Wetting Phenomenon in Cavitations of Electronic Packaging materials During Moisture absorption

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Summary In this paper, we firstly discuss "wetting" mechanism of porous materials when they absorb moisture from ambient. Then, we derive a mechanical model on the foundation of mesomechanics. And under the assumption that materials is linear elastic , the complex variable methods in elasticity is employed to resolve the elliptical micro-void subjected to the combined action of liquid and vapor phase and the accurate solution can be obtained. With the relevant attribution of materials, the analysis of strength of structure can be conducted.

Introduction

Polymer materials have wide applications in industry such as being adhesive film in the microelectronic packing. However, polymers are usually porous materials containing a great number of micro voids which influence the reliability of electronic packing. The moisture absorbed by polymers is stored in the form of liquid and vapor phase in the micro voids and cause expansion of voids which will lead to the failure of materials in the end. In addition, electronic package experiences a reflow process. The peak temperature of devices during this process typically ranges from 220℃ and 260℃, consequently moisture deposited in polymer materials vaporizes and becomes vapor pressure which also cause failure of package[1]. There is much work on the strength issue of cavitation under the action of vapor pressure. However, reliability issue of voids containing both liquid and gas has not been investigated enough yet. When we investigate the effect on micro-voids by liquid phase, the phenomenon of wetting[2] should be taken into consideration. In this paper, we firstly discuss the mechanism of wetting in an elliptical hole during moisture absorption. In the second place, we derive the theoretical solution of strength problem of an elliptical hole in an infinite region subjected to the combined effect of liquid and vapor phase under the consideration of wetting effect. The investigation will be helpful to the selection and design of polymer in the industry of electronic packing.

Wetting during the moisture absorption

Due to hydrophilic property, polymers will absorb ambient moisture which stores in the micro-voids in the form of liquid and vapor phase. At initial time, the voids in polymers are free from moisture. As exposed in humid environmental for a long period, polymers begin to absorb moisture. Because of wetting and the shape of micro-void itself, the configuration of droplet during the process of moisture absorption is depicted in Fig1.

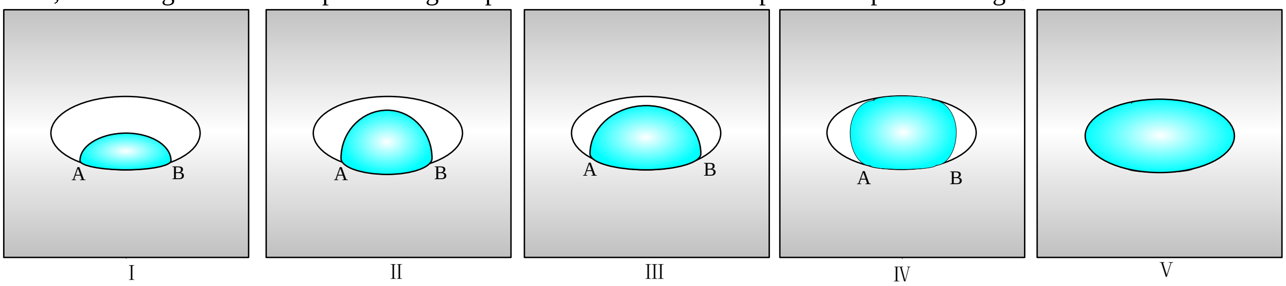

Fig1 the configuration of droplet in micro-void during the process of moisture absorption

With the process of moisture absorption in progress, hygroscopic moisture content increase. As is shown in Fig1. From Ⅰ to Ⅱ, for the rough surface of cavitation, the triple contact line is pinned which means that the horizontal length from A to B l_{AB}^{I} equals to l_{AB}^{II} .Hence macroscopic angle is determined by not only solid material attribution ,but also the volume of the droplet[3].when the volume of droplet reaches a critical value, the triple contact line can not support such a "huge" droplet. Therefore it changes and rebalances in new location like Ⅲ in which l_{AB}^{III} is large than l_{AB}^{II} and l_{AB}^{I} .With the volume of droplet becoming larger continually, the top edge of the elliptical hole is also wetted which is displayed in Ⅳ. At last, the liquid phase may capture the whole space in micro-voids like Ⅴ which indicates that material is saturated. Of course, polymers may lose ability of absorption before process of Ⅴ. Besides, vapor phase also acts at the area except the triple contact line in voids in the form of distributing pressure.

