507. Electrosensitive glue for vibrotesting of radioelectronic industry items

E. Korobko[1,a], E. B. Kaberdina[1], A. Karabko[1], A. Bubulis[2,b]
[1]Heat and Mass Transfer Institute, National Academy of Sciences, Belarus, 15 P. Brovka Str., BY-220072, Minsk, Belarus
E-mail: [a] *evkorobko@gmail.com*
Phone: +375-17-284-13-61; **Fax:** +375-17-284-13-61
[2] Kaunas University of Technology, Kęstučio 27, LT-44312, Kaunas, Lithuania
e-mail: [b] *algimantas.bubulis@ktu.lt*

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Abstract. The possibility of using electrocontrolled glue (ER glue) for fixing radioelectronic industry items during their vibrotesting is discussed. The schemes are presented for fixing items of different materials and shapes to the electrodes of the basic surface of the fixing device. The impact of technological factors is demonstrated to enable us to obtain an increase in the specific fixing force sufficient for mounting the items in order to conduct experiments in the required range of vibro-accelerations.

Keywords: ER glue, vibrotesting, radioelectronic industry.

Introduction

To provide competiveness of the goods produced by the radioelectronic industry it is required to enhance the quality of their operation in the conditions of intense mechanical vibrations. In the radioelectronic industry such items as integrated circuits, capacitors or transistors are tested on a mass scale for vibration strength and vibration resistance [1]. As a rule, bench tests are carried out using special equipment. The requirements on the tests are to provide: real vibrations in the range of frequencies from 0.1 to 5.000 Hz; displacements – from several tens of micrometers to several tens of millimeters; accelerations from one to a few hundreds of m/s^2, spectral density of acceleration – up to 10 m^2/s^3 with the error of reproduction of 10-20 % (for acceleration and displacement) and of 1.5 and 3.0 (for spectral density) and transfer them onto the items of various sizes from elements, for example, resistors, up to whole constructions.

The most important element in the quality assurance system for transfer of vibrations to the object from the source of vibration, in particular, the electrodynamic stand, are fixing devices. In industry different ways and appliances for fixing items in vibrational experiments are well-known and widely used. The majority of them are mechanical fixing type as well as glues, resins and compounds. The basic feature required of any fixing device is to provide maximum transfer of a mechanical energy from a table of the vibrostand to the tested item, which corresponds to the transfer factor (or coefficient) equal to the unity in the entire working range of vibration tests.

Most of the known methods of fixing not only satisfy these requirements but also create additional difficulties due to the use of multiple items. For example, the application of glues, resins, compounds requires using technological fillers (solidification), as well as a difficult operation of releasing items from gluing. Their application does not satisfy the requirement of keeping the surface of tested items intact. We have suggested a new and efficient method of fixing radioelectronic items [2], which is based on the electrorheological effect [3,4], and does not suffer from the drawbacks mentioned above. The method lies in a fast reversible increase in the effective viscosity and elasticity of an electrorheological fluid (ERF) in the slot of a capacitor in a strong electric field.

In electrostatic fixing devices in comparison with magnetic devices, the fixing principle is based on the surface effect due to which it is possible to keep items of different thicknesses pressed with the same force. The method allows us to make fixing of magnetic, non-magnetic, metallic and dielectric materials. Moreover, as the fixing force is evenly distributed over the entire surface, small items could be fastened independent of their position on the surface of the fixing device.

The main components of electrorheological glue are a nonpolar phase with a high dielectric resistance of the carrying medium and a solid dispersed phase with a rather high dielectric permittivity. As dispersion media one can choose light colored oils (vaseline, transformer oil), diethyrs, aromatic carbohydrates, paraffin carbohydrates. As dispersed phase silica in various modifications is widely used (in the form of silica gel, aerosil, and diatomite). Besides silica aluminosilicates, metal oxides, and other dispersed materials could be used.

