Digital Investigation 29 (2019) S71–S79

Contents lists available at ScienceDirect

Digital Investigation

journal homepage: www.elsevier.com/locate/diin

DFRWS 2019 USA — Proceedings of the Nineteenth Annual DFRWS USA

Forensic Analysis of Water Damaged Mobile Devices

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A R T I C L E   I N F O

Article history:

Keywords:
Damaged device forensics
Electrochemical corrosion
Water damaged devices

A B S T R A C T

Mobile devices routinely arrive at forensics labs suffering from water damage, which can be the result of either intentional efforts to destroy evidence of a crime or accidental exposure. Chip-off analysis has traditionally been chosen as an effective data recovery method for damaged devices, including water damaged ones. However, with the implementation of full-disk encryption, chip-off analysis is becoming less promising. In many cases involving encrypted devices, the only option to extract user data for digital forensic purposes is to recover the original function of the device and then input the unlocking/decrypting code. While this could be achieved by transplanting electrical parts that hold user data and decryption keys to a donor circuit board, given the typical backlog at forensic labs, it is unrealistic to perform this transplantation for all water damaged devices. In this paper, we examine the electrochemical reactions that happen inside mobile devices when they are exposed to water. If handled properly, and appropriate procedures are conducted at a forensic lab, there is a high chance of restoring the water damaged mobile device to operating status to conduct successful forensic data recovery. Common diagnoses of water damaged devices, as well as effective repair methods, are discussed in this paper.

1. Introduction

Modern digital devices contain pieces of information or data that are critical in virtually every type of criminal investigation. Law enforcement officers conducting search and seizure operations for criminal investigations routinely encounter situations where individuals try to submerge their devices in water in an attempt to destroy evidence of a crime. When digital devices make contact with liquid, there is a great chance of system failure. Traditionally, digital forensics labs have attempted various techniques to extract data from such devices. The most common method is to disassemble the target device, and then clean and dry the circuit board (Bair, 2017). If this procedure does not help the device return to a working state, digital forensic investigators then turn to conducting chip-off analysis (Breeuwsma et al., 2007; Fukami et al., 2017), or performing chip transplantation (Heckmann et al., 2018). When a device is lightly damaged, proper cleaning of the logic board could restore the device back to normal status. On the other hand, when a device is severely damaged and missing electrical parts from its logic board, it is likely that chip transplantation or chip-off are the only options to forensically analyze the device. The most common scenario regarding water damaged devices, however, is that the device does not boot properly after cleaning and drying, even if the logic board in the device looks clean and undamaged. For those devices, proper identification of faulty parts could lead to performing restoration of the target device. In this paper, we investigate the key electrochemical reactions that occur in digital devices while they are in contact with water, which leads to a discussion about what to check when a forensic investigator faces a water damaged device. Metal corrosion is a well-known occurrence in high humidity environments, and research has been widely conducted from device manufacturing and reliability perspectives (Tanaka, 2002; Minzari et al., 2009; Jellesen et al., 2010; He et al., 2011; Minzari et al., 2011; Zhou et al., 2013; Li et al., 2017; Zhong et al., 2017). Water damage to digital devices by water submersion can be viewed as the most extreme example of humidity-based corrosion. With the aggressive scaling and miniaturization of digital devices, the potential for electronic corrosion damage has been increasing, since device components are placed much closer to each other. In this paper, we investigate the metal corrosion that occurs inside a smartphone when it is submerged into water. We will first explain metal corrosion in the presence of moisture. Then we will examine the actual corrosion process by conducting lab tests using working smartphones. After that, we will discuss

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https://doi.org/10.1016/j.diin.2019.04.009

Fig. 1. Example components of a smartphone.

methods of repairing water damaged devices, as well as recommendations for proper handling of water damaged devices.

2. Basic structures of mobile devices

2.1. Electrical parts in mobile devices

A mobile device typically consists of a screen, a circuit board, a housing case, peripheral components (cameras, antennas, sensors, etc.), and a battery. Fig. 1 shows an example of the internal structure of a smartphone. In a working mobile device, the circuit board controls the operation of the connected components and continuously draws power from the battery. A printed circuit board (PCB) is typically used for the circuit board in a mobile device. The inputs from the user, or the peripheral sensors connected to the PCB, are processed by the main application processor, and the results are passed on to other components, including the display screen. All of the processing that takes place among the components on the PCB is in the form of electrical signals, which travel among conductive metals of the components.

2.2. Metals in mobile devices

Fig. 2 shows the cross-sectional view of a mobile device PCB. Components on a PCB are connected electrically through pads on the surface and conductive layers inside the board.

The conductive layers inside the PCB are typically made of copper, and they are insulated by glass–epoxy interface. The electrodes exposed on the surface (the top layer of a PCB) are usually plated with nickel-gold (Ni/Au). Electrical components, such as resistors, capacitors, and IC (Integrated Circuit) chips are bonded on the electrodes of the PCB by solder, which is a metal alloy, containing multiple kinds of metals, such as tin (Sn), silver (Ag), and copper (Cu). All the electrical components and IC chips have metal electrodes on the surface to receive electricity from the PCB. The housing cases for mobile devices are also sometimes made of metal, with aluminum alloy being the most commonly used metal due to its light weight.

