개선된 회전형 레올로지 측정법을 이용한 박형 반도체 패키지 내에서의 3차원 몰드 유동현상 연구

Full Three Dimensional Rheokinetic Modeling of Mold Flow in Thin Package using Modified Parallel Plate Rheometry

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Abstract

The EMC's rheological effects on molding process are evaluated in this study. When considering mold processing for IC packages, the major concerning items in current studies are incomplete fill, severe wire sweeping and paddle shifts etc. To simulate EMC's fast curing rheokinetics with 3D mold flow behavior, one should select appropriate rheometry which characterize each EMC's rheological motion and finding empirical parameters for numerical analysis current studies present the new rheometry with parallel plate rheometry for reactive rheokinetic experiments, the experiment and numerical analysis is done with the commercial higher filler loaded EMC for the case of Thin Quad Plat Packages (TQFP) with package thickness below 1.0 mm. The experimental results and simulation results based on new rheometry matches well in point of the prediction of wire sweep, filling behavior of melt front advancement and void trapping position.

1. Introduction

There are several historical works on the rheology of highly filled EMC. Nguyen investigated the non-isothermal dynamic parallel plate rheometry with assuming modified Cox-Merz rule, however this relation was not experimentally proved. Pahl and Hesenkamp investigated isothermal parallel-plate rheometry with original Cox-Merz rule to characterize the rheokinetic behavior of moderated filled EMC, but dynamic shear rate sweep data requires experimental time for each frequency and the sweeping results distort easily by unwanted cure effects. Halley et al. showed that the used of multi-wave test which alleviate the effect of cure during experiments. Blyler et al. used a capillary rheometer inside a transfer but cure effect were not considered and Han and Wang devised a modified slit rheometer with reservoir but gelation times were not monitored. Harry obtained the chemorheological data by isothermal and non-isothermal test with a parallel plate rheometer using steady and dynamic multi-wave tests and compared the Cox-Merz and modified Cox-Merz relation with steady shear viscosity and showed Cox-Merz relation correlate much better than does the modified Cox-Merz does for the case of 1% strain on the linear viscoelasticity region assuming no wall slip or yield stress region.

Current studies also applies the multi-wave parallel plate rheometry with non-isothermal test has been performed. For the correlation of dynamic to steady viscosity relation, the modified Cox-Merz rule has been applied, because we regarded the actual case of transfer mold case of IC packaging as wall slip condition.The model used for this study is Kamal's equation for the curekinetics and power lay Mocosko-Cross model for full rheokinetic representation. For the Numerical modeling, we applied full 3D FVM based tools from Coretech inc. instead of traditional 2.5D simulation tool based on Hele-Shaw approximation.

2. Rheological Analysis of EMC

The conversion or degree of cure a at a given time, t, is defined as the ration of total heat of reaction release at time t to the total heat of reaction. The cure kinetic model with a general form for different reactive resins is described as follows equation (1) Kamal's n-th order kinetics).Fig 1. represent the DSC data of sample EMC with three different temperature ramp-up speed(a) and the conversion fitted numerically by the Kamal's equation (b)

