Micro Bonding Using Hot Melt Adhesives

Stefan Böhm†, Gregor Hemken, Elisabeth Stammen, and Klaus Dilger

Institute of Joining and Welding, Technical University Braunschweig, 38106Braunschweig, Germany
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Abstract: Due to the miniaturization of MEMS and microelectronics the joining techniques also have to be adjusted. The dosing technology with viscous adhesives does not permit reproducible adhesive volumes, which are clearly under a nano-liter. A nano-liter means however a diameter of bonding area within the range of several 100 micrometers. Additional, viscous adhesives need a certain time, until they are cross linked or cured. The problem especially in the MEMS is the initial strength, since it gives the time, which is needed for joining an individual adhesive joint. The time up to the initial strength is with viscous, also with fast curing systems, within the range of seconds until minutes. Until the reach of the initial strength, the micro part must be fixed/held. Without sufficient adjustment/clamping it can come to a shift of the micro parts. Also existing micro adhesive bonding processes are not batch able, i.e. the individual adhesive joints of a micro system must be processed successively. In the context of the WCARP III 2006 now an innovative method is to be presented, how it is possible to solve the existing problems with micro bonding. i.e. a method is presented, which is batch able, possess a minimum joining geometry with some micrometers and is so fast that no problems with the initial strength arise. It is a method, which could revolutionize the sticking technology in the micro system engineering.

Keywords: *micro bonding, hot melt adhesive, MEMS, micro electronics*

1. Introduction

The high degree of miniaturization of Microsystems requires joining processes, which make a bonding of smallest components possible. Thereby, the adhesive bonding attains a growing importance [1]. Reasons for this are the possibility of joining different materials pure or as material mixture, having a sufficient bond strength and a good dynamic behavior without thermal influence. Additionally, adhesives can imply an electrical and thermal conductivity or isolation for both, an optical transparency or isolation. Reasons which prevent an even stronger usage of adhesive joining in the micro system engineering rely on the properties of presently used viscous adhesive systems. These are the doses of the minimum volume that do not allow joining smallest geometries (<< 200 μm), the processing time, which is needed until the joining connection has handling strength (>> 1 s), the adhesive-dependent pot life, in which the adhesive can be used and the missing ability for the use in a batch wise.

2. Hot Melt Adhesives for Micro Bonding

2.1. Properties of Hot Melt Adhesives

The listed limitations of viscous adhesives in the microsystem engineering are to be compensated by using hot melts. These hot melts are thermoplastics, physical setting adhesives, which are single-component, non-viscous and non-solvent at room temperature. The range of melting temperature is from below 60°C up to 180°C, Figure 1.

So temperature-sensitive substrates can be adhesively bonded with low temperatures. If the melt temperature and thus the temperature resistance are too low, reactive hot melts can be used. Reactive hot melts are formulated by using additionally reactive components, so that this kind of hot melt can become cured. Curing the hot melts, the temperature resistance increases clearly above the melting temperature of the pure thermoplastic hot melt.

An important advantage of hot melts (reactive or not)

†Corresponding author: e-mail: s.boehm@tu-bs.de

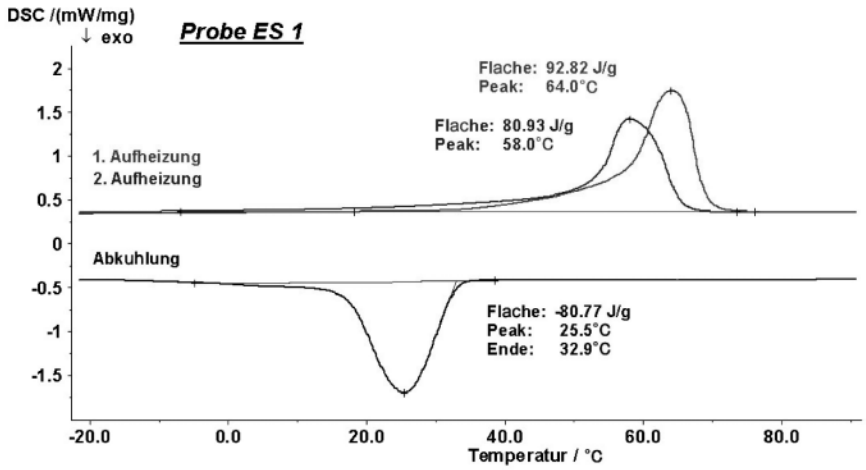

Figure 1. DSC curves of a hot melt (polycaprolactone) with a melting temperature of approx. 60°C.

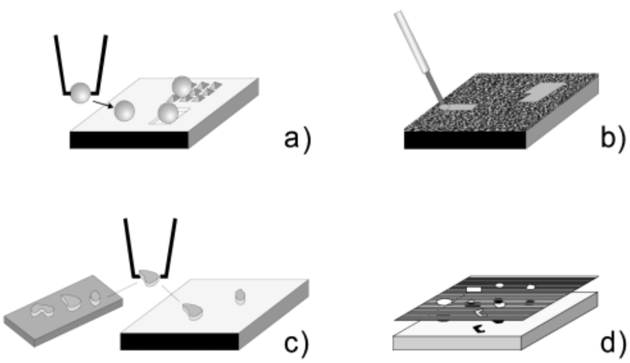

Figure 2. Application of hot melt. a) spheres, b) powder, c) foils, d) dispersion.

in relation to viscous adhesive systems is - particularly in micro system engineering - the possibility of being able to pre-apply hot melt systems, e.g. as powder or adhesive spheres, in melt liquid form, as dispersion or as an adhesive foil. The joining procedure does not have to take place directly after applying the adhesive to the substrate; this can happen at any time later on.

