Ročník 2016 electroscope Číslo III

The Viscosity Thermal Dependence of Paste Material for Electronics

I.. Beshajová Pelikánová [1], J. Močička[1]
[1] Katedra elektrotechnologie, Fakulta elektrotechnická, ČVUT v Praze,
Technická 2, Praha
E-mail : pelikano@fel.cvut.cz

Anotace:
Práce se věnuje problematice prstovitých materiálů pro elektroniku. Byly testovány pájecí a polymerní sítotiskové pasty. Byla analyzována dymamická viskozita zmíněných past. Viskozita pasty silně ovlivňuje výsledek technologického procesu. Sítotiskové a pájecí pasty patří mezi tzv. nenewtonovské kapaliny. Viskozita se mění s teplotou. U nenewtonovských kapalin viskozita také závisí na rychlosti toku kapaliny. Pro vybrané vzorky byla měřena teplotní závislost viskozity v rozsahu od pokojové teploty do 50°C. Také byla sledována změna viskozity při pokojové teplotě a při teplotě skladování v chladničce. Pro měření viskozity past byl využit rotační viskozimetr HBT. Viskozimetr byl vybaven měřícím systémem v konfiguraci kužel – deska a závěsným systémem se sadou standardních disků.

Abstract
The work is focused on properties of paste materials for electronics. Soldering pastes and pastes for screen printing were tested. The dynamic viscosity dependencies of pastes were analyzed. Viscosity of paste strongly affected the result of technological process. Viscosity is changed with temperature. Mentioned pastes belong to non Newtonian fluids. That means that viscosity of pastes is changed with shear rate too. Viscosity dependence on temperature increasing from room temperature to 50°C approximately was measured for chosen samples. Differences between viscosity of paste at room temperature and viscosity at storage temperature in refrigerator were determined too. Dial viscometer HBT type was used for viscosity measurement. Viscometer was equipped by measuring system with geometrical configuration cone – plate and system with standard disc spindle.

INTRODUCTION

Soldering pastes and pastes for screen printing are widely used in electronics. Viscosity of these paste materials is important parameter for electronics production. Inadequate viscosity of paste can cause the serious defect of technological process. Low viscosity of screen printing paste is caused to spread out of paste outside the defined structure. On the contrary, too high viscosity of paste resulting in rough surface of printed layer. Bumps remains under mesh and do not spread into smooth surface. Viscosity can be critical at the process of depositing of soldering paste on small pads of PCB or for fine pitch of pads. The risk of deposition of insufficient amount of paste occurs in case of using soldering paste with high viscosity for example. At high viscosity the paste hardly flow through the hole in stencil during paste printing. On the contrary, the paste is underflow out of margin of hole of stencil. Then paste does not shrink to soldering pad on PCB and can create the unwanted conductive join. Result of paste deposition process can be regulated by tempering paste before printing.

VISCOSITY AND ITS MEASUREMENT

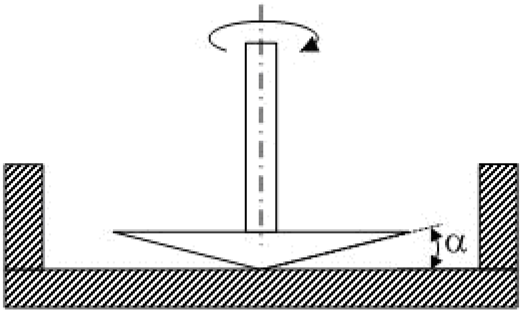
Theory of viscosity

Soldering and screen printing pastes belong to non Newtonian fluids. That means the viscosity at given temperature and pressure is not constant in comparison with Newtonian fluids. Viscosity of non Newtonian fluids depends on velocity at paste mixing.
Internal friction is arisen into real fluids. Viscosity is resistance which acts the fluid to deformation. Relative shift of neighboring layers of fluid occur when the layer are moving different speed during deformation. Viscosity is reflected externally by deceleration of fluid movement and by deceleration of bodies in fluid. That behavior can be expressed by dynamic viscosity. Dynamic viscosity η of non Newtonian fluids is depending on shear stress τ and on shear rate γ and can be expressed as:

