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Low Resistivity polymeric adhesives

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Abstract:

Samples of low resisitivty polymeric adhesives of epoxy type were prepared. Curing took place at the ordinary temperature and hardening was complete within about 15 minutes. The volume resistivity was about 1.5 $\times$ 10^{-4} Ω Cm when the sample contained 25% by weight silver. Such low resistivity and short curing time allow the use of mentioned adhesive for repairing the broken low power electrical conductors. The prepared adhesive may also find many applications in electronic packing and silk screening.

Key Words :

Polymeric adhesives - Epoxy adhesives - conductive polymers - conductive epoxy - low resistivity adhesives - welding - low power conductors.

Introduction :

Organic polymers with all-carbon backbones are very efficient electrical insulators since their electrical resistivity is very high. Resistivity of such polymers can be decreased when carbon black or ultra fine metal powder is added to the polymer and distributed in such a way that conduction can easily take place via the filler whereas the polymer merely acts as a supporting matrix. Conductivity of the poly tetrafloroethylene (PTFE) is about 10^{-18} S Cm^{-1}, that of metallic copper is about 10^{6} S Cm^{-1} and that of the electrically conductive silver epoxy (ECSE) varies from 10^{4} up to 10^{5} S Cm^{-1}[1-3].

The epoxy based conducting polymers are important for protecting the integrated circuits against damage, humidity or corrosion [4,5]. ECSE is a very versatile low resistance adhesive. It can be used as an adhesive, ink, sealant or as a coating material.. It is also silk screenable like the 100% solid system[6-10]. It has also good thermal conductivity, excellent wetting characteristics and consequently good adhesion to metallic, glass, ceramic and plastic substrates. High speed epoxy chip bonding is also one of the fields of applications of the ESCE[11,12]. In this study , the adhesive constituents have been selected in such a way to satisfy the requirements mentioned elsewhere[13-14] as:

–Excellent corrosion resistance.

–Excellent impermeability to moisture.

–Fast curing at the ambient temperature and pressure.

–Good electrical conductivity.

–Suitable viscosity and expansion coefficient.

–High solvent volatility.

–Low modulus of elasticity.

2- Experimental :

2.1- Materials:

Adhesive selection depends on the viscosity of the resin-hardener mixture, cure schedule, operating temperature range and the average strength of the required joints. Such strength is dependent mainly on the adhesion of the adhesive to the substrate, cohesion of the adhesive itself, glue line thickness, surface preparation, cure schedule and temperature.

Table (1) lists the different epoxy resins used for preparation of the ESCE samples. The used metallic powders were all 99.9% pure and between 150 to 200 mesh in size. Small amount of urea, salycilic acid, formaldehyde, glycerol or ethylene glycol may be added to regulate the drying operation and to improve the plasticity of the resulted joint.

Methyl ethyl ketone peroxide (MEKP) and cobalt naphthenate were used as curing catalyst and accelerator respectively. Triethylenetetramine (TETA) was used as a hardener for most of the prepared samples.

2.2- Adhesive Preparation and Testing :

The conductive adhesive samples were prepared according to the following proportions:

–Resin	50-80% (by weight)
–Hardener	20-50% (by weight)

–Accelerator 0-3% (by weight)

–Metallic powder 0-25% (by weight)

The following rules were adopted during the sample preparation:

–The resin (A) must be always kept away from the hardener (B). Mixing takes place few minutes only before application.

–Contact between the metal particles is essential for lowering the sample resistance, therefore the degree of dispersion must be accurately controlled, otherwise conduction will be nearly impossible.

–Powder content affects also the sample viscosity and the resulted joint properties, therefore this parameter must be accurately controlled otherwise both electrical and mechanical properties of the joint will be affected. Application of the adhesive may also be difficult if the viscosity is not suitable.

Table (2) shows the compositions of the prepared seven samples and their corresponding volume resistivity as measured using the highly accurate four point resistivity probe FPP-5000. Powders of three different metals, seven different epoxy resins and three different hardeners were employed in this study.

3- Results and Discussion :

The obtained results are given in table (1) and presented on fig (1). From these results one can notice the following:

The volume resistivity decreases continuously as the silver content of the adhesive increases (see fig 1). A considerable drop was recorded in the region between 20 and 21% silver. This drop may be attributed to the

particle-particle contact which becomes more and more probable above 20% silver.

The unusual small conductivites recorded for the samples containing copper and aluminum powders may be due to the thin oxide film which covers their particles. It wasn't easy to remove such highly resistive films before dispersing the mentioned powders.

The magnetic silver powder was not as efficient as the pure silver, this also may be attributed to the bad conductivity of the iron particles present in such magnetic powder.

The use of 5 minutes epoxy led to the smallest resistivity compared with the other six resins, this may be attributed to its relatively smaller initial viscosity and the consequent easy and efficient dispersion of the silver particles in it. The fast hardening hinders any further settling operations and keeps therefore the initially formed uniform silver distribution.