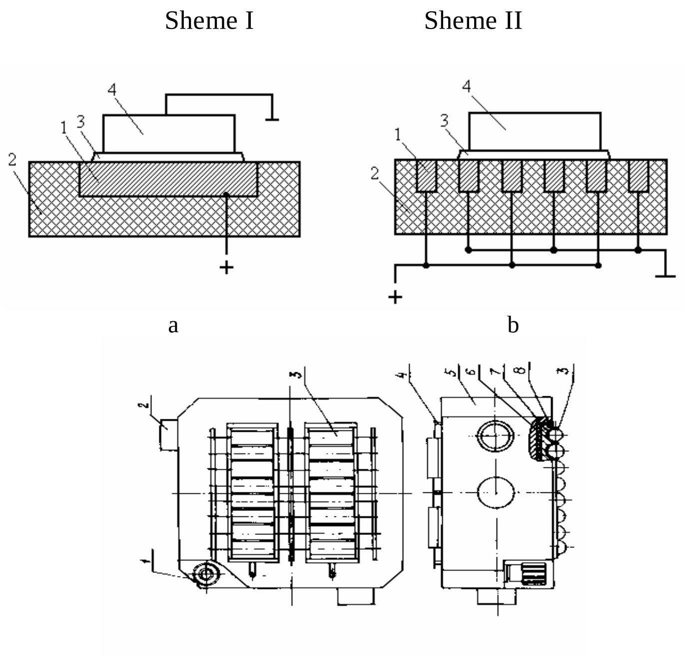
The dispersity of solid particles plays an important role, the best results have been obtained for the particles with the size smaller than one micron. Material should be homogeneous and without intrusions, that can enhance its conductivity. The main factor is the presence of an activator in ER-glue, which adsorbs on the surface of the particles. The most widely spread activator is water, besides we can use amines and alcohols. For practical use of ER glue it is very important to have stable glue properties, to avoid layering of phases and changing of the dispersed system properties with time. This requirement is satisfied by the introduction of fourth component – surfactant, the type and quantity of which are chosen empirically by considering the value of solid phase surface.

The durability of the structure of an ER glue depends on its content and electric field strength. It is clear that the total durability of the structure is made up of the durability of one contact multiplied by the number of contacts of particles with each other in the volume unit. The first part of the problem is solved by choosing the most electrosensitive fillers or by their modifications, for example, by adsorption of special substances on the surface. It is known, for example, that inorganic substances can be used as a filler for an ER glue, for example, crystallohydrates in which the activator is bonded water and also polymers with adsorbed activator.

Electrosensitive paste prepared for fixing represents a thick mass that becomes a fluid starting from a small deformation. In the experiments we specifically used an ER glue of multicomponent composition.

In Fig. 1,a-c the fixing schemes of item surfaces to the electrode through the layer of ERF are presented. In the case of conductive surfaces of an item, the scheme has an electrode 1, which is fixed to a nonconductive base 2, to which we apply a high voltage potential from the source, the layer of ER glue 3 and item 4, linked to the other pole of the source (scheme I). For fastening an item having a dielectric surface, scheme II is used. The basic surface of the mounting table consists of the surface of alternating electrodes 1, linked with the different poles of the voltage source and fixing on the nonconductive base 2. This scheme can be applied to fixing metallic items if their surface or the surface of electrodes is protected by special isolation coating. Item 4 is situated on the layer of ER glue 3, the potential difference is created between neighboring electrodes. In case of mounting according to scheme I, the current chain passes structural bridges in the glue layer from the electrodes to the item. According to scheme II – from one electrode through the bridges, then along the surface of the item and again through the bridges to the other electrode.

To obtain fairly rigid connection of the item with the electrodes it is necessary to consider the mechanical properties of the ERF structure in the electric field and conditions of the interactions of the ERF particles with the electrodes and item surfaces. For experiments with the capacitor of cylindrical shape it was suggested to use a device which is described in Fig. 1c. High voltage is applied to the terminal block 1. The capacitors under investigation are situated in the depth of the cylindrical form, which repeats the capacitor surface. In between of metallic insert 7 and capacitor 3 there is the ER glue. The appliance as well as the table shown in Fig. 1 a, b can be mounted on the working table of a vibration stand.



c

Fig. 1. Schemes of fixing items to electrodes through a layer of ER glue: a – plane item with a conductive surface, b – item with a dielectric plane surface, c – cylindrical items with conductive surfaces - 1, terminal block; 2, current protection unit; 3, capacitors; 4, plate for making soldered terminals of capacitors; 5, body; 6, insulator; 7, insert; 8, ER glue

The rigidity of the fixing depends not only on the rigidity of the structure in the layer of ER-glue, but on the forces that fix the structures to the surface of the electrodes and item, which in turn depend on the condition of the base surface and item, and on the presence of special coatings. For metallic items the binding with the electrodes in the electric field can be enhanced by covering the surface with an oxide film that has semiconductor properties. It prevents the appearance of electrical breakdown at the same time. For our purposes the electrodes from aluminium alloys have been preliminarily subjected to solid anodizing to the depth of 30-80 μm. For enhancing the fixation of ER glue to the dielectric surface of an item we have deposited a special developed lacquer coating that has a relatively good adhesion to most of dielectrics and ensures magnitude of the conductivity of the item necessary for fixation.