$$\eta = \frac{\tau}{\gamma} \text{ (Pa·s)} \quad (1)$$

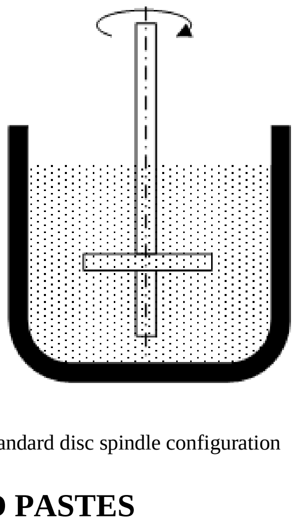
Configuration of viscometer

Dial viscometer HBT type was used for viscosity measurement. Viscometer was equipped by measuring system with geometrical configuration cone – plate. Schematic picture of cross section of measuring configuration is shown in fig. 1. Defined amount of fluid is placed in plate in form of cup. The cup do not rotate, is in standstill position. A spindle, in our case in the shape of cone, rotates at given speed in measured fluid. The torque necessary to overcome the viscous resistance to induced movement is measured. Geometric configuration of measuring system cone – plate type CP 51 was used. That type of cone has the angle α=1.565° (see fig. 1) and radius is 12 mm. Required amount of fluid for measurement is 0.5 ml. Cup is adapted for sample tempering, has the double wall jacket and allows connection to cooling or heating circuit. The embedded temperature sensor is included.



Obr. 1: Cone – plate configuration

System with standard disc spindle is another configuration for dial viscometer HBT. Schematic illustration is shown in fig 2. The spindle does not immerse into a special cup as in case previous configuration cone – plate. The rotating spindle can be put into container with paste directly. Thereby the preparation on measurement is easier and time of preparation is significantly shorter in comparison with system cone – plate. However that method is applicable to comparison less accurate measurement for one batch of paste rather. Containers with paste material have different shape and can contain different amount of paste. That factors influence the result of viscosity measurement.



Obr. 2: Standard disc spindle configuration

TESTED PASTES

Several types of soldering and screen printing pastes with different composition from few producers were used for experiment. Informations to tested pastes are shown in Tab. 1. Symbols used for pastes in this paper are in first column. Second column with specification contain complete name, producer and composition of paste. Third column include information to viscosity given by producer.

Tab. 1: Information to tested pastes

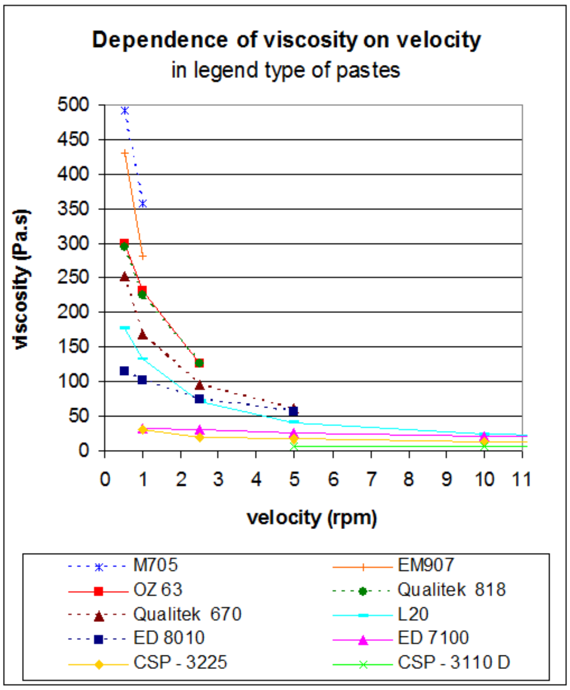
Identification	**Specification**	**Viscosity given by producer**
Screen printing pastes:		
ED 8010	Dielectric polymer paste ELECTRADOR	no info
ED 7100	Carbon-black polymer paste ELECTRADOR 10kΩ/sq.	no info
CSP – 3225	Carbon-black polymer paste CHANG SUNG CORPORATION solid content 42% wt.	20 ± 5 Pa·s RION VT-04#2 Spindle
CSP – 3110D	Silver polymer paste CHANG SUNG CORPORATION solid content 75% wt.	15 ± 5 Pa·s @50 rpm, 25°C Brookfield, SSA#14
Soldering pastes:		
OZ 63	Sparkle paste OZ 63-330F-40-10 SENJU Sn63 Pb37	250 Pa·s
Qualitek 818	No clean solder paste type 818 QUALITEK Sn62 Pb36 Ag2	900 Pa·s ± 10% @25°C, 5 rpm Brookfield RVTD, TF spindle, 075” spindle depth
EM907	Solder paste EM907 KESTER Sn96,5 Ag3 Cu0,5	180 Pa·s @25°C, 10 rpm Malcom Viscometer
M705	Eco Solder paste M705-GRN360-K2-V SENJU Sn99,3 Cu0,7	200 ± 20 Pa·s
L20	Eco solder paste L20-SSG-O10-42-10 SENJU Sn42 Bi58	no info
Qualitek 670	No clean solder paste type 670 QUALITEK Sn42 Bi58	1000 Pa·s ± 10% @25°C, 5 rpm Brookfield RVTD, TF spindle, 075” spindle depth

