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Tip-on-a-chip: Automatic Dotting with Glitter Ink Pen for Individual Identification of Tiny Parts

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ABSTRACT

This paper presents a new identification system for tiny parts that have no space for applying conventional ID marking or tagging. The system marks the parts with a single dot using ink containing shiny particles. The particles in a single dot naturally form a unique pattern. The parts are then identified by matching microscopic images of this pattern with a database containing images of these dots. In this paper, we develop an automated system to conduct dotting and image capturing for mass-produced parts. Experimental results show that our "Tip-on-a-chip" system can uniquely identify more than ten thousand chip capacitors.

CCS CONCEPT

• **Computing methodologies** → Object identification

KEYWORDS

IoT; Traceability; Image recognition; Individual identification; Classification; mIDoT; my dot

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1 INTRODUCTION

As mass-production expands in manufacturing industries, product recall is growing in size and number [1]. In order to minimize the recall-related costs, it is important to specify failure causes as soon as possible. The first step is identifying the faulty parts and tracing back the manufacturing records. Part identification is typically implemented by ID markers such as barcodes or RFID tags. However, it is difficult to attach them to tiny parts due to lack of space. Nowadays electric parts and precision mechanical parts are getting smaller and smaller [2], thus there exists growing demands for an ID marker with a maximum size of a few millimeter.

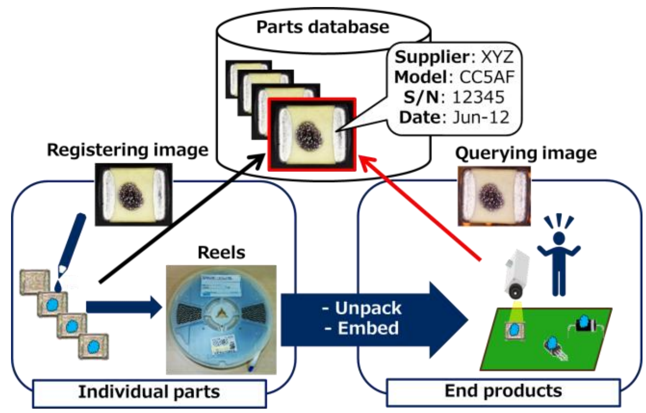

Figure 1: Concept of Tip-on-a-chip system. A parts supplier registers individual parts into a database by dotting and capturing mIDoT. When a recall occurs on an end-product, the supplier can identify the parts ID and information by capturing mIDoT on the parts.

Recently, an ID marker which marks the parts with a single dot of glitter ink has been proposed [3]. The dot, named mIDoT (micro-size Identifier as a Dot on Things), is identified by image matching of the micro pattern formed by tiny particles mixed in ink with registered images from a database. The generated patterns are random and unique, which allows for exact identification. Unlike conventional ID markers, mIDoT uses up to 1 mm^2 of space. This lets mIDoT meet the size requirement of ID markers for tiny parts. mIDoT has been applied to various applications, such as generating smart-keys on small belongings [4]. Since mIDoT has been dotted and captured manually up till now [3] [4], automation of dotting and capturing is currently a critical issue in order to apply mIDoT as the ID marker for mass-produced tiny parts.

In this paper we present a new parts identification system named "Tip-on-a-chip", which can automatically mark and capture numerous parts with mIDoT. Figure 1 shows the concept of the Tip-on-a-chip system. Mass-produced parts are automatically dotted and captured by a parts supplier. Microscopic images of the parts with mIDoT are registered into database with information including manufacturing date, serial number and etc. When a recall occurs on an end-product, the supplier can identify the parts by capturing mIDoT on the parts.

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Since the Tip-on-a-chip system enables individual identification by mIDoT, the supplier can retrieve the part's information even after the parts are unpacked and embedded to the end-product.

The following sections of this paper are organized as follows. We describe the system overview and components in section 2. Then we evaluate the system by marking and capturing mIDoTs on more than ten thousand chip capacitors in section 3. We also describe our demonstration setup in section 4.

2 SYSTEM OVERVIEW

Figure 2 shows an overview of Tip-on-a-chip system. The system can automate both dotting and capturing for numerous parts. The system hardware is composed of four units: 1) automatic dotting unit, 2) image capturing unit, 3) parts feeder unit, and 4) image matching unit (PC). The dotting unit is attached to the parts feeder unit and automatically places a dot the parts. The image capturing unit is attached to the parts feeder unit and captures an image after marking. The matching unit stores a database with the captured images and individual parts information and matches requested query images with the database to identify the queried parts. The following subsections explain each unit in detail.