Derivation of theoretical theory

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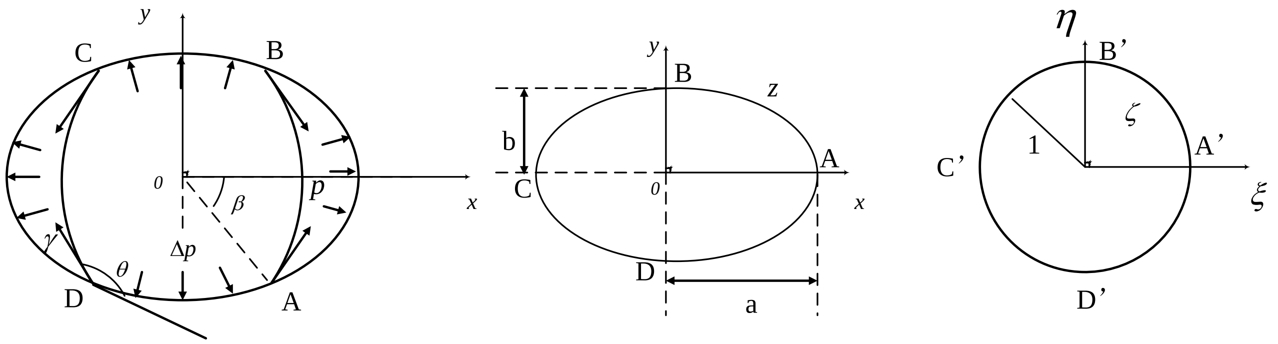
How to analyse the influence of wetting phenomenon on the voids in mechanics? We take the case Ⅳ of Fig 1 for example. From the perspective of mesomechanics, we can extract the 2D mechanical model as show in Fig 2(a). as illustrated in Fig 2(a), the droplet generates two types of loads: Δp which denotes the Laplace pressure, γ which represents surface tension. According to Young's equation, the relationship between Laplace pressure and surface tension is $\Delta p = 2\gamma \sin\theta / R$ .in this equation, θ represents macroscopic contact angle of droplet. When the surface is smooth, the magnitude of Contact angle is related to the property of materials; but when the contact surface is rough, it is also relevant to the volume of the droplet owing to the "pinning" phenomenon[3]. R is the horizontal projected radius of the droplet cap. It is notable that Laplace pressure will firstly increase, but then decrease with the increasing of contact angle from 0 ° to 180 °. Besides, polymers simultaneously bear moisture pressure P in the other segment of the elliptical hole.



(a) (b) (c)

Fig 2 (a) 2D mechanical model of case Ⅳ;(b)z-plane ;(c) ζ -plane

Under the assumption of infinitesimal deformation analysis, there exits theoretical solution towards any procedure during moisture absorption. According to complex variable methods in elasticity, we should transform the z-plane to a unit circle via conformal transformation. The common transformation from an ellipse in infinite region to an unit circle in infinite region is: $z = \omega(\zeta) = R(1/\zeta + m\zeta)$ .where $R = (a+b)/2$ and $m = (a-b)/(a+b)$. Hence, we can solve this problem in circular domain conveniently. In terms of Muskhelishvili's methods, the potential function is :

$$\varphi(\zeta) = -\frac{i\Delta pR(\ln(\frac{\zeta-\sigma_b}{\sigma_b+\zeta}) + (\zeta+\frac{m}{\zeta})\ln(\frac{\zeta^2 - Im(\sigma_b^2)}{\zeta^2-\sigma_b^2}) + (m\sigma_b + \frac{1}{\sigma_b})\ln(\frac{\bar{\sigma}_b+\zeta}{\zeta-\bar{\sigma}_b}) + \frac{4m\ln(\sigma_b)}{\zeta})}{2\pi}$$

$$-\frac{ipR(\ln(\frac{\zeta-\sigma_a}{\sigma_a+\zeta}) + (\zeta+\frac{m}{\zeta})\ln(\frac{\zeta^2 - \mathrm{Im}(\sigma_a^2)}{\zeta^2-\sigma_a^2}) + (m\sigma_a + \frac{1}{\sigma_a})\log(\frac{\bar{\sigma}_a+\zeta}{\zeta-\bar{\sigma}_a}) + \frac{4m\ln(\sigma_a)}{\zeta})}{2\pi} + \frac{i\gamma(\sin(\beta+\theta)\ln(\frac{(\sigma_a+\zeta)(\sigma_b+\zeta)}{(\sigma_a-\zeta)(\sigma_b-\zeta)}) + i\cos(\beta+\theta)\ln\left(\frac{(\sigma_a+\zeta)(\sigma_b-\zeta)}{(\sigma_a-\zeta)(\sigma_b+\zeta)}\right))}{2\pi}$$

$$\psi(\zeta) = -\frac{i\Delta pR((\frac{m}{\sigma_b}+\sigma_b)\ln(\frac{\bar{\sigma}_b+\zeta}{\zeta-\bar{\sigma}_b}) + \frac{4\zeta(m^2+1)\ln(\sigma_b)}{\zeta^2-m} + (m\sigma_b+\frac{1}{\sigma_b})\ln(\frac{\zeta-\sigma_b}{\sigma_b+\zeta}))}{2\pi}$$

$$-\frac{ipR((\frac{m}{\sigma_a}+\sigma_a)\ln(\frac{Im(\sigma_a)+\zeta}{\zeta-Im(\sigma_a)}) + \frac{4\zeta(m^2+1)\ln(\sigma_a)}{\zeta^2-m} + (m\sigma_a+\frac{1}{\sigma_a})\ln(\frac{\zeta-\sigma_a}{\sigma_a+\zeta}))}{2\pi} + \frac{i\gamma(\sin(\beta+\theta)\ln(\frac{(\sigma_a+\zeta)(\sigma_b+\zeta)}{(\sigma_a-\zeta)(\sigma_b-\zeta)}) + i\cos(\beta+\theta)\ln(\frac{(\sigma_a-\zeta)(\sigma_b+\zeta)}{(\sigma_a+\zeta)(\sigma_b-\zeta)}))}{2\pi}$$

where, σ represents the coordinate values of points in circle domain after transformation. With the potential function and material parameter, the stress and strain distribution near the hole can be obtained.

Conclusion

In this study, we have analyzed the wetting phenomenon in a cavitation in electronic packaging and presented an exactly physical model for analyzing the strength problem of a elliptical hole subjected to the combined effect of liquid and vapor phase in an infinite region. First, we elaborate changes in micro-voids when polymers absorb moisture during the course of moisture absorption. Then, the mechanical model is derived under the consideration of mesomechanics. Besides, we obtain the theoretical solution via complex variable methods. This investigation will be favourable towards the selection of polymer applied in the field of electronic packaging.

References

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