2.3. Potential bias on a PCB

Fig. 3 shows examples of PCB surfaces in digital devices with the level of applied voltage labeled on each electrode. In this example, potential bias as high as 19.5 V exists between electrodes that are aligned as close as 0.4 mm from each other. As different components on a PCB take different voltages for communication, different levels of electric potentials exist on a PCB. Multiple Power Management Integrated Circuit (PMIC) chips mounted on a PCB create different levels of voltages, supply power to multiple components. With the ever-shrinking size of digital devices and components, the distances among biased components on a PCB are also minimized.

3. Metal corrosion in digital devices under humidity

Corrosion of metals in digital devices, especially in high

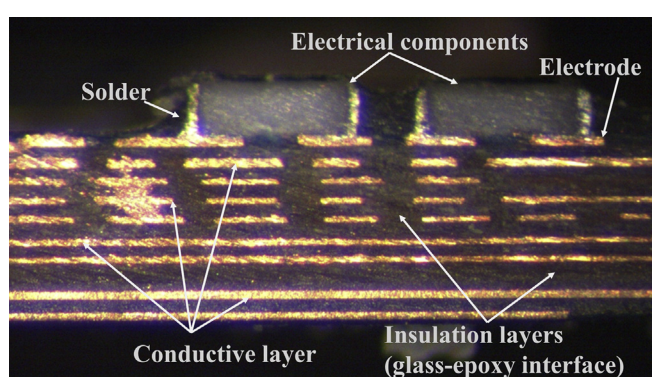

Fig. 2. Cross-sectional view of a PCB.

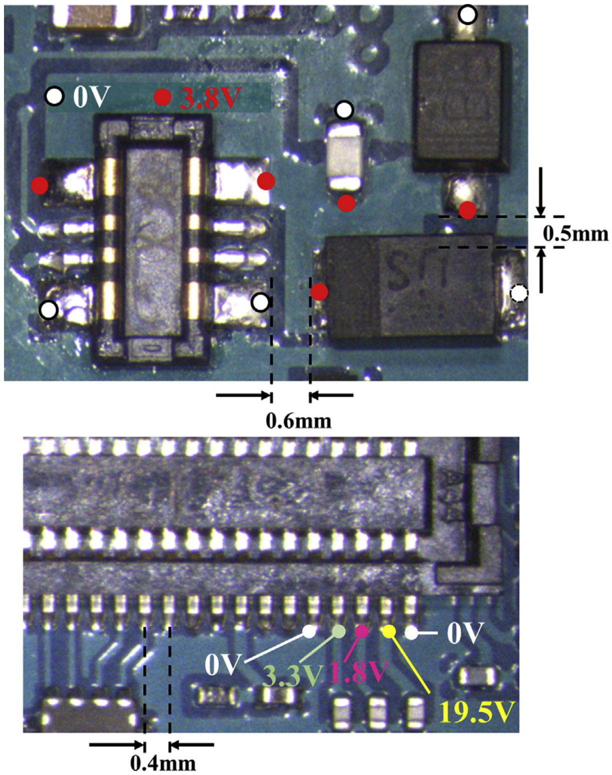

Fig. 3. Examples of smartphone PCB parts with applied voltage.

humidity, high temperature, and high voltage biased environments, has been widely researched from the manufacturing reliability perspective. The three major causes of metal corrosion in digital devices: electrochemical migration, galvanic corrosion, and conductive anodic filament are explained in this section.

3.1. Electrochemical migration

The most common corrosion observed on a PCB in a humid environment is electrochemical migration (ECM) (Takemoto et al., 1997; Tanaka, 2002; Tang et al., 2003; Minzari et al., 2009; He et al., 2011). ECM happens in the presence of a potential bias between two conductors that are connected by a fluid media. When two metal electrodes are biased greater than 1.23 V (Watanabe et al., 2001), under the presence of water, the following reactions happen on the anode (positive electrode) and the cathode (negative electrode) (Zhou et al., 2013):

- Anode (M stands for metal)

$$M \rightarrow M^{n+} + ne^- \tag{1}$$

$$M^{n+} + nOH^- \rightarrow M(OH)_n \tag{2}$$

$$M(OH)_n \rightleftharpoons MO + H_2O \rightleftharpoons M^{n+} + nOH^- \tag{3}$$

- Cathode (M stands for metal)

$$M^{n+} + ne^- \rightarrow M \tag{4}$$

$$2H^+ + 2e^- \rightarrow H_2 \tag{5}$$

Under the presence of potential bias, the metal on the anode first gets ionized (1). The metal ions are then combined with hydroxide ions produced as the result of water electrolysis (2). Thereby, hydroxide metal is deposited on the anode. This deposited hydroxide metal then continues the reaction described in (3). The metal ions produced here are driven to the cathode by the potential bias, where they receive electrons to migrate with the metals (4). Meanwhile, on the cathode, hydrogen is produced since hydrogen ions receive electrons (5). The deposited metals on the cathode are known to grow in the shape of dendrites toward the anode (Tang et al., 2003). Once the dendrite reaches the anode, due to the dendrite's conductivity, a short circuit is established. Multiple dendrites keep growing as long as the metal, water and the potential bias are present. At the same time, on the anode, since metals continue ionization, the electrode loses solid metal, which leads to an open circuit.

