Towards Hybrid Assembly of RFIDs

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1 Introduction

Wider scale adoption of RFID requires lower cost per unit than today's assembly technology, which is based on conventional robotic pick-and-place technology. It is very hard to dramatically reduce the assembly cost using conventional robotic assembly machine while keeping the current precision requirement.

On the other hand, component self-assembly technologies has been actively researched, based on different technologies, e.g. shape recognition [1], capillary force [2] or electric field [3]. Most of the self-assembly technologies are working in liquid environment, except a few. Moreover, those self-assembly technologies are usually carried out in parallel, in a stochastic manner.

Even though parallel stochastic self-assembly are effective when the assembly density is relatively high, it is not the case for RFIDs, where the density of the assembly is quite low, e.g. one assembly per ten square centimeters, where the chip size is less than one square millimeter.

To tackle this low-density problem, hybrid assembly technology is a natural choice. Hybrid assembly is a technology that joining the technologies of robotic assembly and component self-assembly [4]. In this particular application, a capillary force self-alignment assisted robotic manipulation approach is adopted.

This paper discusses the application of this novel hybrid assembly technology in the assembly of RFIDs. The goal of the research is to replace the high-precision robotics with low cost mechanics while at the same time achieving the high precision needed for RFID. This technology allows reusing of existing tools and setups without heavy reinvestment, as in contract with the conventional self-assembly technology proposed by many research groups and some companies.

2 Concept

The concept of the hybrid assembly technology is using a robotic feeding mechanism, e.g. pick-and-placing device or other mechanical feeder to deliver the RFIDs to the neighborhood of the target on the assembly site, e.g. the antenna, at a

relatively low precision, then capillary force based self-alignment will align the RFID to the desired location at a higher precision.

The basic steps are as following:

1. The hybrid assembly process is done in ambient air environment. The process starts by coarsely positioning chips near the assembly site using mechatronic feeding device or robotic tools, such as vacuum gripper or tweezers.

2. A droplet is dispensed on the assembly site, which has patterned pads that have favorable wetting properties for the liquid. The dispensing can be done using controller manner e.g. a noncontact droplet dispenser or screen printing or by automatic wetting from jet dispenser or steam generator. The liquid wets part of these pads or the whole pads. Liquid used can be water or adhesive. The background of the electrodes has non-favorable wetting properties for the liquid.

3. The bottom side of the chips and the bumps have a favorable wetting property for the liquid. Upon contacting the liquid on the pads, a liquid meniscus is formed between the chips and the pads and the chip is self-aligned to the outer edge of the pads.

4. The liquid is vaporized, leaving the chip on the pads with bumps contacting their respective pads.

5. The chip can be pressed on the pads to finalize the connection if needed. And adhesives can be dispensed around it and hardened to protect the assembly.

Process steps 1 and 2 can be replaced by alternative process, e.g. the chip is placed coarsely on the pads using similar feeding mechanisms as before, but without any liquid, then liquid e.g. water is condensed from the surrounding environment or droplet jet on the surface. The wetting properties of the bottom side of the chip and the pads will attract the liquid to fill the gap between the chip and the pads.

Process steps 4 and 5 can be replaced by alternative process, e.g. the chip is pressed using a mechanical tool and the liquid will overflow from the gap between the chip and the pads to surroundings. The pressing will make the electrical connections between the chip and the pads. If the liquid is adhesive, final bonding can be achieved by curing of the adhesive, using e.g. thermal or UV curing.

3 Experimental case study

To examine the concept, an experimental case study has been carried out for a type of RFID chip and artificial antenna pads.

3.1 RFID tag and antenna pads

The RFID tags has a dimension of about 730×730 µm with 4 bumps at the corners, each has a diameters of 70 µm and a height of 20 µm. The antenna pads are made of metals, e.g. Al or Cu, whose size is usually larger than the tag. Both the RFID tag and antenna pads are shown in Fig. 1.

