International Communications in Heat and Mass Transfer 38 (2011) 1061–1066

Contents lists available at ScienceDirect

International Communications in Heat and Mass Transfer

journal homepage: www.elsevier.com/locate/ichmt

Application of D-optimal design for modeling micro channel flow with different dispensing patterns ☆

Chih-Cherng Chen

Department of Automatic and Control Engineering, ChungChou Institute of Technology, No.6, Lane 2, Sec. 3, Shanjiao Rd., Yuanlin Town, Changhua County 51001, Taiwan, ROC

ARTICLE INFO

Available online 5 July 2011

Keywords:
D-optimal
RSM
Desirability

ABSTRACT

The dispensing pattern of fluids along the periphery of two parallel plates with full micro channels plays an important role for an effective underfilling process. In this paper, a capillary-driven flow model was used to examine the effect of different dispensing patterns such as U-type and L-type on the filling time. A response surface modeling (RSM)-based D-optimal design is employed to construct statistical models relating filling time and designed effective parameters known as bump diameter, bump height and clearance between each bump. The experimental plan consists of a four-factor's (three numerical plus one categorical) matrix. The results show that the U-type dispensing pattern has significant effect on the reduction of filling time than that done at the L-pattern condition. Besides, bump height is the most influential factor on the filling time in both dispensing patterns. Meanwhile, the variations of filling time are compared between the raw data and the values obtained from RS models and have good agreement to each other. Through the desirability function approach, the optimal combination of effective factors is also determined for the U-type pattern and the values of bump height, diameter and clearance are 172 μm, 146 μm and 120 μm, respectively. Finally, the improvement of filling time is around 18.3%.

1. Introduction

To date, the electronic devices were generally designed with multiple functions applied to a variety of fields such as microfluidic system. In addition, the common features of these products are light, thin, short and small. Higher I/O arrangement of pins on flip chip and advanced micro manufacturing process can satisfy the aforementioned requirements; especially for integrated circuit (IC) chip packaging industry [1,2].

A successful flip chip packaging technology has gone through several stages of development and shows more performances than other methods. The underfill dispensed along one or more sides of the chip periphery are drawn into micro channels under capillary action. These channels are constructed by interconnectors, namely, solder bumps between the chip and the substrate. Then the bumps are fixed by the solidified underfill and provide mechanical strength for the IC chip. However, the longer filling time and incompletely encapsulation are still the key problems of the packaging technology needed to be solved during underfilling process [3,4].

According to the capillarity theory, the filling time can be generally modeled in terms of flow length of fluid, surface tension, contact angle, etc. Based on the Washburn model, several researches show that the filling time was directly proportional to the square of flow distance of infiltration fluid and inversely proportional to the surface tension [5,6]. Khor et al. [7] studied the influence of bump arrangement on capillary driven underfill process based on numerical simulation. Besides, the flow behaviour and filling time of the underfill flow were also compared. Jong et al. [8] reported that the filling time decreases with increase of the fluid reservoir height. As the reservoir height reaches to 8.97 mm, the same effect of gravity on the flow time as the capillary force was experimentally observed in the literature. Shen et al. [9] studied on flow visualization of pressurized underfill encapsulation of flip chip and proposed that the injection situation is the most important factor for processing parameters. In addition, to improve the characteristics of underfill material, a mixture of resin and filler particles is usually used. Then the flow behaviour of encapsulant varied with the content of particles. Yap et al. [10] analyzed the particle transport in a micro-channel system and reported that the sizes of particles could affect the fluid flow significantly.

Because the capillary flow of fluids through micro channels is a time-consuming process, a systematic investigation of dispensing patterns on the filling time is therefore of great importance. In the present work, two different dispensing patterns of fluids, as schematically represented in Fig. 1, have been employed along the periphery of a simulated flip chip constructed by two parallel flat plates with full array of bumps inside the space. According to aforementioned literatures, the bump diameter, bump height, bump clearance and dispensing pattern are also chosen as effective parameters. Then all designed experiments of the underfilling processes are conducted via the commercial software MPI 5.0. In

☆ Communicated by W.J. Minkowycz.

E-mail address: jcchen@dragon.ccut.edu.tw.

0735-1933/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.icheatmasstransfer.2011.06.003