region, the larger meander width shows the larger leaning defect, and it was found that correlation is strong near at 2.56 mm of loop length with meander measurement divided section. In order to express in digit this, results of coefficient of correlation are shown in Table 2

[0032]

[Table 2]

Table 2. Correlation between leaning to meander measurement divided section length and meander width

	**	***	**	*
Coefficient of correlation	0.62	0.74	0.61	0.49
Divided section (cm)	0.5	2	5	15

[0033]

Namely, it is recognized that there is a correlation between meander degree measurement divided section length and leaning defect, it is confirmed that tendency of correlation varies by changing divided section.

Where coefficient of correlation(r) is expressed as follows, when number of leaning is x, degree of meander is y,

$$r = S_{xy} / (S_x * S_y)^{1/2}$$

Where,

$$S_x = \sum x_i^2 - (\sum x_i)^2 / n$$

$$S_y = \sum y_i^2 - (\sum y_i)^2 / n$$

$$S_{xy} = \sum x_i y_i - (\sum x_i) (\sum y_i) / n$$

Moreover, whole number of 0.5 cm divided section is 119 pieces as above-mentioned, when in the case of 2 cm, 5 cm, and 15 cm; each number was 29, 11, and 3 pieces.

From this result, it was found that coefficient of correlation is shown more than 0.7 as in ***, 0.6 to 0.7 as in **, 0.5 to 0.6 as in *, and less than 0.5 as in -, 2 cm divided section *** is the best expression of relationship between degree of meander and leaning defect, and 0.5 cm and 5 cm divided section length are shown **, and the better expression of it.

[0034]

From Table 2, in the case of wire diameter is 25 micron-meters and loop length is 2.67 mm, it was recognized that there was a strong correlation between degree of meander of 2 cm length of degree of meander divided section and leaning defect. On the other hand, since wire diameter and loop length affect to meander and leaning defect, it is supposed that optimum meander divided section length will change by wire diameter and loop

length.

The wire diameter becomes big, curvature radius of wire meander also becomes big, and cycle of wire meander becomes big on the average. Therefore, it is better to set divided section length of meander longer. Moreover, loop length becomes short, meander of short cycle affect greatly leaning. Hence, it is better to set divided section length of meander shorter. In order to articulate these relationships, it has been evaluated that sample wires of combination of wire diameter and loop length at 4 levels, or using 32 spools of each in Table 3.

First of all, measurement range of meander set at 30 cm for 32 spools of each at 4 levels, 2-dimensional curves gotten were divided at 0.5 cm, 2 cm, 15 cm and 30 cm of measurement range, degree of meander were evaluated for each divided section. Then leaning defects were measured on 32 spools of each at 4 levels. Finally, correlation between degree of meander and leaning defect was calculated, and results were shown in Table 3 based on the following criterion.

Where,

“****” is shown when it is larger than 0.7 or equals to 0.7.

“**” is shown when it is less than 0.7, and larger than 0.6, or equals to 0.6.

“*” is shown when it is less than 0.6, and larger than 0.4.

“-” is shown when it is less than 0.4 and equals to 0.4.

[0035]

[Table 3]

Table 3. Correlation between loop length and leaning defect to divided section width and degree of meander

Coefficient of correlation	Divided section width (cm)	Loop length (mm)	Wire diameter (Micron-meter)
**	0.5	2.67	15
**	2	2.67	
**	5	2.67	
-	15	2.67	
-	30	2.67	
**	0.5	4	
***	2	4	
**	5	4	
-	15	4	
-	30	4	
**	0.5	2.67	25
***	2	2.67	
***	5	2.67	
*	15	2.67	
*	30	2.67	
**	0.5	4	
***	2	4	
***	5	4	
**	15	4	
*	30	4	

[0036]

From the results above-mentioned, leaning defect does not depend on bonding wire which diameter is 15 micron-meters to 25 micron-meters, the larger degree of meander is the more leaning defects, namely degree of leaning defect has correlation to wire length which is used, or loop length, it was found that accuracy of measurement becomes more precisely and leaning defects can be judged the most appropriately and correctly by using evaluation method at divided sections of 2 times to 25 times of loop length.