Values of viscosity and specification of condition and method of measurement are given for most of pastes. That data do not usable for comparison between mentioned pastes. Viscosity was measured by different method and under different conditions for particular paste. Detail information is missing for some pastes. Further details such as melting points, conditions of curing of paste do not so important from view of topic of this paper. Detail information is possible to found in datasheets on web of producers.

RESULT DISCUSSION

Viscosity and velocity

Measurement of viscosity at different velocity for pastes mentioned in chapter 3 was realized. Viscometer equipped by system cone – plate was used. Graph in fig. 3 summarize dependencies of viscosity on velocity for all measured pastes. Measurement of viscosity was carry out for range of velocity from 0,5 rpm to 50 rpm. Some pastes with higher viscosity do not possible to measure at higher velocity because the viscometer was going out of range. On the contrary, reading of very small values on viscometer at lower velocity has insufficient accuracy for pastes with lower viscosity.

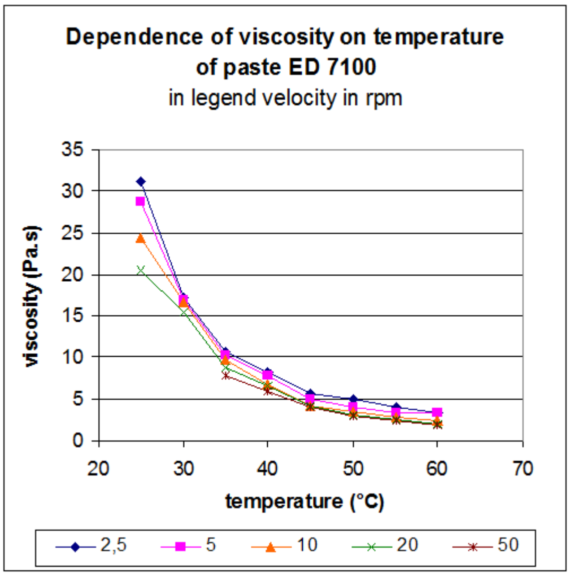


Obr. 3: Dependence of viscosity on velocity for all pastes

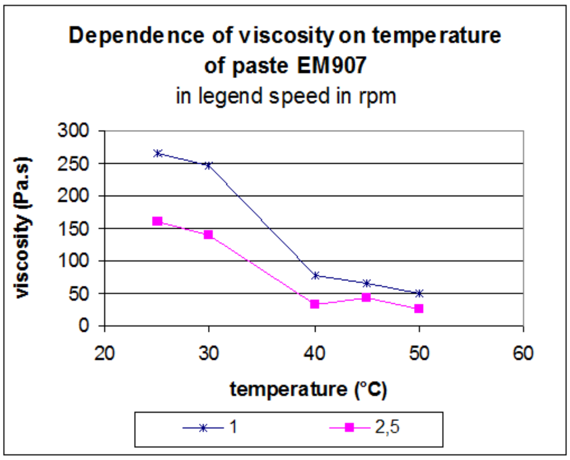
From graph in fig. 3 we can see that viscosity decrease with increasing velocity more significant for soldering pastes in comparison with screen printing pastes. Decreasing of viscosity is higher at low values of velocity. Lowest viscosity exhibit screen printing pastes (marked as ED… and CSP…). Then pastes Qualitek 670 and L20 follows in graph. Both that pastes have identical composition, both contain 42% Sn and 58% Bi. Almost identical dependencies we can observe for paste Qualitek 818 and OZ 63. Both are lead paste with very similar composition (Sn, Pb). Pastes EM907 and M705 reach the highest viscosity. These lead free pastes contain high amount of thin, more than 96%.