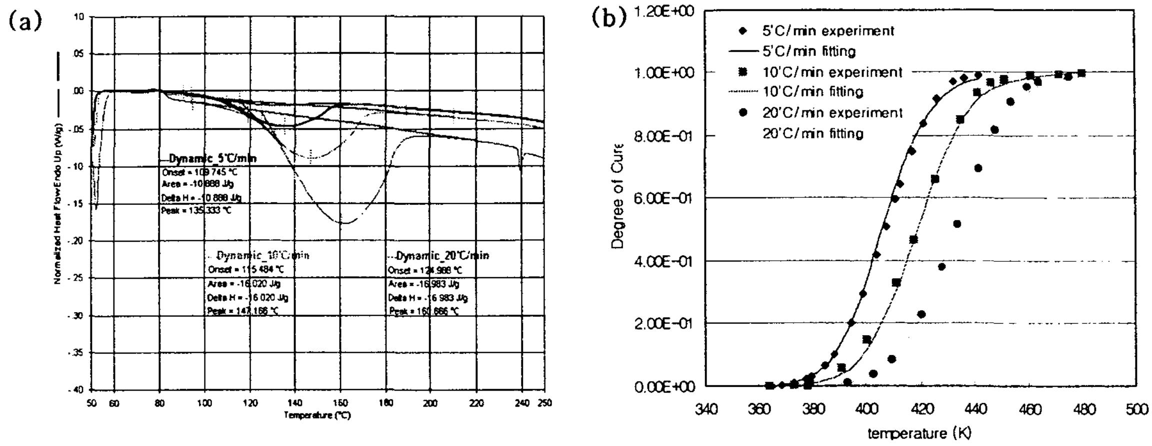


Fig 1. (a) DSC graph of the sample with different temperature ramp speed, 5, 10, 20 °C/min, (b) Cure conversion of the EMC sample from DSC data

$$\frac{d\alpha}{dt} = (k_1 + k_2\alpha^m)(1-\alpha)^n$$

$$\text{where} \quad k_1 = A_1 \exp(-E_1/T)$$

$$k_2 = A_2 \exp(-E_2/T) \qquad (1)$$

In the equations, k_1 and k_2 are the reaction rate constants. A_1 and A_2 are the pre-exponential Arrhenius constants, and $E1$ and $E2$ are the energies of activation. The other parameters, m and n, are related with the order of reaction rate, which is $m+n$ for reaction system of polymers. The rheokinetic equation of power law Macosko-Cross model is shown as below equation (2). The physical meaning of the wg is the effective shear rate which represents the Modified Cox-Merz relationship, T_b represents the temperature sensitivity of the zero-shear rate viscosity. n is the constant for power law behavior of fluid. a is the conversion level determined by curing kinetics. a_g is the conversion level at which the polymer gelation is occurred and viscosity increases as infinity. a_i is the initial conversion.

$$\eta(\alpha, T, \omega\gamma_0) = \eta_0(\alpha) \cdot e^{T_b/T} \cdot (\omega\gamma_0)^{n-1}$$

$$\ell n \eta_0 = a_0 + a_1\alpha + a_2 d$$

$$T_b = b_0 + b_1\alpha + b_2 d$$

$$n = c_0 \exp[c_1\alpha + c_2 d]$$

$$d = \tan\left[\frac{\pi}{2} \cdot \left(\frac{\alpha - \alpha_i}{\alpha_g}\right)\right] \qquad (2)$$

$$\frac{\partial}{\partial t}(\rho\vec{u}) + \nabla \cdot \rho\vec{u}\vec{u} = -\nabla p + \nabla \cdot (\eta\dot{\gamma}) + \rho\vec{g} \qquad (3)$$

$$\frac{\partial}{\partial t}(\rho C_p T) + \nabla \cdot (\rho C_p T\vec{u}) - k\nabla^2 T = \eta\dot{\gamma}^2 + \frac{d\alpha}{dt}\Delta H \qquad (4)$$

$$\frac{\partial \rho}{\partial t} + \nabla \cdot \rho\vec{u} = 0 \qquad (5)$$

$$\nabla \cdot \rho\vec{u} = 0 \qquad (6)$$

The equations (1)~(2) are so called constitutive relation whereas (2)~(6) represents the governing equations of fluid motion, (3) is the Navier-Stokes equation which indicate the conservation of momentum in the fluid motion and (4) is the equation related with conservation of energies, the 1st law of thermodynamics. (5)and (6)are related with conservation of mass, normally called continuity equations, for the case of compressible and incompressible flow respectively.

Based on above rheokinetic model, the parallel plate rheometry with the conditions listed at table 1. Non-isothermal dynamic sweeping for multi-wave modes have been performed with the four different temperature ramp-up speed with four different temperature ramp speed, 16 data set, totally.

