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TEMPLATE BASED ASSEMBLY FOR SOLID STATE COOLING

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ABSTRACT

This paper presents a fully dry assembly method to obtain densely packed arrays of parts from 400-800µm in size. This approach shows promise for enabling formation of a module of n and p type materials optimized for micro scale thermoelectric cooling performance.

INTRODUCTION

Inertial force (mass of the assembled parts) plays a critical role for part alignment and orienting in a dry micro-assembly process [1]. However, when the parts get smaller, adhesion force and friction force become significant compared to inertial force and cause failures [1]. This paper: (1) presents a novel fully dry self-assembly process with a cross scaled feasibility study for small parts; (2) defines three major kinetic states for stochastic part manipulation; (3) utilizes the surface energy gap caused by differences in roughness with dynamic annealing to achieve face orienting and parallel self-assembly; no specific part features [1] or hydrophobic coatings [2] are necessary. This **fully dry assembly process** is capable of (1) high-density parts arrangement and packing within a single batch; (2) multi-batch assembly; (3) the possible unique orienting with specific template design and dynamic annealing. A comparison of different dry and semi-dry microassembly technologies is shown in Figure 1.

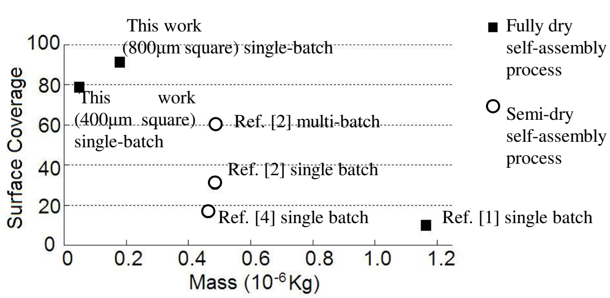

Fig. 1: A comparison of different *dry* and *semi-dry* assemblies.

MATERIALS AND SETUP

Figure 2 shows a schematic diagram and photo of the experimental setup for dry assembly. Both double and single side polished Si dummy parts are tested on the smooth and rough templates. All parts are square and ~120µm thick with five size scales (width =150, 200, 400, 600, 800µm). They are made from polished SOI wafers with DRIE. The template for each part has 20µm clearance and 55µm depth to facilitate the assembly. The template is mounted with an antistatic cylinder and driven vertically by a coil motor under a range of frequencies (from 200 to 1000Hz). The antistatic cylinder confines parts on top of the template without inducing extra electrostatic charge into the process.

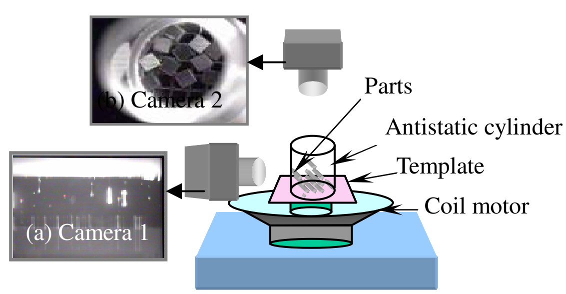

Fig. 2: Experimental set-up for parts assembly: The template is attached to a coil motor whose vibration is controlled by a function generator and optional power amplifier. The parts are confined to a volume above the template using an antistatic cylinder.

The assembly process has three steps (Figure 3) for achieving high density of part assembly. First, using the competition among template trapping potential energy, part kinetic energy and surface energy between solid-solid interfaces, we trap the parts in shape matched recessed templates. The parts are then transferred to a carrier surface with modified PDMS (Reprorubber© on smooth silicon wafer) for semi-permanent lock-in of assembly. A solder (eutectic AuSn or SnAg) patterned substrate is then flip-chip bonded to the assembled parts to obtain permanent mechanical, electrical and thermal interconnect formation.

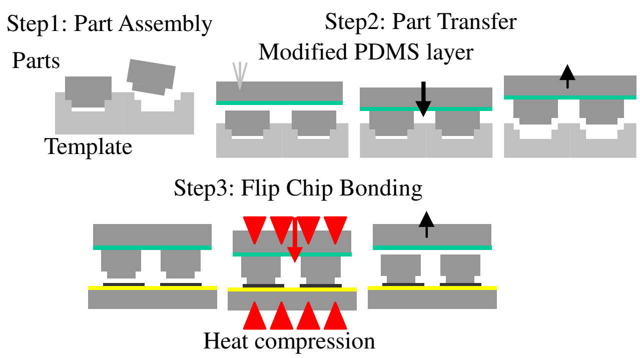

Fig. 3: Process flow schematic: (Step 1) The parts are first assembled using a coil shaker; (Step 2) they are then transferred to rubber surface with high van der Waals forces; (Step 3) the parts are then transferred to the final destination substrate (silicon die with patterned solder) by flip chip bonding.