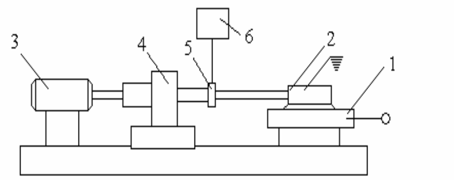


Fig. 2. Scheme of the appliance for measurement the fixing loading of fixing an item to the working table

The rigidity of fixing to the electrodes has been checked by applying a displacement force to the item. In Fig. 2 the scheme of the appliance for determination of magnitude of fixation forces is illustrated. At the beginning we clean the surfaces of electrodes 1 and item 2, then we deposit a lacquer on the surface of the item. The lacquer is usually dried at a temperature of 18-22 °C during 15-20 minutes, the suspension is stirred to the fluid condition. Further a thin layer of the ER glue is deposited on the surface of the item and the item is pressed to the electrodes. Since the item is made from conductive materials, it is connected to earth by scheme I. Drive 3 (Fig. 2) transmits a step motion (ν = 0.04 mm/s) to the slide 4. The value of the fixing force is measured by a sensor 5 and is registered by a recorder 6. We determine the force at which the item is moved from the electrodes. Its value is divided by the surface of the item and the specific fixing force is calculated (in kPa). The fixing of the items from dielectric materials has been implemented by means of scheme II.

Results and discussion

In Fig. 3 a dependence of specific fixing force at the surface unit – 1 cm^{-2} of the aluminium detail on applied electric voltage (by scheme I, Fig. 1) is presented. The depth of the dielectric layer of aluminium oxide of 35 μm is not sufficient since on application of voltage higher than 1500 V a breakdown occurs, but below 1500 V the fixing force reaches maximum. At a thickness of the dielectric layer of 75 μm its electrical resistance is high and the fixing force is substantially lowered.

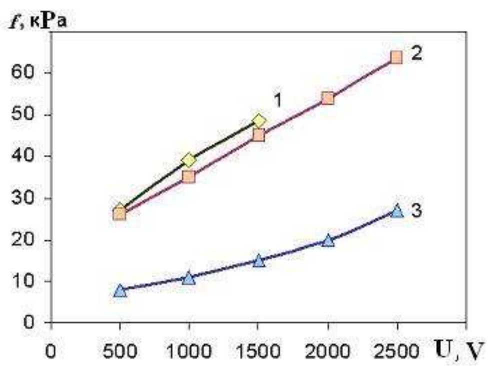


Fig. 3. Dependence of the specific fixing force in fixing an aluminium item on the voltage of the electric field: 1 − the thickness of dielectric coating of the electrode 35, 2 – 50, 3 – 75μm

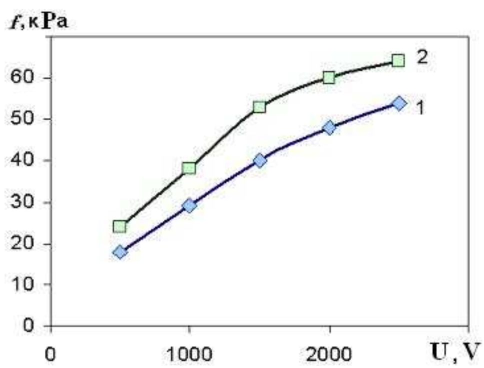


Fig. 4. Dependence of the fixing force in fixing an asbestos cement item on the voltage of the electric field: 1 – without a coating, 2 – with a lacquer coating

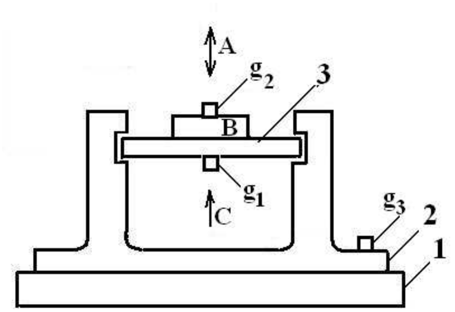


Fig. 5. A sketch of the resonance table for the investigation of the coefficient of transmitting mechanical loadings by the ER method of fixing items:1 – vibrostand platform; 2 - frame; 3 – resonance disk; A – the direction of vibrations; B – fixing table with a sample, C – the direction of tightening of the resonance disk.; g_1, g_2, g_3 – sensors to measure acceleration.

Dependence of the value of specific fixing force of a dielectric detail from asbestos cement without a coating and with a lacquer coating on the value of the applied electric voltage (Fig.1 b, the electrode width is 2 mm, the width of the dielectric slot is 2 mm) is shown in Fig. 4.

An increase in the electric field leads to an increase in the fixing force, at high voltages (U > 2500 V) it is possible to lower the force – fragile splitting of the ER glue from the surface of the item and the electrode occurs. The choice of optimal composition of the ER glue, techniques of the treatment of the electrodes and the surface of an item, optimization of the fixing method allows us to get the values of the specific fixing force of about 60 kPa, which is substantially higher than the results, presented in [5].

