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Fluid and van-der-Waals Forces in MEMS Production

INTRODUCTION

The “NEXUS Market Analysis for MEMS and Microsystems III, 2004-2009” report predicts a CAGR (Compound Annual Growth Rate) of 16% for 1st level packaged MEMS components with a market of $25 billion in 2009. These production volumes demand a highly automated assembly line. At the same time the dimensions of microparts have been decreasing over the last years, e.g. in the field of minimally invasive surgery, which increasingly challenges the handling devices. To ensure a cost-effective production, a highly reliable assembly process is vital for a smooth material flow.

FLUID FORCES

To examine the downscaling effects of material flow technology, the experiments were conducted exemplary with a vibratory conveyor. For that reason the experimental setup includes a vibration exciter, a high-speed camera for analyzing the motion and a laser scanning vibrometer, which measures the conveyor’s displacement and acceleration. The experiments have shown that small silicon parts with dimensions of 1x1x0.4 mm stick to the vibratory channel even though the acceleration is greater than *2g* at a preset

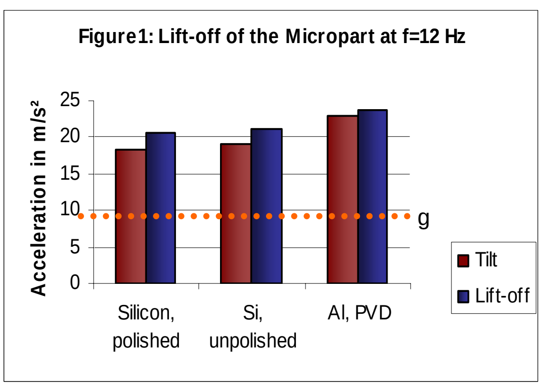

Figure1: Lift-off of the Micropart at f=12 Hz

frequency of 12 Hz (Figure 1). Classic theory would predict a lift-off as soon as the plate overcomes the acceleration of gravity. Various experiments have proven that fluid forces are mainly responsible for high interaction forces. For a final proof the experimental setup was arranged inside a vacuum chamber. The experiment was conducted without changing the parameters of the vibration exciter, but this time the air pressure was decreased to 7 mbar. As a result the micropart lifted off the surface at a much lower acceleration of 1.3g instead of 2g. The reason is that the fluid force is directly dependent on the dynamic viscosity of the surrounding medium. At a pressure lower than 100 mbar the viscosity begins to decrease because the air changes the friction property from viscous to molecular.

EFFECT OF PART SIZE

To investigate the effect of part sizes we used three different microparts with the same thickness (Fig.3). Since the parts were extremely difficult to move on a flat surface, the surface of the silicon vibratory channel was patterned by photolithography and deep reactive ion etching to reduce the area of contact with microparts. The resulting surface has 35% contact area compared to the flat surface.

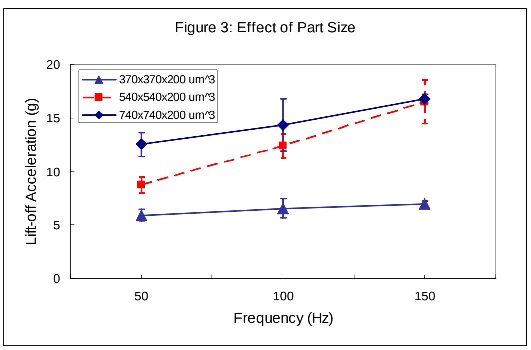

Figure 3 shows the experimental results. As the part size decreases the lift-off acceleration also decreases despite the decreased mass. This result indicates that the surface area related forces dominate the motion of the parts. The lift-off acceleration increases with frequency, which is consistent with the previous results.

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