ANISOTROPIC EFFECT WHEN USING ISOTROPIC CONDUCTIVE ADHESIVES

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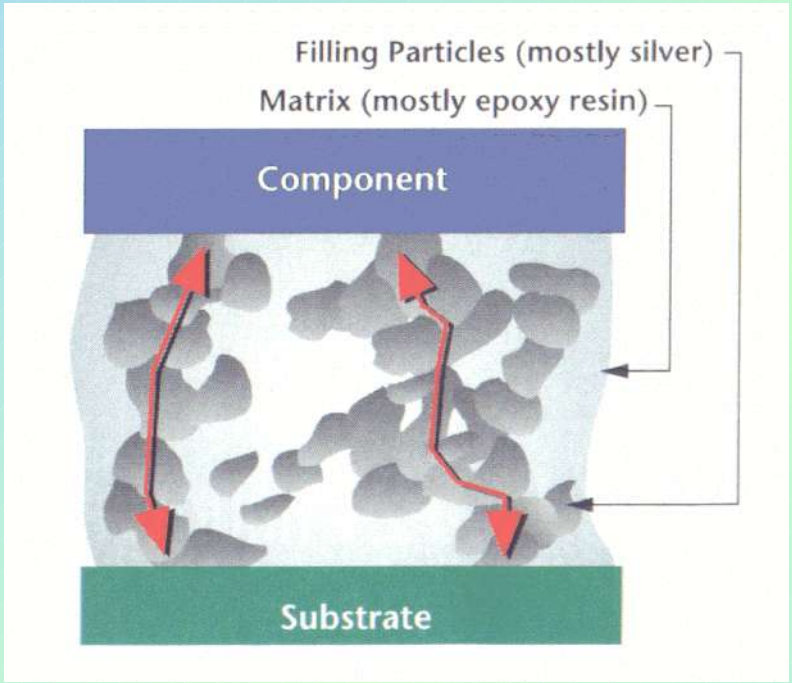
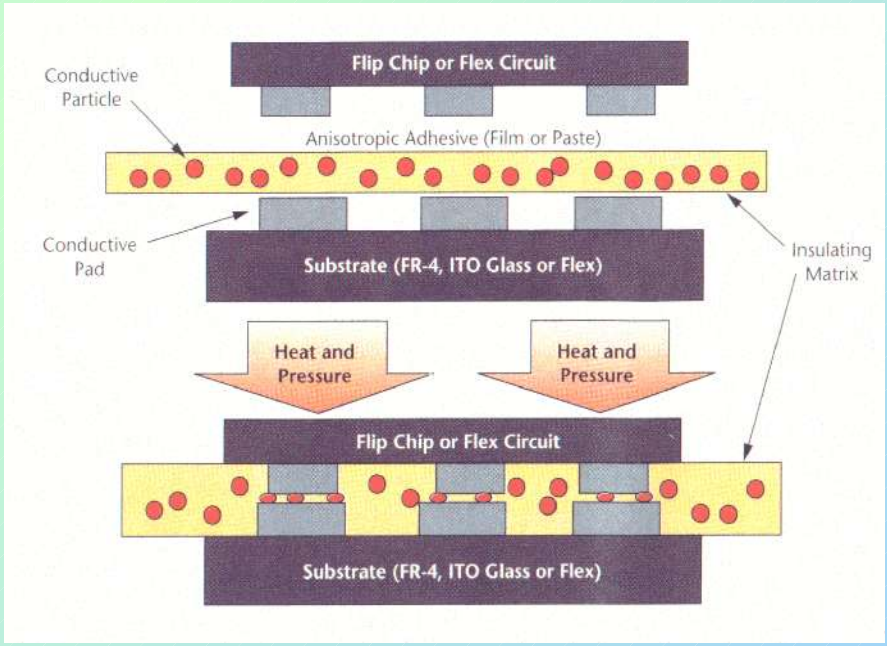
Electrically Conductive Adhesives