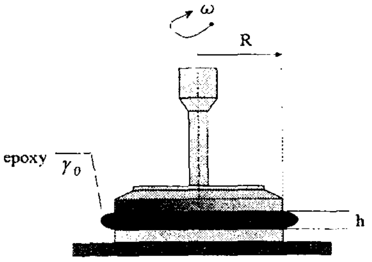


Fig 2. Parallel Plate rheometry

Plate radius(R)	12.5 mm
Plate distance(h)	1 mm
Sample weight	1.0 g
Strain	0.05 (1)
Angle frequency	20、 50、 100、 200 1/sec
Effective shear rate $\omega \cdot \gamma_0$	1.0、 2.5、 5.0、 10.0 1/sec
Temperature ramp (Q)	10、 20、 40、 60 ℃/min
Temperature (T)	90~250℃

Table 1. Experimental conditions

3. Results and Discussion

The results of the experimental data from the rheometer are fitted by the numerical expressions based on the power- law Macosko-Cross Model, which matches well each other for every 16 cases. Fig3 show the two cases of different effective shear rates . The dynamic sweeping curves are shifted to right as the ramp temperature increases. As the angular frequencies, in other expression, effective shear rates increase, the overall sweeping results getting lower than lower effective shear rates..

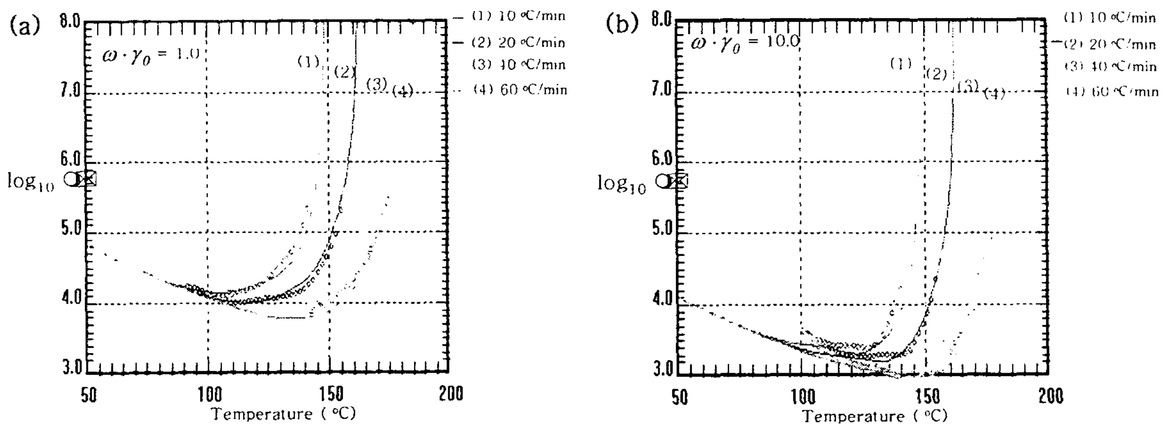


Fig 3. The results of the experimental data from the rheometer are fitted by the numerical expressions based on the power- law Macosko-Cross Model (a) effective shear rates=1.0 1/s (b) effective shear rates=10.0 1/s

Fig 4 shows the full three dimensional FEM mesh (a) and its internal geometry including wire bonding configuration. The total number of mesh is about 200,000. Also paddle down set is considered to simulate the void trapping phenomena. The total height of the package is1.0mm which is separated by 2 area the lead-frame and die paddle. The paddle down set gap is 0.2mm form package bottom to die paddle and the gap of die top and package top is 0.3 mm. The package size is 14mmx14mm with the die size of 7.62x7.62mm. All the geometry information is fully designed as 3-dimensionally to simulate flow between lead to lead spaces. The gate also designed as actual cases.