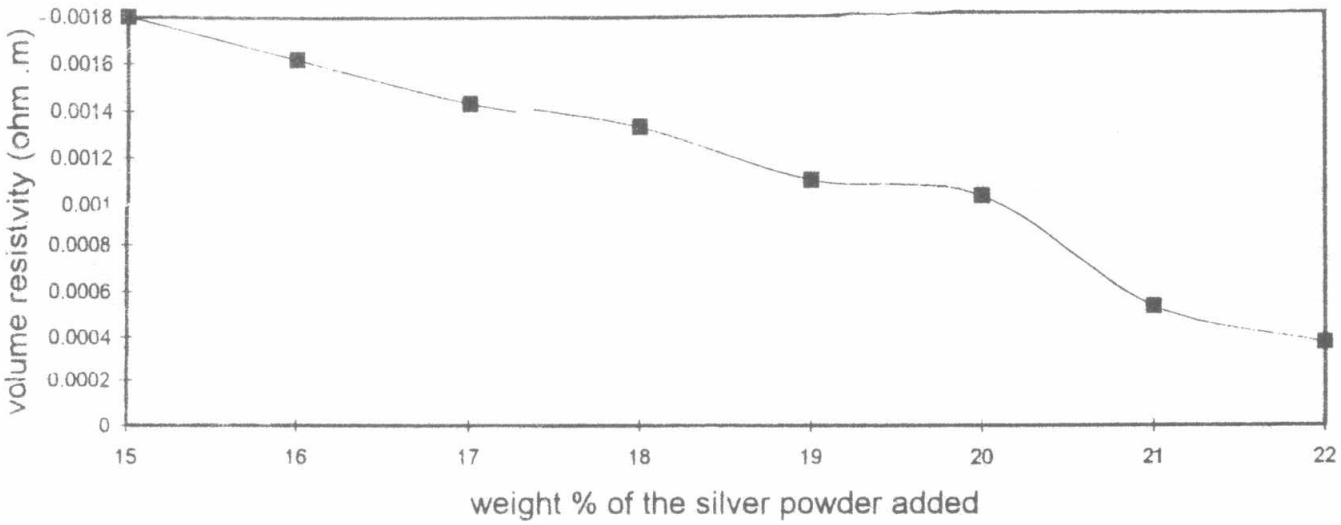
4- Conclusion :

ECSE is an improved, two component, soft flowing, epoxy paste containing pure silver powder. This system was designed to have very high electrical conductivity that is reproducible as well as excellent handling characteristics.

Curing took place at ambient temperature with complete hardening within about 15 minute. Very low volume resistivity of about 1.5×10^{-4} Ωcm was obtained for the epoxy paste containing 25% by weight silver. This low resistivity and short curing time allow to use such polymeric adhesives for repairing a broken low power electrical conductor. It may also find many applications in electronic packing and silk screening[15-17]

Table(2): Conductive polymer composition and conductivity measurements:

Sample Number	Epoxy resin (part A)	Curing agent + additives (part B)	Filler 20 25% (w/w)	Volume resistivity ρ/ohm cm
1	Araldite GY 260	Tri ethylene tetramine (TETA)	Cu-powder Al-powder Mag. Silver powder Ag-powder	1.1×10^{-2} Ext. high 0.5×10^{-2} 2.1×10^{-3}
2	Beckopox EP 140	(TETA)	Cu-powder Al-powder Mag. Ag-powder Ag-powder	1.5×10^{-2} Ext. high 2×10^{-2} 3×10^{-3}
3	Epoxy steel	(TETA)	Ag-powder	4.7×10^{-3}
4	Metal free epoxy	(TETA)	Ag-powder	1.2×10^{-3}
5	Beckopox EP 080	Beckopox special hardener EH 652 + Glycerol (0.5%)	Ag-powder	2.9×10^{-3}
6	5 Min epoxy	TETA	Cu-powder Al-powder Mag. Silver powder Ag-powder	1.8×10^{-2} Ext. high 2.1×10^{-3} 1.6×10^{-4}
7	Unsaturated polyester	Cobalt nophthalate and MEKP(0.2% and 2%, 10% solution respect.)	Ag-powder	6.9×10^{-4}



Fig(1):The relation between volume resistivity and weight %of silver powder added

Table (1): Selected Resins Used For ECSE Manufacturing :

Resin	Abbreviation	Supplier	Remarks
Araldite GY 260	DGEBA	CIBA-GEIGY	Diglycidyl ether of bisphenol A
Beckopox EP 140	DGEBA	Hoechst	
Epoxy steel	DGEBA	CIBA-GEIGY	
Metal free epoxy	DGEBA	CIBA-GEIGY	
Beckopox EP 080	EHGE	Hoechst	2.Ethyl hexyl glycidul ether
5 Min epoxy	DGEBA	Devcon corp.	
Unsaturated polyester	UP	Lab. prepared	Prepared according to the procedure given in ref.[10]

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