Isotropic Conductive Adhesives



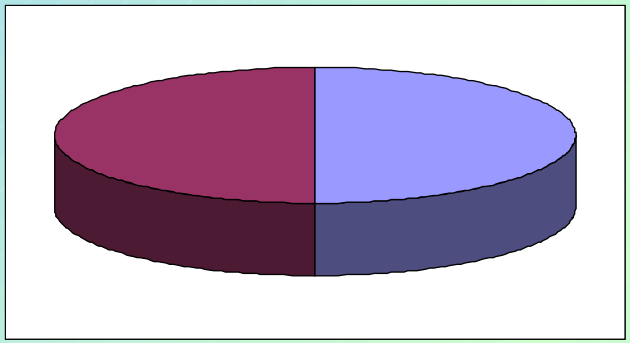
Anisotropic Conductive Adhesives



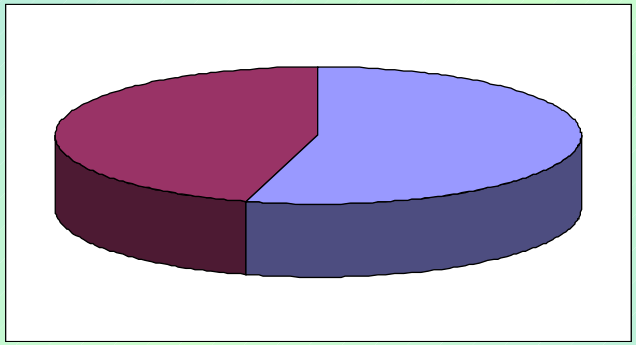
Electrically Conductive Adhesives

Polytronic™ 2001-2003

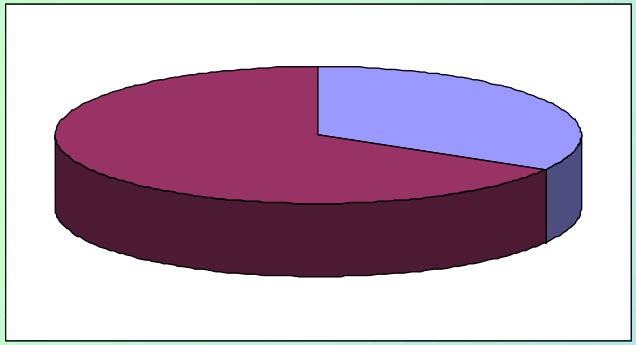
Potsdam, 2001



Zalaegerszeg, 2002



Montreux, 2003



Isotropic Conductive Adhesives

THE CHANGING OF THE TYPE OF THE FILLER, ITS CONTENT IN ADHESIVE, SHAPE AND DIMENSION OF FILLER'S PARTICLES OR INTRODUCING SOME ADDITIVES IS RELATIVELY EASY IN THE FORMULATION

Anisotropic Conductive Adhesives

ANISOTROPIC CONDUCTIVE ADHESIVES ARE MOSTLY DELIVERED IN THE FORM OF FILMS (ACF) WITH PARAMETERS GUARANTEED BY A PRODUCER

Aim of the Work

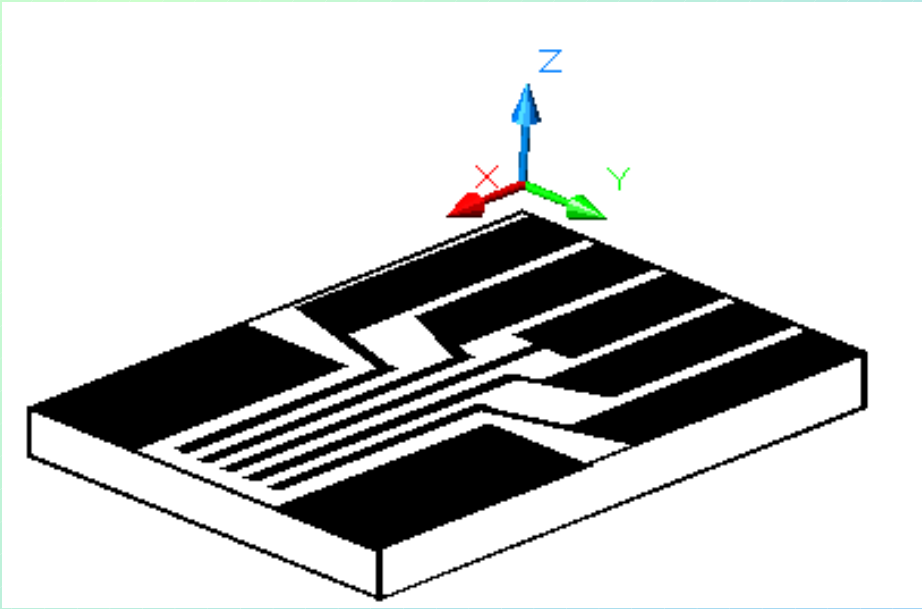
THE POSSIBILITY OF *ICA* APPLYING FOR FLIP CHIP TYPE INTERCONNECTIONS WHEN *ACA* IS NORMALLY USED WAS INVESTIGATED