2.1 Automatic Dotting Unit

Figure 3 shows the schematics of the automatic dotting unit. A linear ball guide (SSEB6-40, MISUMI) is used to realize accurate vertical translation of the pen. A solenoid (67-120-610-620, BLP) and a round wire coil spring (WY13-30, MISUMI) are used to press/return movement of the pen. The pen is pushed onto the parts for dotting when a voltage is applied to the solenoid for a predetermined amount of time (100 ms). After the dotting the pen is pulled away from the parts by the restoring force of the spring. The solenoid is controlled by a motor driver (SN754410NE, Texas Instruments) and the voltage of the driver is controlled by Arduino Uno (A000066, Arduino Foundation). Housings of the components are made by acrylic based resin and manufactured with a FDM 3D printer (Objet Eden 250, Stratasys Inc.).

Figure 4a shows the pen used for dotting. We use an off-the-shelf decorative drawing pen (Decorese Glitter Color, Sakura Color Products Corp.) to place mIDoTs on the parts. Ink of this pen contains glitter micro particles that are suitable for forming a mIDoT. The ink is adhesive onto a large variety of materials including plastic, glass and metal. With this property of the ink, we can easily place mIDoTs on various parts.

2.2 Image Capturing Unit

Figure 4b shows the image capturing unit. We use an off-the-shelf handheld microscope equipped with a ring LED, Dino-Lite Edge (DINOAM4815ZT, AnMo Inc.). A diffuser is attached to the microscope so that the LED beam of the microscope is well-diffused [3]. This provides a suitable imaging condition for capturing the micro pattern in an ink dot. By just replacing the dotting unit to the capturing unit, the system can capture and register the images (Fig. 2b).

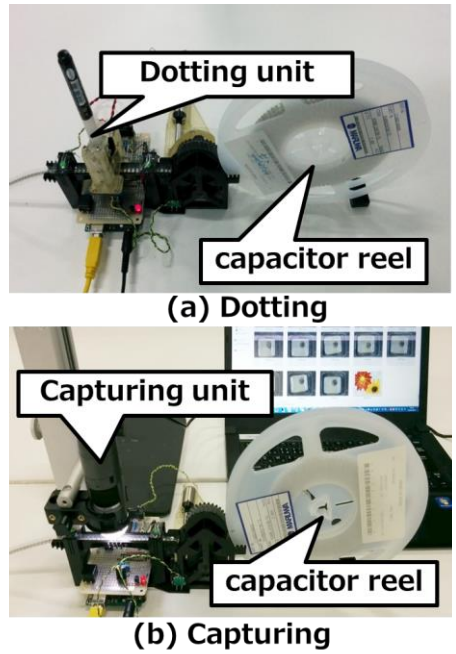


Figure 2: the overview of Tip-on-a-chip system; (a) dotting, (b) capturing

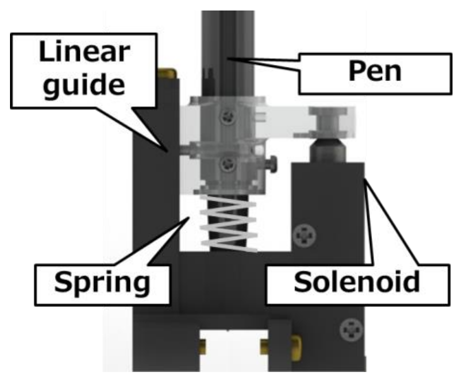


Figure 3: Schematics of automatic dotting unit.

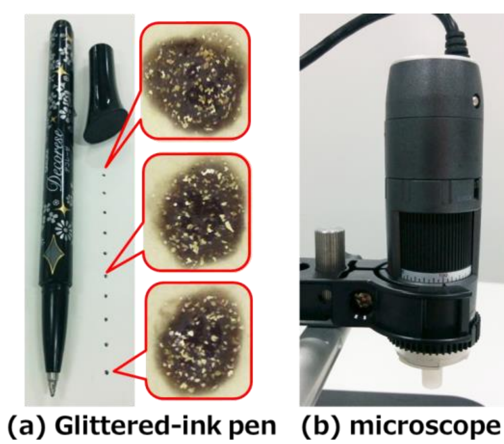


Figure 4: Hardware components and mIDoT images dotted and captured by them; (a) glitter ink pen for marking unit, (b) microscope for capturing unit.