In the part assembly step (first step), we define three kinetic states of the parts on the template surface. Initially, the parts are static and the vibration of the coil is initiated. At a certain input power, named *Migration Voltage*, the parts start moving along the surface. As the voltage is increased, the parts start flipping over, called *Jumping Voltage*. Subsequently, if the voltage is decreased slowly, the parts settle on the surface and this voltage is called *Settling Voltage*. When the part kinetic energy is less than the sum of solid/solid interfacial energy and template trapping potential energy, the parts will assemble to the templates. The control voltage is maintained above the *Settling Voltage* for parts delivery but below the *Migration Voltage* to confine the part kinetic energy within good trapping conditions.

TEST RESULTS

Preliminary experiments using various part size/trap configurations have shown the feasibility of using this method to successfully assemble square parts in the 400-800µm range (Figure 4). However, for the small parts (width: 130 and 200µm), the combination of low aspect ratio (width:thickness) and inertial/surface force ratio caused the disappearance of *Migration Voltage* (only one state (jumping) is identified). The parts will either jump around the traps without assembly or stay on the substrate. The jumping voltage is significantly higher than the settling voltage for all part sizes, which is not suitable for part assembly. In the parts transfer step (second step), assembled parts (width: 400-800µm) were successfully picked up using the modified PDMS layer (Figure 5 a-c). We have also transferred parts from the PDMS layer to solder defined

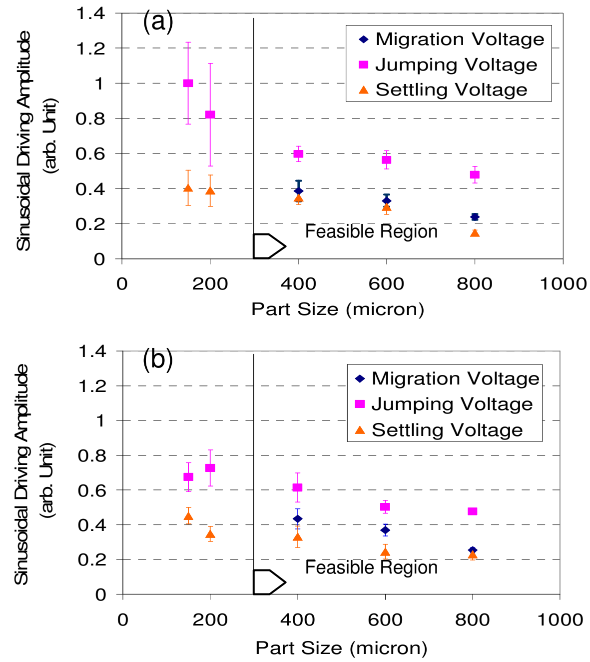

Fig. 4: Migration Voltage, Jumping Voltage and Settling Voltage for different part sizes from 150µm to 800µm scaled to the highest average value. Graph (a) is for double side polished parts on smooth surface and (b) double side polished parts on rough surface. The vertical bar shows the standard deviation of experimental results from five different measurements.

substrate sites using thermo-compression flip chip bonding (Figure 5.d). Depending on the part/template configuration, the packaging ratio is between 62% and 92%.

The proposed application of this dry assembly method is to enable Thermo Electric Cooler (TEC) module integration for

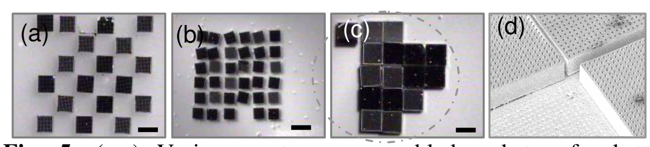

Fig. 5: (a-c) Various parts are assembled and transfered to Reprorubber© substrate. The bar is 800µm in all 3 images. (a) 600µm size parts assembled on traps made of an array of alternating 600µm and 580µm traps. (b) 400µm size parts assembled in alternating 600/580µm 6*6 traps. (c) 780µm parts assembled in alternating 800/780µm traps (the partial array fill is due to use of small antistatic cylinder). The density of packing for this case is close to 92%. (d) 780µm parts also can be transferred from the PDMS layer to solder defined substrate using thermo-compression flip chip bonding.

microelectronic cooling. The TEC components consist of two types of materials with possibly different dimensions and need to assemble in regions corresponding to the 'hot spots' or high heat flux regions of the "core" [5]. Simulations using methods in [6] show that the hot spot temperature reduction is enhanced by up to 3 times when TEC element density is changed from 25% to 92% at use conditions.

In conclusion, we have shown feasibility of a novel dry assembly of parts with subsequent flip-chip bonding with an intermediate PDMS pick-up step. This method holds promise for application in assembly and interconnects of solid state cooling elements for hot spot cooling of microprocessors.

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