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Self-assembly of microdevices onto silicon substrate via complementary shape matching

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As the market for low-cost and high-performance electronic, optoelectronic, and electromechanical integrated circuits grows, many new assembly and integration techniques must be developed. This paper reports a novel self-assembly technique, i.e., directed self-assembly (DSA), by exploiting mechanical shape matching mechanism to locate semiconductor devices into recesses patterned into a silicon substrate. This integration technique is advantageous for an efficient placement of a large number of microdevices into receptor sites. Moreover, the assembly of microdevices with unique face orientation and in-plane orientation can also be achieved by this technique.

The flowchart of whole process is shown in Figure 1. Test vehicles with dimension 1mm $\times$ 1mm $\times$ 0.5mm are used for demonstration. A key feature of this assembly method is to have complementary patterns for locking chips into the preassigned locations on substrate. Generally the patterns on chips consist of two features with different height. The feature with higher protrusion facilitates the chips coarsely positioning on the locations. The other feature with lower protrusion promotes a perfect orientation. Four different test vehicles with different patterns were fabricated. A typical design is shown in Figure 2.

On the other hand, the substrate is also fabricated to have the same pattern with recesses. The dimension of recesses on the substrate is bigger than its corresponding dimension of chips. The difference in dimension allows the possibility of chips filling into the recesses. However, if the tolerance is designed too large, the chips will be loosely controlled to rotate. Therefore, the alignment accuracy is determined by the tolerance of each design.

The first step of assembly is loading chips on the substrate. For the present shape matching system, unique face orientation is a must. It is implemented by placing the dicing tape attached with chips facing down onto the substrate, then rinsing them into ethanol. The dicing tape then loses its adhesion ability. A gentle agitation is applied to allow the diced chips to peel off from the tape.

Movement of the chips on substrate is realized by external vibration applied. Cautious control is needed to manipulate the vibration. Too vigorous agitation causes chips to flip over, while too gentle agitation cannot provide enough energy for chips to overcome the surface friction. The number of devise supplied *vs* the number of receipt sites is optimized to give maximum assembly yield (see Figure 3).

After the substrate is filled with microchips, the wafer can be processed further to transfer the microdevices to boards that are integrated with the underlying circuitry.

In summary, DSA provides a new technique for assembling and integrating microdevices onto a silicon wafer. It is anticipated to become a manufacturing approach that will be driven by its simplicity and promise of high yield and unique orientation at low cost.

Keywords: Self-assembly, shape matching, face orientation, in-plane orientation

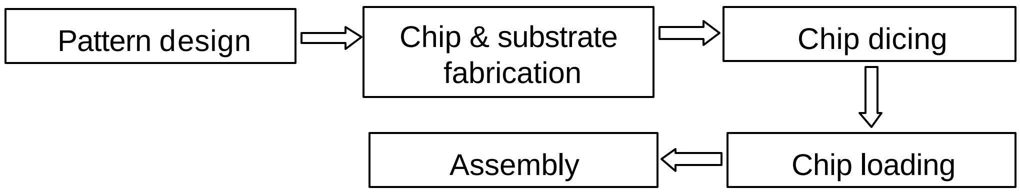

Fig. 1. Flow chart of direct self-assembly process by shape matching system

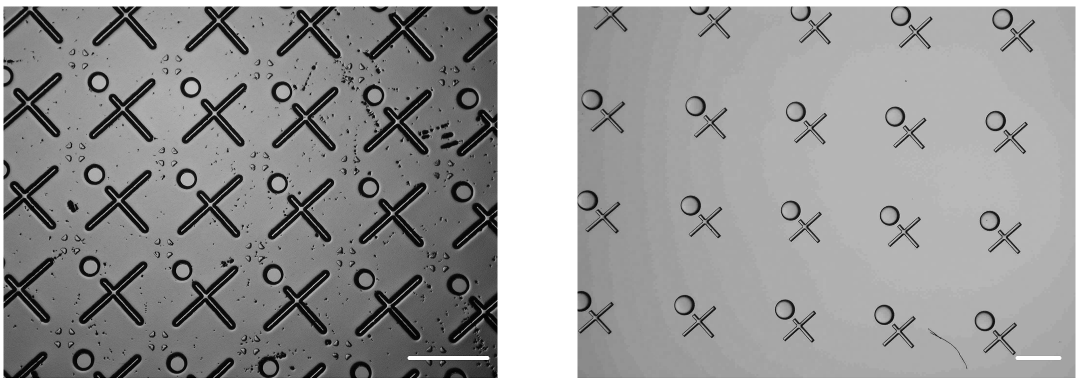

Fig. 2. Optical photographs of patterns on chips before dicing (left) and in substrate (right). (Scale bar: 1mm)

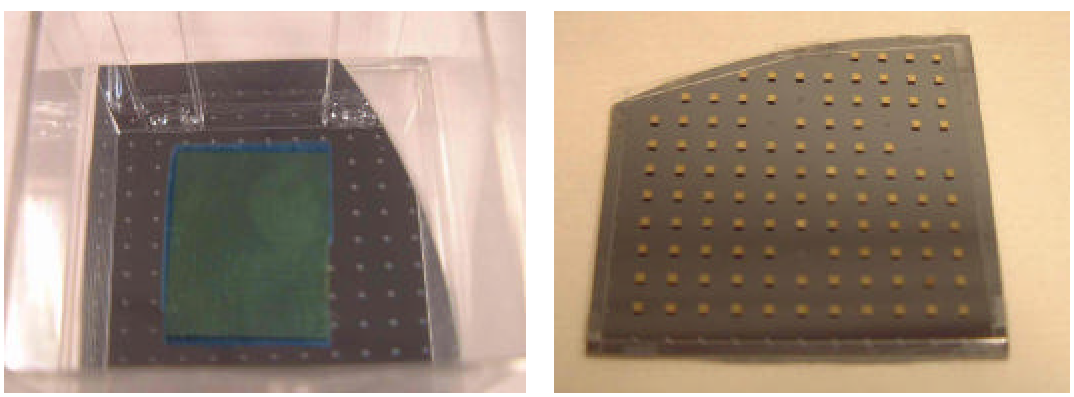

Fig. 3. Chip loading by rinsing the dicing tape into ethanol (left); chip assembly on substrate