The investigations of the vibration characteristics of plane and cylindrical items by using the ER-method of fixing the items have been carried out on a resonance table of electrodynamic vibrostand VEDS – 10A. The sketch of the table is presented in Fig. 5. In our experiments ER glue on the basis of silica and transformer oil has been used. ER glue was deposited on the contacted surface, and after this the item tested was pressed to it with some effort.

Fig. 6 represents the transfer coefficient of the system at different vibration frequencies 1 – 5000 Hz. The transfer coefficient retains the value K = 1 in the range up to 3800 Hz which corresponds to reliable fixing of an object in vibration tests and meets the requirements of the state standards.

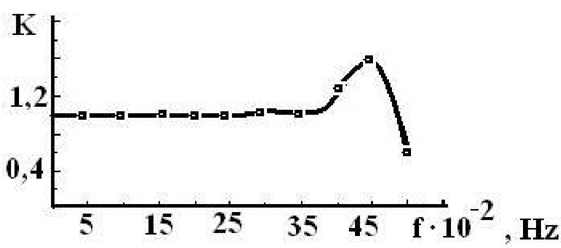


Fig. 6. Transfer characteristic of the resonance table disk

The results of investigations of the intensity of the influence of vibrations on the fixing dynamic efforts for the aluminium sample m/S=5.4 g/cm^2 without the use of isolating spacers have shown that in order to provide a stable fixing with the coefficient of transfer $K \cong 1$ it is necessary to use the electric field of $U \cong$ 500 - 750 V, the dynamic force of breaking-away of an item is equal to mg^2/S = 23.3 kPa.

Fig. 7 illustrates the change of the dynamic characteristics of ER fixing of an aluminium sample *m/S*=5.4 g/cm^2 at different voltages. The fixing was made using nylon net of width of 15 μm, soaked with ER glue which is introduced to avoid breakdowns between the sample and the table. Optimal voltage for these conditions is *U* = 1500 - 2000 V, at which, on one hand, the possibility of the electric breakdown is reduced, and, on the other hand, the required strength of the field for structuring in the ER layer is formed. At the same time, the coefficient of transfer (curve 1) of ER glue is equal to $K \cong 1 \div 1.2$, and the dynamic force F (curve 2) is equal to 17.7 kPa. At voltages on the ER layer *U* = 3000 V the electric breakdown occurs and the fixing effect disappears.

Thus in the former case the effect is higher than in the latter, but the electrical breakdown remains and this lowers its effective use.

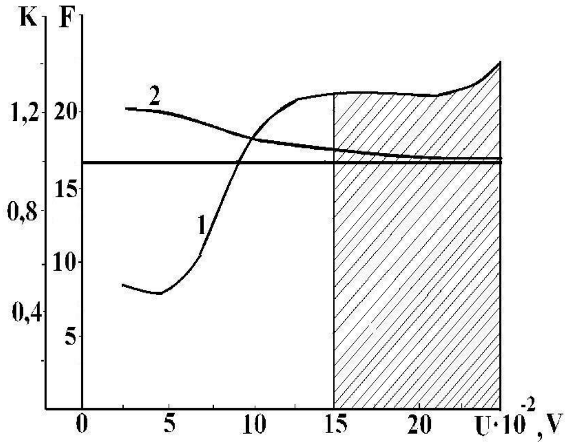


Fig. 7. Vibration characteristics of ER-methods of fixing an aluminium sample by using the isolating spacer

The possibility of applying the ER glue for fixing items during shock proof testing is illustrated in the table below. The range of durations of the influenced percussion impulses was 2 - 5 m/s. The applied electric voltage – *U* = 500 V.

The direction of shock	Applied acceleration, m/s^2	The acceleration of the sample, m/s^2	*K*	Weight, g	mg/s
Vertical	125	120	1.1	50	-
	150	150	1.0	20	95
	75	60	0.8	35	18
	100	75	0.75	50	-
	75	69	0.81	50	-
Horizontal	150	125	0.83	50	57

Conclusions

Reported research work has proved the possibility of applying electrorheological method for fixing different items with the aid of a universal device of a new type on the table of a vibrostand. At the same time the error of reproduction of the acceleration is 11 %, which is significantly lower in comparison to mechanical appliances used before for the same purpose.

The ER method of fixing radioelectronic items is promising for the technique of testing the influence of mechanical forces. The proposed method provides the coefficient of transfer $K = 1$ creating the condition of effective transfer of mechanical energy from the table of a vibrostand to the tested item with the aid of ER glue. It will allow us to provide high quality vibrotests for radioelectronic items. In addition to providing stable output characteristics, the suggested fixing devices possess the required reliability and safety in service. Other advantages include their universality, simplicity of design and low energy intensity (currents of about 10^{-5} A).

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