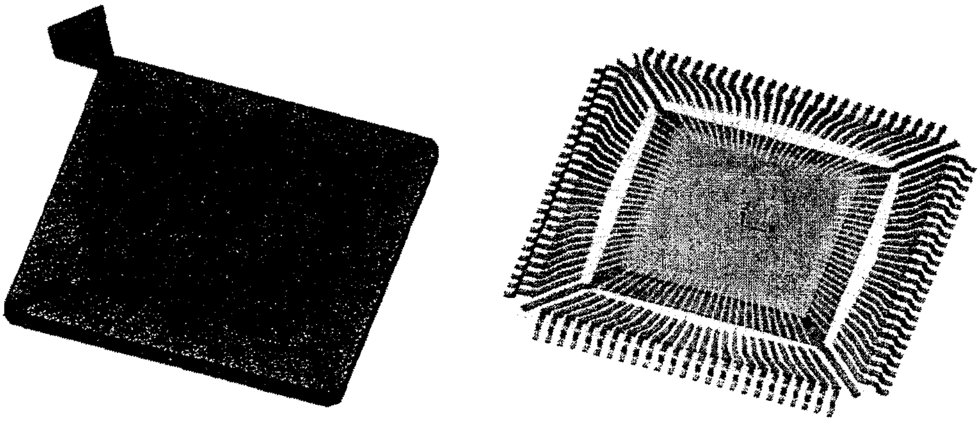
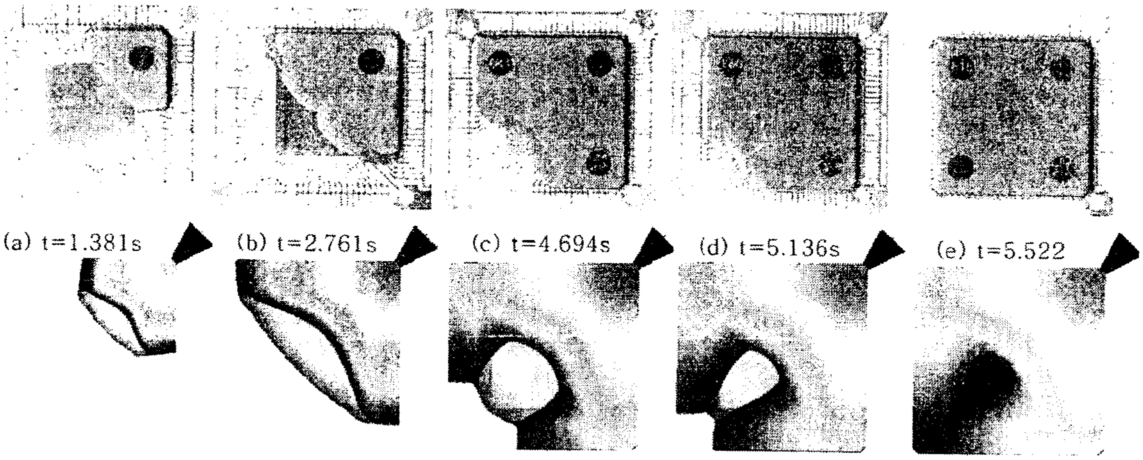


Fig 4. (a) Full 3 Dimensional FEM mesh(Mesh counts:200,000) of TQFP packages with 1.0 mm total thickness (b) internal structure of TQFP packages with full wiring configuration and down set

Fig 5 shows the experimental results of the actual cases of concerned packages and the simulation results for each melt front advancement cases. The concerned void trapping area of package bottom side of actual cases which have limited spaces because of paddle down-set and the same feature of simulated cases show reasonable match.



(a) t=1.381s (b) t=2.761s (c) t=4.694s (d) t=5.136s (e) t=5.522

Fig 5 Comparison of melt front advancement and void trapping area for experimental case and simulation case for each transfer time (a) t=1.381s (b) t=2.761s (c) t=4.694s (d) t=5.136s (e) t=5.522

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