Therefore, before using metallic fine wire drawn as bonding wire, it is possible to accomplish simple and rapid evaluation of appropriate straightness quality, or evaluating straightness by degree of meander for each divided section of 2 times to 25 times of loop length of wire when capturing images of metallic fine wire.

BRIEF DESCRIPTION OF THE DRAWINGS

[0037]

[Fig. 1] is a Schematic configuration shown the all over measuring equipment of present invention.

[Fig. 2] shows 4 representative meandering curves of metallic fine wire drawn.

[Fig. 3] shows Relationship between meandering curves of metallic fine wire drawn and degree of meander.

[Fig. 4] shows the method of measurement of meander width in the present invention.

[Fig. 5] is the explanatory illustration on the meander measurement of metallic fine wire.

[Fig. 6-1] is correlation between degree of meander at 0.5 cm and 2 cm of meander measurement section and leaning defect.

[Fig. 6-2] is correlation between degree of meander at 5 cm and 15 cm of meander measurement section and leaning defect.

[Explanation of symbols]

[0038]

- | | |
|----|------------------------------|
| 3 | Spool for metallic fine wire |
| 7 | Metallic fine wire |
| 10 | Wind shield housing |
| 11 | Window for observation |
| 12 | Photo taking apparatus |
| 13 | Image processing apparatus |
| 14 | Monitor |
| 18 | Guide ring |

CLAIMS

What is claimed is:

1. Method for measurement of straightness of metallic fine wire, method comprising: a metallic fine wire is hanged down vertically, a photograph of the said metallic fine wire is taken from vertical direction to hanged down direction, digital data is acquired from the photograph, virtual centerline, which is calculated from the image of said wire, is transformed to 2-dimensional continuous meander curve, it is divided into plural sections from 2 times to 25 times of loop length of wire-bonding as the measurement range of said 2-dimensional curve, straightness of the said curve for each divided section of the 2-dimensional curve is evaluated.
2. Method for measurement of straightness of metallic fine wire, method comprising: a metallic fine wire is hanged down vertically, a photograph of the said metallic fine wire is taken from vertical direction to hanged down direction, digital data is acquired from the photograph, virtual centerline, which is calculated from the image of wire, is transformed to 2-dimensional continuous meander curve, it is divided into more than 5 sections from 2 times to 25 times of loop length of wire-bonding as the measurement range of said 2-dimensional curve, measuring width of meander curve for each section, straightness of the said curve is evaluated using acquired values, which are sorted by size and only using values selected from a half number of sections to one tenth of number of sections.
3. Method for measurement of straightness of metallic fine wire of claim 1 or claim 2, method comprising: evaluation of the above-mentioned straightness of metallic fine wire is performed by using distance of parallel lines putting around the above-mentioned divided section curve of metallic fine wire.
4. Method for measurement of straightness of metallic fine wire according to claim 1 to claim 3, method comprising: the above-mentioned image of photograph is calculated into digital data and transformed into 2-dimensional curve, and expanded image along width direction is used.
5. Method for measurement of straightness of metallic fine wire according to whichever claim 1 to claim 4, method comprising: the range of diameter of the above-mentioned metallic fine wire is from 0.015 to 0.025 mm.
6. Method for measurement of straightness of metallic fine wire according to whichever claim 1 to claim 5, method comprising: each divided section of the above-mentioned 2-dimensional curve, is overlapped with neighboring sections.
7. Measuring Equipment for straightness of metallic fine wire drawn for wire bonding, equipment comprising:

- a) Guide ring with a through hole for positioning of metallic fine wire hanged down from a spool
- b) Means of taking photographs in vertical direction to metallic fine wire hanged down direction, and
- c) Processor to acquire distance data between said parallel lines, which are putting around each divided section of 2-dimensional curve, which is expanded 2-dimensional meander image only width direction, and the 2-dimensional curve from calculated centerline of the image is divided into sections to from 2 times to 25 times of loop length of wire bonding.

8. Measuring Equipment for straightness of metallic fine wire of claim 7, measuring equipment comprising: back light illumination for the said metallic fine wire.