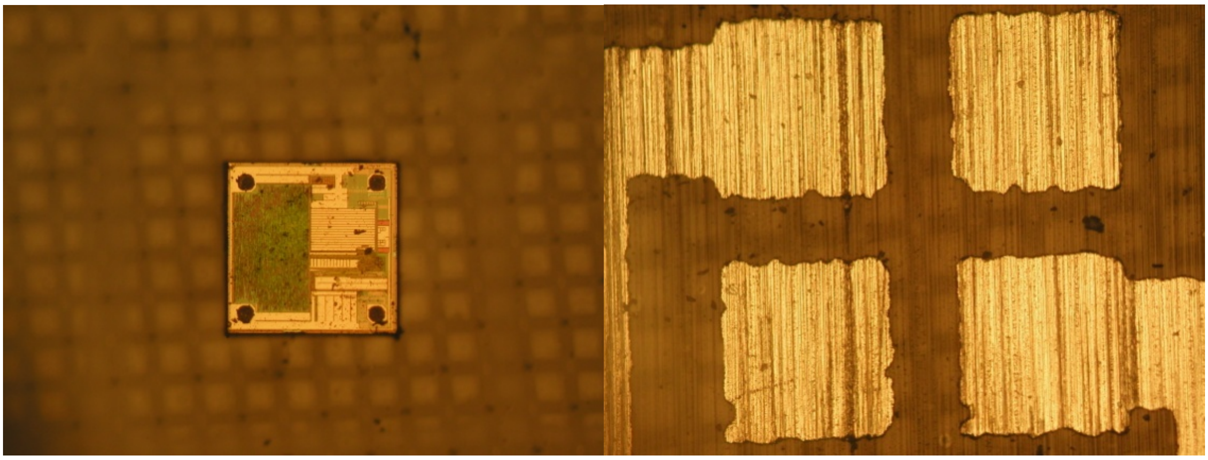

Fig. 1 RFID tag and Antenna pads compared. Figures are in same scale.

The active side of the RFID chips is naturally hydrophilic, due to the dielectric passivation layer. The bumps are made of gold usually.

3.2 Artificial antenna patterns

Due to the definition of the antenna pads, they cannot be directly used in self-assembly. Therefore, artificial test patterns that emulate the behavior of antenna patterns were fabricated on silicon. Silicon was chosen because of the ease of processing, but the basic fabrication sequence should be applicable to other substrates also.

Firstly, the surface was rendered hydrophobic through RIE Teflon deposition. Then, photoresist was deposited on the surface and lithography was used to pattern the resist. 20nm Al was sputtered on the patterns and the resulting surface was plasma treated to make it more hydrophilic. Finally, the photoresist was lifted off to reveal hydrophobic background, resulting in hydrophilic aluminum patterns on a hydrophobic background.

Different pattern designs, including pad gaps from 50 to 400 µm and total pad sizes from 705 x 705 to 745 x 745 were fabricated. Some of the pad patterns contained wiring to the pads, while others did not, to see the effect of irregular pad shapes on the self-alignment.

3.3 Hybrid assembly tests

Self-alignment of RFID chips on the artificial antenna patterns was tested using robotic tweezers and a droplet dispensing system. Typical test sequence is shown in Fig. 2. The initial position error is around 50 µm in x- and y-direction.

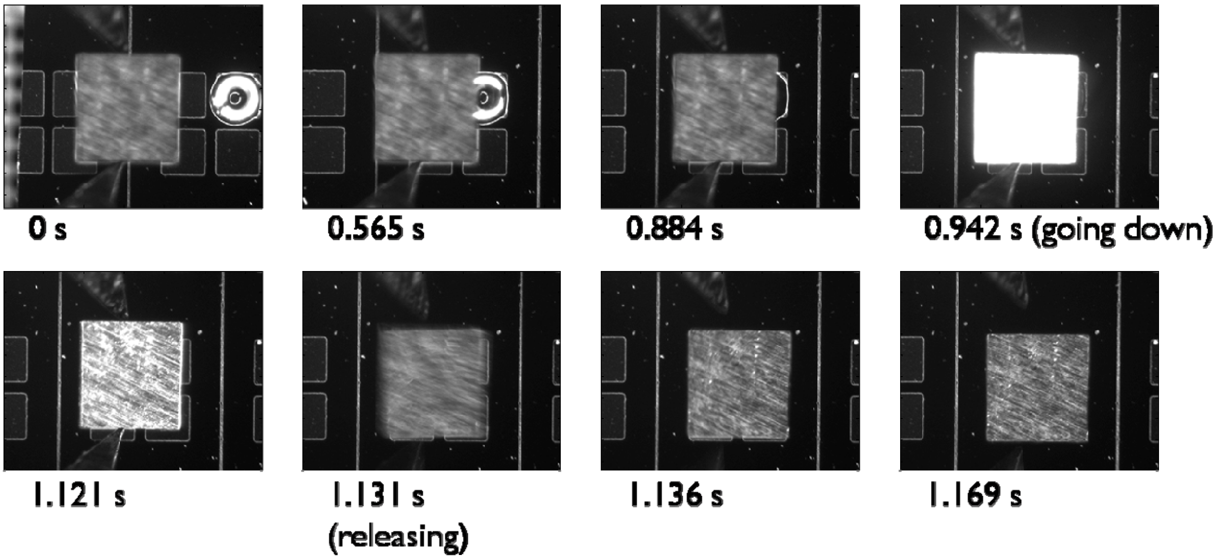

Fig. 2. Assembly of RFID die on an artificial pattern. About 20 nl water was dispensed on the pattern.