IT IS POSSIBLE, UNDER THE CONDITION THAT AN ANISOTROPIC EFFECT CAN BE ACHIEVED, WHEN USING ISOTROPIC CONDUCTIVE ADHESIVES

Samples and Test Method

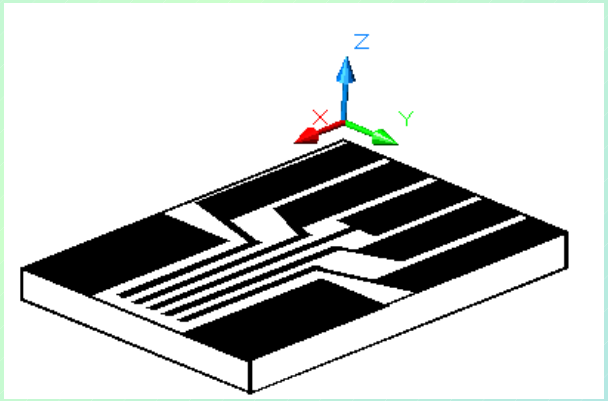
Cross-section in *Y* direction

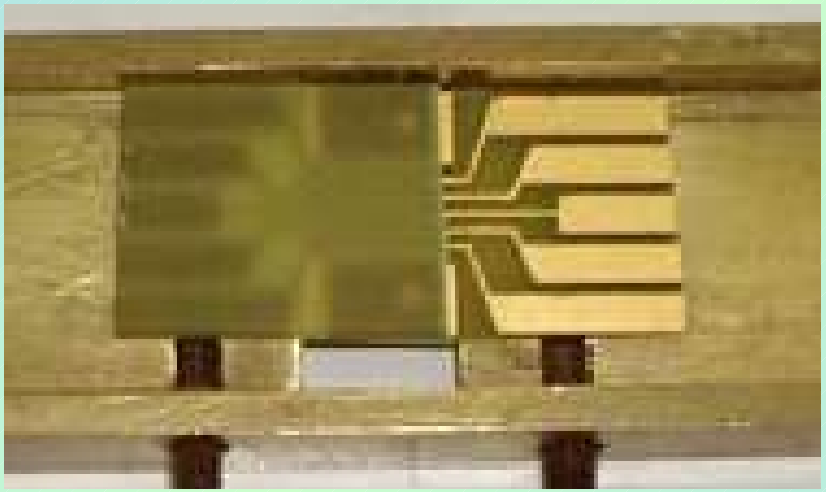
- **width - 500 µm**
- **distances between bumps - 500 µm**
- **height 145 µm (Cu 140 µm + Ni 5 µm + Au ~ 100 nm**

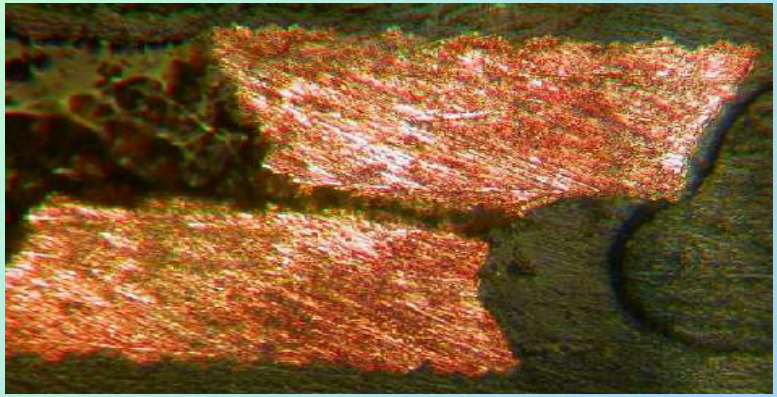


Samples and Test Method

ADHESIVES WERE PRINTED BY THE STENCIL OF 0.3 mm THICK, 1 mm WIDTH AND 15 mm LONG, LOCATED CROSSWISE THE STRIPLINES (in *Y* DIRECTION). IT MEANS, THAT THE SAME VOLUME OF THE ADHESIVE WAS USED FOR EVERY TEST