2.3 Parts Feeder Unit

Figure 5 shows schematics of the parts feeder unit that we developed in order to realize automatic dotting and image capturing. A capacitor reel is fed by DC motor torque. By meshing a gear module and the reel, the torque is transmitted to the reel and feeds it into the subsequent modules. The DC motor and the detection module stated below are controlled by the same Arduino Uno as described in section 2.1.

The Size of the chip capacitor (VC40R2E473K-TS, MARUWA CO., LTD.) is 3.2 x 2.5 mm. Excluding the electrode region of the longitudinal ends, the blank area left for dotting is only around $2mm^2$. Position detection of the capacitor to the dotting unit is needed in order to place a dot accurately within the area. The position detection module is shown in figure 5. The module is composed of a photo resister (HW5P-1, Haiwang Sensors Co., Ltd.) and a green LED (G502DC, Chengguangxing Co., Ltd.). The LED and the photo resistor are arranged facing each other. Position detection is realized by the occlusion of the LED light when the capacitor is just above the photo resister. Figure 6 shows example images of the chip capacitors onto which mIDoTs are marked. Accurate dotting onto the parts is realized for each part.

2.4 Image Matching Unit

We employ an image matching algorithm described in [3]. We use Oriented FAST and Rotated BRIEF (ORB) [5] to obtain the corresponding point pairs between the query image and the registered image. The matching method is brute force matching with cross check. The corresponding point pairs are verified by checking the geometric consistency between the registered image and the query image. This geometric verification step uses RANSAC [6] to obtain the correct correspondences as inliers. We employ a similarity transformation as the geometric model in RANSAC, since the capturing angle is nearly perpendicular to the parts and thus projective distortion is negligible. We use the number of inliers as a matching score between the two images. Finally, the two images are identified as the same individual if the matching score is higher than a predetermined threshold.

Figure 7 shows example image matching results of mIDoT. In the case of a genuine pair, which means an image-pair captured from the same dot, plenty of corresponding point pairs are determined as inliers (figure 7a). On the other hand, in case of an imposter, which means an image-pair captured from different dots, only a few inliers are obtained (only a few features are accidentally matched, figure 7b). Thus we can simply use the number of corresponding point pairs to identify mIDoTs.

3 EVALUATION

3.1 Setup

To evaluate our system we marked 11,423 chip capacitors with mIDoTs using the dotting and feeding units. The capacitors were captured twice to collect two unique sets of captured images, using the capturing and feeding units as shown in figure 4b, which are used for register and query image sets. The resolution

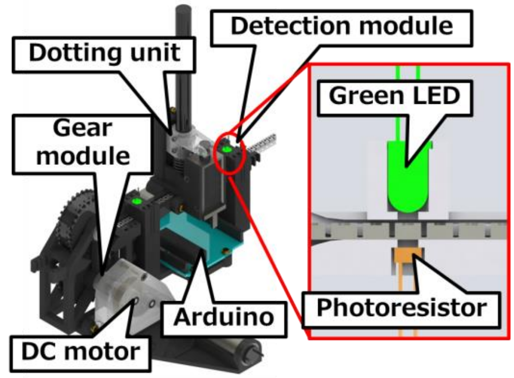


Figure 5: Schematics of the parts feeder that we developed in order to realize automatic dotting and capturing.

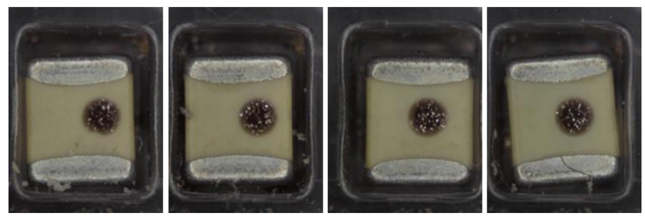
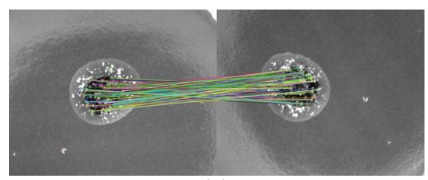
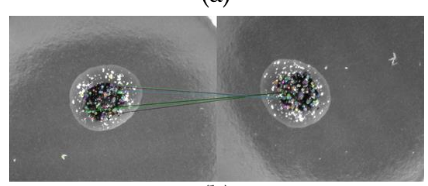


Figure 6: Example images of the chip capacitors onto which mIDoTs are marked.