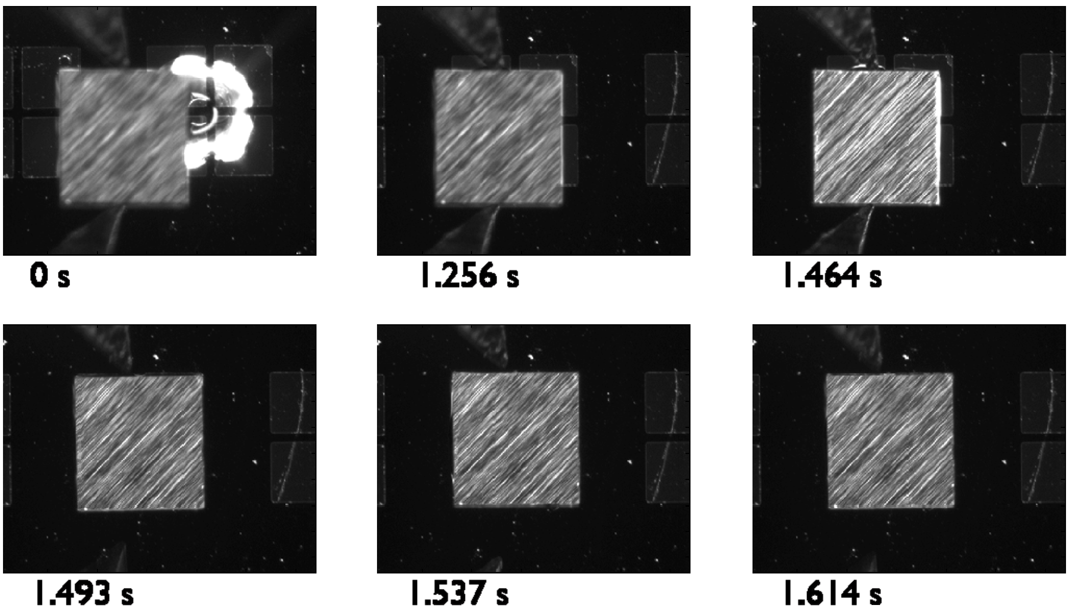

Fig. 3. Successful assembly of RFID dies and patterns with 50 µm gap. About 20 nl water was dispensed.

With a pad pitch of 50 µm, successful self-alignment of RFID was repeatable. About 20 nl water was dispensed in the middle of the pattern in each test. The total pad size seems not affecting the result. One example of successful self-alignment can be seen in Fig. 3.

With larger gaps (100 µm+) and about 20 nl water, the performance was not as good. There were often small problems with alignment, but still all the bumps were on the pads. With the largest gap (400 µm+), successful handling was still possible, but uneven wetting might take all water to one pad or the gap is so big that the droplet is not even touching the pads. However, once the die is brought into contact with the droplet, the wetting of the die makes the water to spread and successful handling is still possible. This is illustrated in Fig. 4.

