Developing an effective, fast-curing, environmentally sound conformal coating

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Introduction

The electronics industry has recently undertaken the transition to lead-free processing as a direct consequence of the RoHS directive, which came into force in July 2006. However, this is unlikely to be the last transition required since the European Solvent Emissions Directive, 1999 is starting to be implemented and enforced by national governments. This is resulting in pressure on larger manufacturers, currently emitting more than 5 tonnes of solvent vapour per annum to take steps to limit and reduce their emissions.

Water-based coatings offer a convenient solution to the Volatile Organic Compound issue, but suffer from the fact that they take longer to cure. Conformal coatings suppliers, therefore, need to develop effective alternatives to meet the solvent reduction and faster processing targets. In this article, HumiSeal illustrates what it takes to create an effective solvent-free coating such as its revolutionary UV40.

So what are the facts?

Now that the RoHS directive has largely been implemented, it is time for electronics manufacturers to think about reducing the amount of solvent they use, to help meet the requirements of the European Council Directive EC13/1999. Essentially, under this legislation, a good 'rule of thumb' is that any organic solvent with a boiling point less than 250°C is considered to be a VOC emission.

Basically, all of the solvent that enters a factory needs to be accounted for under the legislation. Any site emitting more than 5 tonnes of VOC emissions per annum is required to take action to reduce this level by either adopting an alternative lower VOC material or by installing expensive solvent-burning systems prior to exhaust.

Is meeting the requirements of the legislation the only issue?

There is much concern about the safety implications of using solvents in manufacturing processes, of storing and transporting flammable materials, and of course exposing operators to the effects of solvent vapours, with unknown long-term health implications.

It is against this background that many companies are further looking to reduce their solvent usage and in so doing reduce their insurance liability, storage and transportation costs and increase their likelihood of achieving ISO 140001 status.

Water-based fluxes have already made a significant impact on the wave-soldering production process, and so the conformal coating process is likely to remain one of the largest contributors to VOC emissions in an electronic manufacturing assembly process.

Developing a viable alternative

UV curable conformal coatings are solvent-free, 100% active liquid materials, which, when exposed to the correct wavelengths and intensities of ultra violet light polymerise extremely rapidly, to form a tough, durable coating. All of the liquid coating applied is converted into solid coating, unlike solvent-based or water-based

materials, which rely on evaporation of the solvent, before any cross-linking mechanism can occur.

UV curable solutions, such as HumiSeal UV40, offer a route to significantly improve the quality of the conformal coating protection, whilst largely eliminating VOC emissions and yet dramatically increasing the speed of curing. Generally, the implementation of lead-free processing has required the installation of longer ovens to achieve the higher reflow profiles necessary, which has put pressure on floor space. HumiSeal has found that customers using its UV40 have been able to reduce the floor space requirements of a typical coating cell by at least 50 per cent.

Extensive development and testing has meant that UV40 gives outstanding thermal endurance at high temperature (+150ºC), largely meeting the performance of silicone materials, whilst having outstanding flexibility at low temperatures (-65°C), traditionally a major downside of UV conformal coatings.

The strategy was to develop a product with a viscosity low enough to enable automated application, yet sufficiently high to prevent material from running off sharp edges and flowing underneath components and into vias by capillary flow. This advantage was uniquely combined with perhaps the most effective secondary cure mechanism available, to ensure that any material which does not see UV light from the curing lamp will still reliably cure in under 3 days at ambient temperatures and humidity.

Development considerations

Moisture secondary-cure mechanism

Having a secondary cure mechanism is vital to ensure that the entire application of the coating forms an effective seal throughout the application. For example, UV40 contains some polyurethane chemistry, to ensure that any material not exposed to UV radiation will still cure by initiation brought about by ambient moisture, in the form of both humidity and liquid water residing in the solder resist.

It has been found that most solder resists contain some un-reacted amine from their thermal cure mechanism, and these can both act as a catalyst for the moisture cure mechanism, as well as provide active sites for coating products to react with, thus forming extremely strong covalent chemical bonds. This chemical reaction results in extremely good adhesion of UV40 to most solder resists.

Electrical properties

The only area where the coating will cure through its secondary mechanism alone is in the case of material that is drawn under low stand-off components by capillary forces.

In this case the material will be surrounded by fully UV exposed material, which will provide the mechanical and protective barrier properties. Thus, it is only the electrical properties that are of concern in areas that are not UV irradiated. Through a careful blend of polymer engineering and rigorous testing, HumiSeal has been able to provide a highly effective secondary cure mechanism yet even in the liquid form, the material is sill highly insulating, enabling functional testing immediately after UV cure.