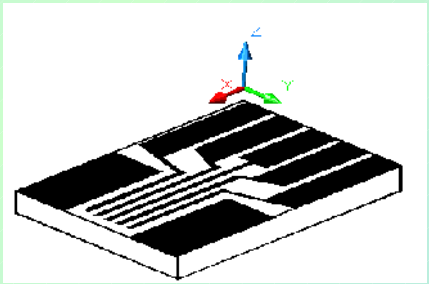


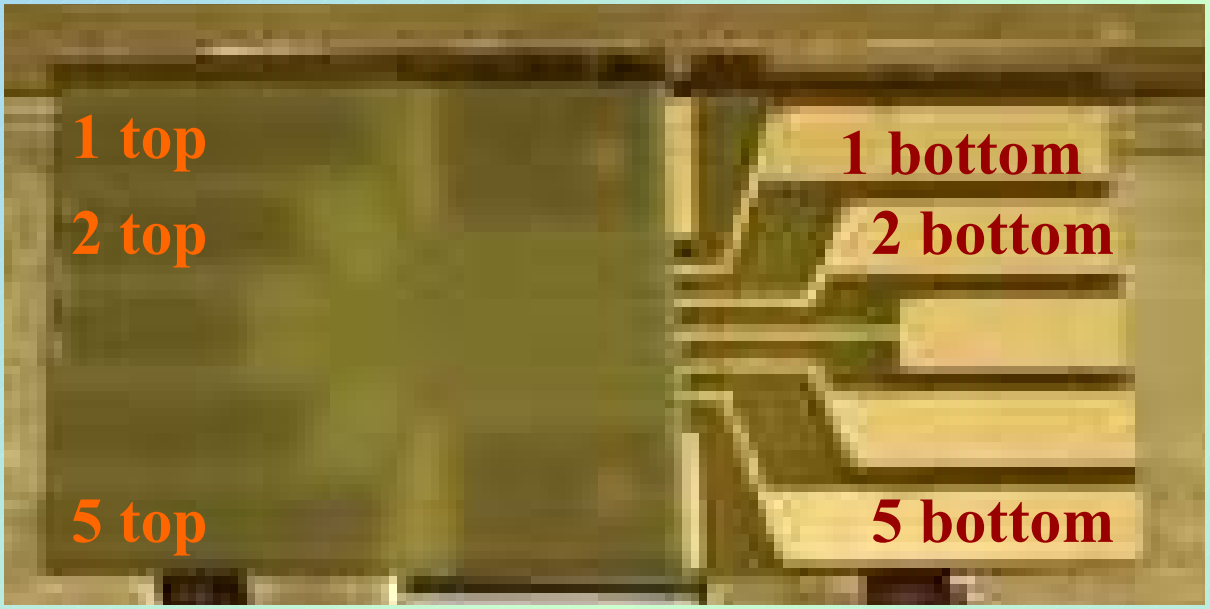




accuracy not worse than 200 µm

Samples and Test Method





contacts between corresponding lines – in *Z*-direction (1→1, 2→2, …5→5) + lack of contacts between every possible adjoining lines – in *Y*-direction (line 2-bottom with line 1-bottom and 3-bottom and 1-top and 3-top etc.)

ANISOTROPIC EFFECT

Adhesives for Tests

TWO TYPES OF ISOTROPIC CONDUCTIVE ADHESIVE WERE SELECTED, BOTH WITH THE SAME POLYMER BASE MATERIAL *Epoxy 601*, BUT WITH DIFFERENT FILLERS:

- ***I*-type** — **not higher than 6%vol**

  CONTAINS THE SILVER FILLER OF SPHERICAL SHAPE WITH THE AVERAGE DIMENSION LOWER THAN 1 μm AND THE TAP DENSITY OF 1.5÷2 g/cm³

- ***II*-type** — **not higher than 3%vol**

  CONTAINS THE SILVER FILLER IN THE FORM OF IRREGULAR FLAKES WITH AVERAGE SIZE OF 3.5 μm AND THE TAP DENSITY OF 5.8÷6 g/cm³