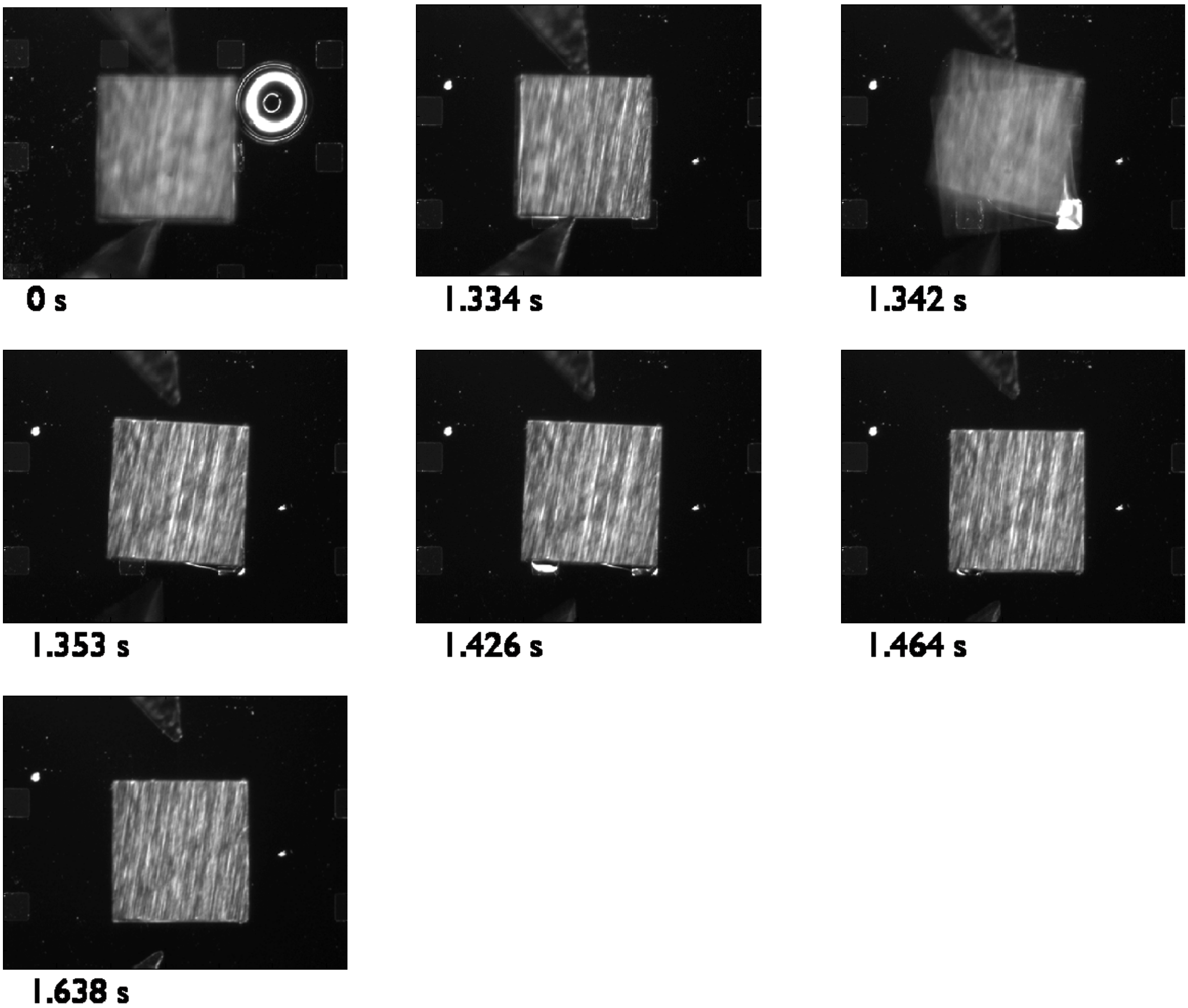

Fig. 4. Successful assembly of RFID dies and patterns with 400 µm gap. About 20 nl water was dispensed. The gap is so big that the droplet does not even wet the pads

The influences of the pad size have also been studied. However, their influence is considerably smaller than the gap size, and is also coupled with the gap size.

3.4 Discussion

Initial positioning error. In these tests self-alignment was able to correct positioning errors around 50 µm. This is nowhere near the limit that can be used in practice. Successful self-alignment has been observed with initial positioning errors as large as 400 µm.

Assembly accuracy. The final assembly accuracy achieved using droplet self-alignment has been measured as 2 µm std and better accuracy is also possible with better defined chips and patterns. It is important to note that the final assembly accuracy has little to do with the assembly accuracy of the robot. The accuracy mostly depends on the definition of the parts and the patterns.

Throughput. State-of-the-art assembly machine can achieve a precision of 50 µm at a throughput of around 100,000 UPH. Although our test setup was not optimized for speed, it is foreseeable that hybrid microassembly could be used to achieve ultra high throughput, while still achieving very high precision.

Only the time taken by the assembly robot can be included to the cycle time, since the robot can work on the next chip as soon as the first chip is released. However, the self-alignment is also very fast, taking in the range of tens to hundreds of milliseconds.

4 Summary

We have proposed of novel assembly technology for RFID tags, based on surface treated antenna patterns and hybrid assembly technology, combining robotic feeding and droplet self-alignment.

This technology has shown great potential to achieve high precision and high throughput at the same time and consequently will lead to low cost per unit, which is very important for the more widespread adoption of RFID technology.

The concept was validated using artificial antenna patterns fabricated on silicon and real RFID chips and water droplet self-alignment. As a future work, the results will be extended to other substrates and liquids, including different adhesives. Moreover, a complete assembly process including the post process after self-alignment will be studied.

Acknowledgment

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References

1. H.-J.J. Yeh, J.S. Smith, “Fluidic self-assembly for the integration of GaAs light-emitting diodes on Si substrates,” IEEE Photonics Technol. Lett., vol.6, no.6, pp.706-708, 1994.

2. U. Srinivasan, D. Liepmann, R.T. Howe. “Microstructure to Substrate Self-Assembly Using Capillary Forces,” J. Microelectromech. Syst., vol. 10, pp. 17-24, 2001.

3. K.F. Böhringer, K. Goldberg, M. Cohn, R. Howe, A. Pisano. “Parallel microassembly with electrostatic force fields,” in Proc. ’97 IEEE Int. Conf. on Robotics and Automation, 1998, pp. 1204-1211.

4. V. Sariola, Q. Zhou, H.N. Koivo, “Hybrid microhandling: A unified view of robotic handling and self-assembly,” J. Micro-Nano Mechatron., vol. 4, no. 1, pp. 5-16, 2008.