Moisture Insulation Resistance (MIR)
The main function of a conformal coating is to provide insulation resistance under highly humid or condensing conditions, and so MIR is perhaps one of the most important properties of a conformal coating. HumiSeal UV40 provides an MIR value a thousand times greater than the IPC-CC-830 requirement and thus is highly insulating, even at extremely high temperatures and humidities.

High Temperature electrical performance
During the development of UV40 it became apparent that it had extremely high temperature endurance. As such, the product was subjected to a modified MIR test in which the test coupons were heated to temperatures between 100 and 150°C and the insulation resistance measured to ensure it didn't drop below the minimum value required for MIR in CC-830.

Although short-term electrical performance at high temperature is an indication of thermal endurance, it is important to ensure that there will be no degradation in physical or electrical properties over an extended period of time.

By measuring extremely accurate weight loss against temperature at a number of rates of temperature change, using Thermal Gravimetric Analysis (TGA), it is possible to derive a rate constant for degradation of the polymer film at high temperatures and, thus, estimate a lifetime based on time to 30% of total destruction.

At temperatures up to 150°C, UV40 has a similar thermal durability to silicone conformal coatings, and five times the durability of traditional organic materials.

Mechanical Properties
There is no mention of the mechanical properties required in CC-830, because nearly every printed circuit board and operating environment creates the need for different properties of the protective coating.

Coefficient of Thermal Expansion (CTE) and glass transition temperature (Tg).
The CTE value of a conformal coating is of extreme importance during thermal shock and thermal cycle exposures because it is important to minimise the difference between the coating and the substrate. The greater the difference between the CTE of the coating and the substrate (typically 17-20 ppm), the more likely that stress will be built-up and that this stress will be relieved by the coating cracking during thermal shock.

Obviously, once the coating has cracked, it ceases to provide a protective barrier to moisture or any other contaminants.

CTE can be measured by several techniques, but Thermo Mechanical Analysis (TMA) is the most common. TMA is essentially an extremely accurate method for measuring how much a substance expands when it is heated. TMA also measures the glass transition (Tg) of a material, because there is usually a marked difference between CTE above and below Tg.

Tg is of importance because above its Tg value a material's behaviour is more liquid in nature, whereas below its Tg a material is more glass like in behaviour. Obviously, glass would generally offer a better barrier than honey for example.

In general, it is best to have a Tg value as high as possible, so that the coating will give the optimum protection through the anticipated operating range and minimise the CTE mismatch. However, the material must be significantly flexible below Tg so that it does not become brittle and shatter during thermal cycling or shock cycles.

HumiSeal UV40 has a very similar Tg to the popular acrylic class of materials, but has a much lower CTE value than the acrylic material. Both materials have lower values than the silicone.

In the case of UV40, below Tg the CTE value is 70% lower than the silicone material whilst above Tg the CTE value is 45% lower.

Thermal Shock Testing

In order to ensure that UV40 would give the expected performance in real thermal shock testing, traditionally a weak area for UV curable conformal coatings, test boards relevant to today's SMT production were coated at 150 μm coating thickness and subjected to 200 cycles of -40 to +135°C as per fig 6.

Chemical Resistance

In order to evaluate the chemical resistance of UV40, a chemical spot test comparison was performed on fully cured, 100μm thick films and compared with silicone and 2-component polyurethane material.

HumiSeal UV40 gives similar chemical resistance to a 2-component polyurethane material, with obvious benefits in terms of curing and processing. Both classes of materials softened less and gave much better chemical resistance than the silicone materials.

Conclusion

In an effort to comply with the increasing environmental demands, manufacturers have to utilise new techniques and technologies. Thanks to the efforts at HumiSeal's R&D department utilising a solvent-free alternative coating solution may not have the impact that the swap to lead free solder had. HumiSeal's solution is an extremely easy to process, solvent-free coating, which is touch-dry in a matter of seconds. Full cure, in areas not exposed to UV radiation will be achieved by reaction with moisture, catalysed by solder resist in less than 3 days.

UV40 boasts an extremely high MIR value, the main protective property required from a conformal coating, has excellent thermal endurance and displays a comparable life expectancy to silicone materials at 150°C (the operating temperature most often quoted for under-hood and other high temperature electronics).

If you are considering the switch to a low VOC conformal coating solution, it makes sense to align yourself with a supplier that not only understands the intricacies of chemical development but also understands perfectly how they align to manufacturers' needs.

A full detailed white paper on the development of UV40 is available from HumiSeal. Please e-mail phil.kinner@humiseal.eu.

Word Count: 1,795