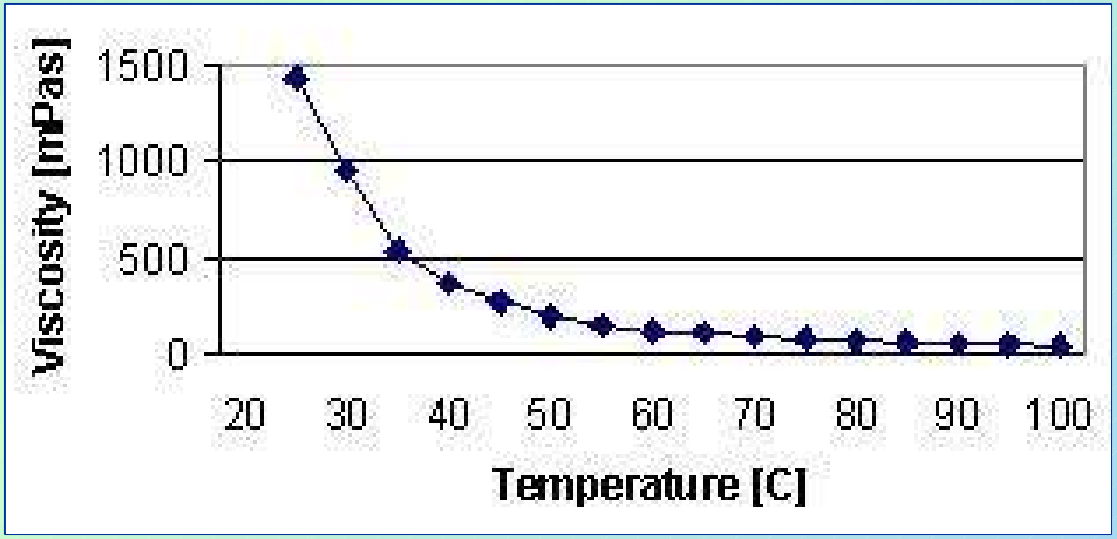
ONLY FORMULATIONS WITH THE FILLER'S CONTENT FAR BELOW THE PERCOLATION THRESHOLDS WERE USED FOR THE TESTS

Adhesives for Tests

the volume content of the filler not higher than 6% (3%)

only the polymer base material determinates the viscosity of the formulation

the viscosity of the polymer were measured by using the Brookfield's method with different rotating speed, in the temperature range of 25÷100°C



Isotropic Effects when Using Adhesives Below the Percolation Thresholds

Type of filler	*I*-type	*I*-type	*II*-type	*II*-type
Weight filler content	5%	7%	7%	10%
Contacts	Resistance [Ω]			
1→1	∝*	6.39	∝	9.87
2→2	∝	15.00	∝	∝
3→3	∝	8.33	∝	3.14
4→4	∝	4.52	∝	∝
5→5	∝	3.14	∝	5.83
others	∝	15.00	∝	4.12

*) **the measuring range up to 2 MΩ**

Modification of Adhesives

Adding to the adhesive formulation a material that influences its surface tension, results decreasing of its wettability

Type of filler	*I*-type	*II*-type	*II*-type
Weight filler content	5%	5%	7%
Contacts	Resistance [Ω]		
1→1	0.18	4.79	0.18
2→2	0.16	7,56	0,50
3→3	0.27	3.95	1.50
4→4	0.23	1.88	0.35
5→5	1.70	0.91	0.68
others	$\propto^{*}$	$\propto$	$\propto$

*) **the measuring range up to 2 MΩ**

ANISOTROPIC EFFECT

Nonconductive Adhesives Effect ?

It can be suspected that the results of investigation were caused only by the high shrinkage of the polymer.

The series of tests with samples like in those, which appeared the anisotropic effect but with only polymer base material, were performed. All results were the same - no electrical contacts between any striplines were stated.