The adhesive is only melted during the bonding process by a thermal impulse and moistens the surface of the other substrate. The heating can be accomplished directly by heating the adhesive or indirectly by heating the substrate or both. Due to cooling, the adhesive sets. During suitable heat conduction hot melts set very fast, i.e. a handling strength (usually the ultimate strength) can be achieved in less than one second as experiments have shown.

2.2. Application of Hot Melt Adhesives

At the beginning of the use of hot melt adhesives for the micro bonding of MEMS, hot melt spheres, hot melt powder or hot melt foils were used [2]. Latest developments use hot melt dispersions which are stencil or screen printed, Figure 2.

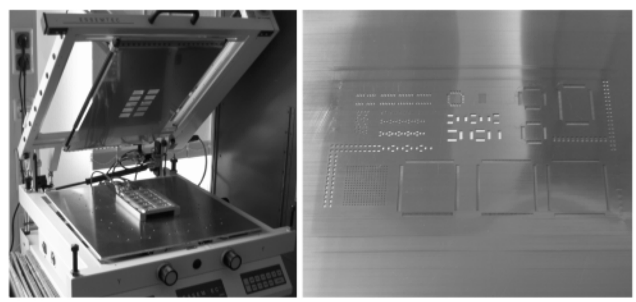

Figure 3. Half-automatic screen printer for hot melt dispersions on the left hand side, test print screen on the right hand side.

The screen printed hot melt dispersions are evaporated and remelted. Afterwards, the pre applied hot melt storable for a long period of time. At this time the minimal size of the pre applied hot melt structures are approx 50 µm. Test printings with test print screen show the quality of this type of adhesive application, Figure 3.

The results concerning the handling, the fast handling strength, the realised geometries and the properties of the adhesive joining were so convincing that a patent was applied for the procedure of micro bonding described above [3].

2.3. Production of Suitable Pre Applied Adhesive Geometries

Commercially available hot melt powder on polyamide (PA) basis and on polycaprolactone (PCAP, Figure 1)

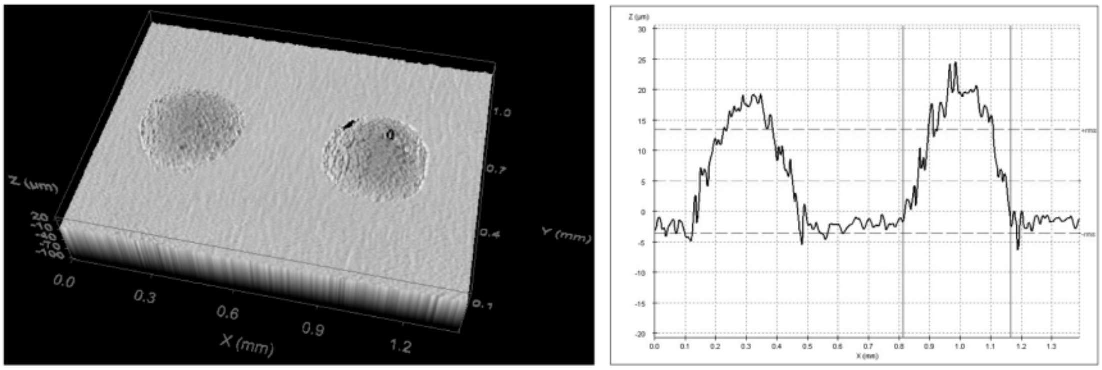

Figure 4. printed and remelted hot melt dispersion. Diameter approx. 300 μm.

basis were particularised by the use of filters or by sighting in graduated grain fractions between 2 μm and 63 μm.

The manufacturing of spheres was done on Teflon in hot-air furnaces. For this, particles were applied isolated to Teflon and warmed up to fusing temperature in the furnace. As a result of the surface tension of the adhesive and the small surface energy of Teflon, a contact angle of approximately 180°C between the adhesive and the Teflon surface arose and the hot melt particle became a sphere.

The adhesive foils (thickness approx. 5 μm and more) were made by hot pressing or extrusion. Mechanical cutting, laser beam cutting or die cutting generated the contours.

Using hot melt powder, the contour of the joining surfaces can be reached in two different ways: sintering by a laser or by electrostatic application. Concerning the sintering by a laser, the surface, which has been applied homogeneously with hot melt powder, is driven off by a strongly focused laser beam. Because of the thermal impulse the adhesive fuses for a short period of time and melts defined on the joining surface. A following cleaning process removes the remaining, non-adhesive powder. Using hot melt dispersions the shape of the screen and the rheology of the dispersion influences the geometry of the pre applied hot melt adhesive, Figure 4.

2.4. Different Possibilities of Heating the Hot Melt Adhesives

The possibility to pre-apply the adhesives is one reason for using hot melts in batch processes. A further reason is the fact that the actual adhesive process (the moistening and the physical setting) happens because of the exactly defined increase or decrease of temperature. A change of the viscosity is connected with this process. Furthermore, the heat input can be carried out directly or indirectly, laminar or local selective. The injection of thermal energy can happen through:

- local selective heating of the substrate by laser (1064 nm, 532 nm, 355 nm)
- local selective heating of the component part by laser (1064 nm, 532 nm, 355 nm)
- laminar heating via heating plate or infrared radiation.

Concerning the local selective heating of hot melts, the injection of the laser radiation can take place directly in the hot melt or indirectly through the hot melt in the substrate's surface. This depends on the laser's wavelength and the absorptive properties of the hot melt. As an alternative to the laser radiation a precision heating plate can be used. This plate is particularly qualified for geometrically expanded work pieces (e.g. wafer). In comparison to the laser heating it takes a longer time to cool down the plate.

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