Temperature dependence of viscosity

The viscosity dependencies of soldering and screen printing pastes on temperature and shear rate were analyzed. The system cone - plate was used for measurement temperature dependence of viscosity. There take advantage the capability of system equipped for sample tempering. Chosen pastes were measured in range of temperature from 25°C to 60°C or to 50°C. The representative of screen printing paste is dependence for paste ED 7100 is shown in fig. 4. In fig 5 is depicted dependence for soldering paste EM907.



Obr. 4: Temperature dependence of viscosity of screen printing paste

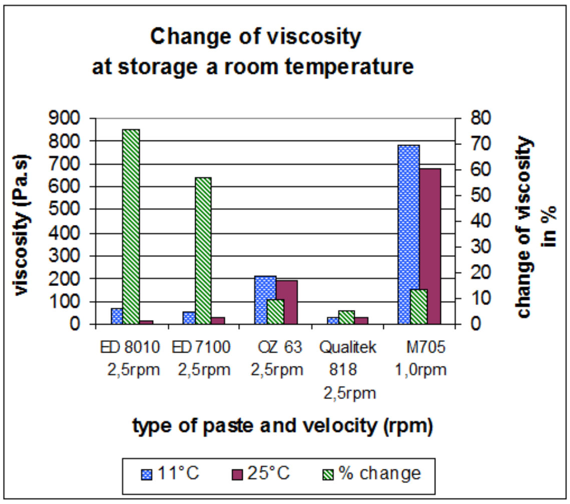


Obr. 5: Temperature dependence of viscosity of soldering paste

Graphs in fig. 4 and 5 shown that viscosity is changed more at lower values of temperature in comparison with case of higher temperature. We can compare dependencies in fig 4 for screen printing paste ED 7100 and dependencies in fig. 5 for soldering paste EM907 from view of sensitivity to two parameters influencing the viscosity – temperature and velocity. Graph for screen printing paste ED 7100 indicate that higher changes in viscosity are connected with temperature changes. For soldering paste EM907 appear opposite effect. Viscosity reacts sensitively to changes of velocity.

Viscosity at room and storage temperature

Experiment of monitoring of change of viscosity at working and storage temperature was realized too. Working temperature was corresponding to room temperature of 25°C in this case. Paste materials were storage in refrigerator at 11°C. The pastes were measured after take out from refrigerator immediately. Then the pastes were leaved at room temperature during some time to be tempering to working temperature. Pastes were tempered 40 minutes. Paste was necessary to measure quickly after take out from refrigerator before is heated by surrounding environment. Regarding to such requirement the measuring configuration with system with standard disc spindle was chosen. Certain more amount of paste in container is suitable for measurement by system with standard disc spindle as is apparent from the principle of method (see chapter 2.2). Pastes that were available in sufficient amount were measured only. Most of tested pastes were measured at velocity 2,5rpm. Viscosity of paste M705 is at 2,5rpm out of range of viscometer. Value of viscosity at 1 rpm is included in graph. Results are summarized in graph in fig.6.



Obr. 6: Comparison of viscosity at room and storage temperature

Besides values of viscosity at storage and room temperatures are the changes of viscosity in % are depicted in graph. Middle green columns in graph represent decrease of viscosity in % at room temperature compared to viscosity at storage temperature. Minor vertical right axis is valid for those values. We can observe that viscosity of screen printing pastes (ED 8010 and ED 7100) is changed more markedly in comparison with soldering paste. Decreasing of viscosity of screen printing pastes is more than 50%. Decreasing of viscosity of soldering pastes is around 10%.

CONCLUSION

Sensitivity of paste viscosity to influencing parameters temperature and shear rate was analyzed in relation to type of pastes. Screen printing paste exhibit higher sensitivity to change of temperature. Higher sensitivity to speed is observed for soldering pastes.

Measured results do not absolute values but they are values depended on measuring method. With using of different equipment with different configuration of measuring system is possible to measure different values that are nevertheless right.

The different degree of fatigue of paste given by life-time and expiration date should not be neglect in comparison of samples of pastes.

LITERATURA

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