The Influence of Technological and Material Parameters on the Anisotropic Effect

THE DESIGN OF EXPERIMENT BASED ON TAGUCHI ORTHOGONAL ARRAYS WAS APPLIED

A -the content of the filler in adhesives; the weight content of the filler in adhesive of 5% -A1, and 12% - A2,

B -the content of the material that degreases the adhesive's wettability (three-hydrooxide *A*-type alcohol) in epoxy resin; the weight content of the modifier of 5% - B1 and 10% - B2,

C -the profile of curing temperature ; the one-step curing of 180°C & 60 minutes –C1, and the two-step curing, first 100°C & 20 minutes and than – 180°C & 50 minutes - C2,

D - the type of filler material; *I*-type (spherical shape with the dimension lower than 1 μm) –D1, and *II*-type (irregular flakes with average size of 3.5 μm) –D2,

E -the vertical pressure during the curing process; without additional pressure (only the weight of top sample) –E1, and additional pressure of 190 Pa - E2

The Influence of Technological and Material Parameters on the Anisotropic Effect

Factor levels were assigned to the columns of orthogonal array L8(2^7)

Test No	Factors & Interactions						
	A	**B**	**AxB**	**C**	**BxC**	**D**	**E**
1	1	1	1	1	1	1	1
2	1	1	1	2	2	2	2
3	1	2	2	1	1	2	2
4	1	2	2	2	2	1	1
5	2	1	2	1	2	1	2
6	2	1	2	2	1	2	1
7	2	2	1	1	2	2	1
8	2	2	1	2	1	1	2

RESULTS [Ω]

Test No	x→x	others	*AE Level*
1	0.48	1.45	0.331
2	4.74	∝*	0.004
3	1.04	∝	0.001
4	0.60	1.44	0.417
5	0.24	2.43	0.099
6	0.49	23.29	0.021
7	0.44	8.77	0.050
8	0.15	0.48	0.313

TO FIND THE FIGURE OF MERIT, THE RESISTANCE VALUES OF CORRESPONDING LINES WERE DIVIDED BY "OTHERS" RESISTANCES (IN THE CASE OF ∝ - BY 1000) AND CALLED AS ANISOTROPIC EFFECT LEVEL (*AE Level*).

THE LOWER VALUE OF ANISOTROPIC EFFECT LEVEL - THE BETTER

The Influence of Technological and Material Parameters on the Anisotropic Effect

The results of the experiment were transformed by the analysis of variance

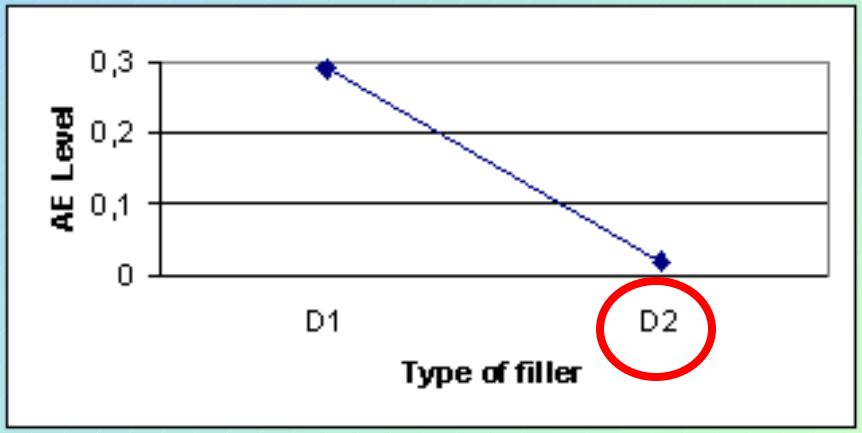
ANOVA

Factor	*SS*	*v*	*V*	*F*	*SS'*	*P%*
A	9112.5	1	9112.5	4.19	6936.5	3.4
B	13284.5	1	13284.5	6.11	11108.5	5.5
C	9384.5	1	9384.5	4.31	7208.5	3.5
D	146882	1	146882	67.5**	144706	71.2
E	20200.5	1	20200.5	9.28	18024.5	8.9
T	203216	7	203216			100.0
e_p	4352	2	2176			7.5

!!!
!