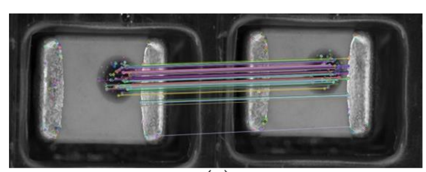


(a)

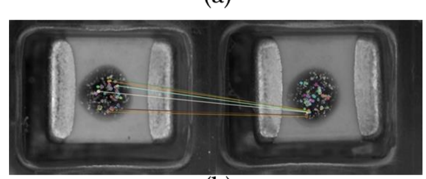


(b)

Figure 7: Example image matching result of mIDoT; (a) same individual (b) different individuals



(a)



(b)

Figure 8: Example image matching result of chip capacitors; (a) same individual (b) different individuals

of the captured images was 1,280 x 1,024 pixels. For image matching, we extracted 200 ORB features from images resized to 640 x 512 pixels. The publicly available OpenCV 2.4.11 library was used to implement ORB and RANSAC algorithms.

aOne query image of an individual capacitor was matched with one registered image of the identical capacitor and 11,422 registered images of the other individual capacitors. Consequently, 11,423 genuine pairs and 11,423 x 11,422 = 130,473,506 imposter pairs were matched in our experiments. The accuracy of identification was evaluated by the False Acceptance Rate (FAR) and False Rejection Rate (FRR).

3.2 Result

Figure 8 shows example image matching results of the capacitors. In case of the same individuals (genuine pairs), plenty of local feature points were extracted from mIDoT area and matched correctly. In case of the different individuals (imposter pairs), few local feature points were matched. Figure 9 shows the cumulative distribution of image matching scores between images of the same individual (genuine pairs) and different individuals (imposter pairs). FAR and FRR are separated, which means identification was successful without error by setting the matching threshold to 40 feature points. In our experiments, more than 100,000,000 imposter pairs were matched as explained above. This means that the system can identify the capacitors with extremely low EER (Equal Error Rate) less than 1/100,000,000.

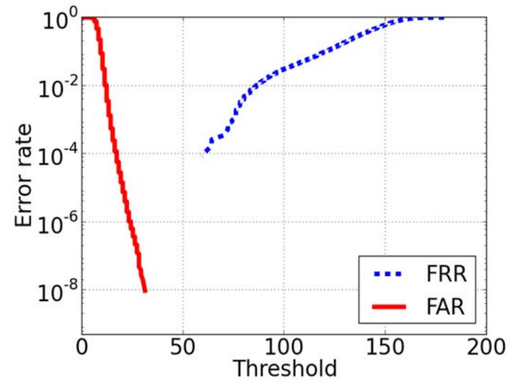


Figure 9: Cumulative distribution of image matching scores between images of the same individual (genuine pairs) and different individuals (imposter pairs).

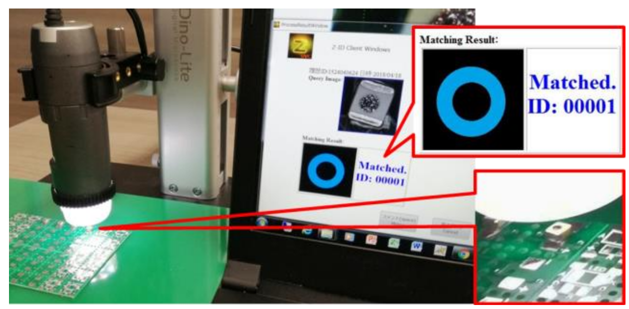


Figure 10: Demo setup for identification of capacitors registered in the database.

4 DEMO SETUP

During our demonstration we will show that the Tip-on-a-chip system automatically marks and captures the chip capacitors with mIDoT. As shown in Figure 2, we prepare some capacitor reels for Tip-on-chip system, so that attendees can see the prototype dotting and capturing in practice. Then we will also show that the prototype identifies the capacitors registered in the database. Figure 10 shows the setup for identification. The attendees will be able to query the capacitors by themselves and see the individual ID number shown on the PC connected to the microscope. Through our demonstration, the attendees can experience both the registering and querying process of the capacitors marked with mIDoT.

5 CONCLUSION

This paper presented Tip-on-a-chip, a new parts traceability system that uses a single ink dot as an ID marker for tiny electronic parts. The system marks the parts with an ink dot, called mIDoT. Then the parts are identified by matching microscopic image of the dot. Unlike conventional ID markers, the system requires a quite small marking space. Experimental results showed that the Tip-on-a-chip system can identify more than ten thousand chip capacitors. As the demonstration, we will show that the Tip-on-a-chip system automatically marks and captures the chip capacitors with mIDoT. We will also show that the system identifies the capacitors registered in the database.

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