***P%* - percent contribution**

The Influence of Technological and Material Parameters on the Anisotropic Effect



D - the type of filler material

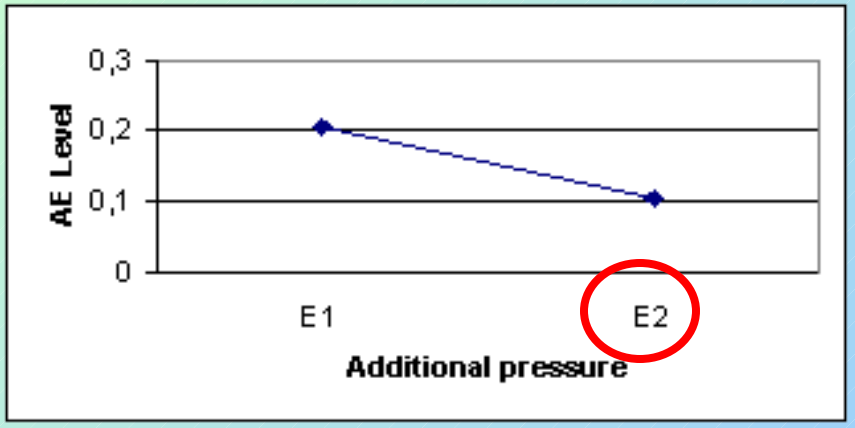
D1 - *I*-type (spherical shape with the dimension lower than 1 μm)

D2 - *II*-type (irregular flakes with average size of 3.5 μm)

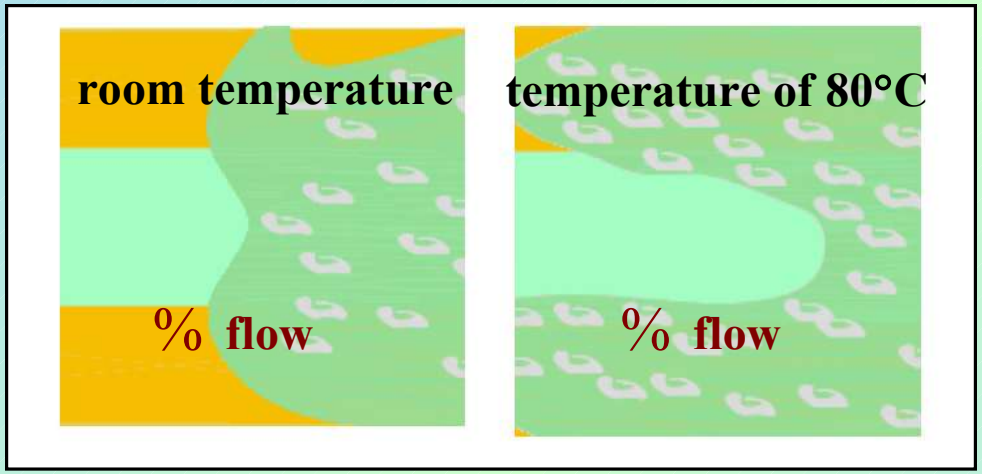
E - the vertical pressure during the curing process

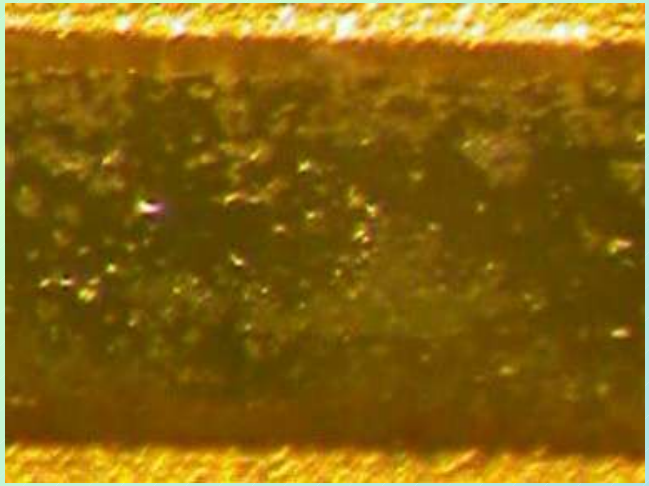
E1 - without additional pressure

E2 - additional pressure of 190 Pa



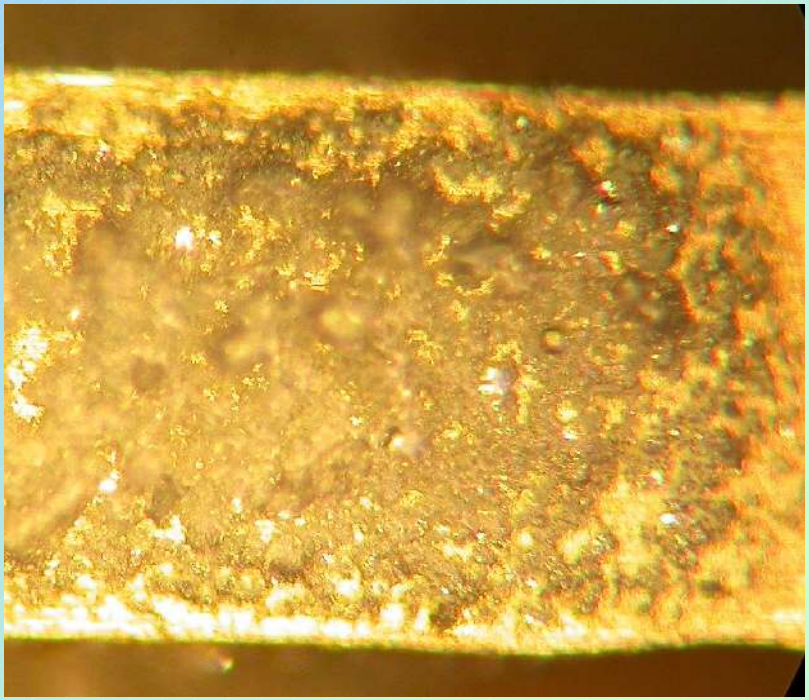
Discussion



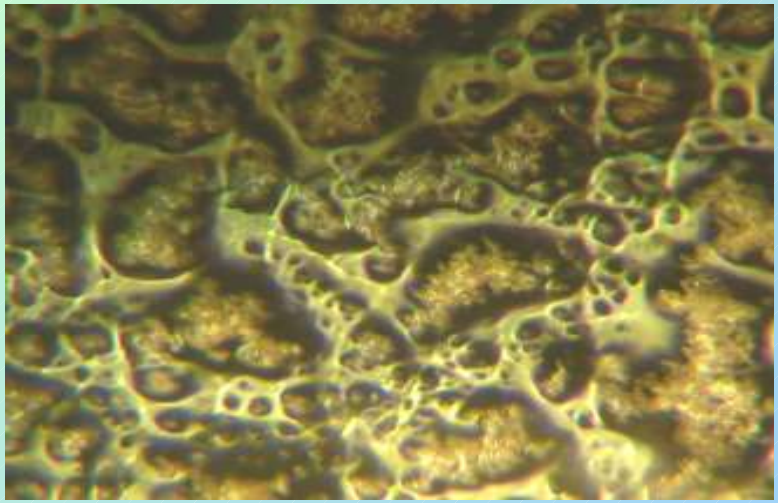


CLUSTERS OF FILLER

Discussion



THE GOLD SURFACE OF THE STRIPLINE COVERED BY A NON-HOMOGENOUS LAYER OF ADHESIVE (AFTER CURING)



THE ISOLATING ADHESIVE LAYER (AFTER CURING) BETWEEN STRIPLINES

Discussion

- **THE MICROSCOPIC OBSERVATION REVEALS THE VIOLENT TURBULENCES AND CLUSTERS OF FILLER – MUCH HIGHER THAN SINGLE FILLER'S PARTICLES. AS THE RESULT, THE CLUSTERS PLAY SIMILAR ROLE AS BIG, BALL-SHAPE PARTICLES IN ACA. ON THE SURFACE OF THE GOLD BUMP THEY CAUSES THE ELECTRICAL CONTACTS IN *Z*-DIRECTION, WHILE VOLUME OF THE ADHESIVE BETWEEN BUMPS HAS THE FEATURE OF AN ISOLATOR.**

- **THE FORMING OF CLUSTERS DEPENDS ON THE FILLER'S PARTICLES. IT WAS STATED, THAT FACTOR D MOSTLY INFLUENCED THE ANISOTROPIC EFFECT. IRREGULAR FLAKES WITH HIGHER SIZE AND SPECIFIC TAP DENSITY OCCURS TO BE BETTER**

- **IN THE CASE OF THE INTERCONNECTIONS WITH ACA, THE ADDITIONAL PRESSURE IS ONE OF THE MOST IMPORTANT TECHNOLOGICAL PARAMETERS. ALSO IN THE EXPERIMENT THE RESULTS WITH ADDITIONAL PRESSURE, FACTOR E, WERE BETTER**

Polytronic 2004

BY MODIFICATION OF THE SURFACE TENSION OF SILVER FILLED ISOTROPIC CONDUCTIVE ADHESIVES

ANISOTROPIC EFFECT

IS POSSIBLE

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