The speed of ECM varies with various environmental elements. Zhong et al. (2017) reported that the presence of chlorides in water accelerates the speed of ECM. Therefore, residual chlorine levels in water can accelerate the speed of ECM. Furthermore, ECM under seawater happens much faster than tap water. Electric field, which can be calculated as a function of a bias voltage between the two electrodes, also contributes to the speed of ECM. Typically, higher voltage bias and shorter electrode distances lead to faster metal corrosion caused by ECM. Other environmental contaminants, such as sulfates and bromide ions in water, are also reported to accelerate the ECM (Zhong et al., 2017).

3.2. Galvanic corrosion

When digital devices are submerged in water, the water works as an electrolyte conduit among different kinds of metals (Novotny et al., 1987). Since various kinds of metals exist in a mobile device (section 2.1), metal corrosion can occur under the presence of water even when no voltage is applied externally. Metals are categorized as noble and less noble metals based on their electric potential. Noble metals have higher standard electrode potentials compared to less noble metals. Therefore, if, for example, aluminum (less noble metal) and copper (noble metal) are contacting each other in an electrolyte, aluminum gives up electrons easily and gets ionized. This reaction can be expressed as:

$$Al \rightarrow Al^{3+} + 3e^- \tag{6}$$

This is the same reaction as discussed in eq. (1). As charge neutrality must be maintained, these electrons then travel towards copper (the noble metal), and are used in the following reaction (Hack, 2010):

$$2H_2O + 4e^- + O_2 \rightarrow 4OH^- \tag{7}$$

The movement of electrons makes current flow between two metal electrodes. As a result, the combination of those different metals and water creates a simple battery cell. Since anodic reaction keeps happening on the less noble metal, the noble metal keeps corroding. This corrosion mechanism is called galvanic corrosion (Hack, 2010). The corrosion keeps happening as long as the metals and water co-exist. The hydroxide ions produced as a result of eq. (7) react with aluminum ions produced in the reaction described in eq. (6), and form $Al(OH)_3$ (Hua et al., 2009).

3.3. Conductive anodic filament

Another type of corrosion that reportedly occurs on PCBs is called conductive anodic filament (CAF) (Boddy et al., 1976; Turbini and Ready, 1998; Caputo et al., 2010; Reid, 2013). CAF is a copper containing filament that grows inside a PCB under the presence of moisture. As shown in Fig. 2, inside a PCB, multiple layers of copper are insulated by epoxy–glass interface. Each layer works as an electrical path between the components mounted on the surface, therefore, potential bias exists between different layers. Under the presence of water, copper ions on the anode are deposited as copper salts. Those copper salts become a filament, which grows through voids in the glass–epoxy interface. Once the filament reaches the cathode layer, a short circuit is created inside the PCB, which leads to system failure. CAF is hard to identify since the reaction happens between internal layers inside the PCB, and no visual corrosion can be seen on the surface.

4. Testing water damage to digital devices

In order to observe the metal corrosion discussed in the previous section, and its impact to the system when a digital device is submerged into water, we conducted a lab test using commercial smartphones. Our testing methodologies are discussed below.

4.1. Water submersion of smartphones

In order to closely investigate how water causes damage to a smart phone, we submerged two different models of smartphones in tap water under different conditions. The Samsung Galaxy S6 Edge (SM-G925) and LG Nexus 5X (H790) were selected for this testing. Two different working phones of each model were submerged in 20 cm of tap water for 72 h, with each phone in a separate glass container. 72-hour submersion was chosen as it is the average reported submersion time of the water damaged devices that the authors receive at their lab.

One of each model was submerged while the device was turned off (we refer to those devices as SM-1 and LG-1); while another of each model was submerged while the device was operating with the display turned on (we refer to those devices as SM-2 and LG-2). Each device was fully charged and running prior to being completely submerged in the water in each container. The residual chlorine concentration of the water on the day of the testing was reported to be 0.4 mg/L (Bureau of Waterworks Tokyo Metropolitan Government, 2018). Since the speed of metal corrosion is not proportional to the temperature (Klyatis, 2003), we chose to keep the testing devices at room temperature (23 °C). After submersion, all the devices were disassembled and dried in a drying chamber until the moisture level reached 0% RH (Relative Humidity).

After the devices were fully dried, their conditions were investigated using a microscope and a micro-focus X-ray system. In addition, contaminants on the PCB on each device were collected and investigated under energy dispersive X-ray spectrometry (EDX) to analyze their composition. EDX analyzes the X-ray spectrum emitted from a target sample bombarded by electron beams. Since each chemical element has a unique atomic structure, a different X-ray emission spectrum is detected for each element.

5. Results

5.1. Conditions of PCBs after water submersion

While submerged, all the tested devices were covered with small bubbles. This is the clear sign of hydrogen production (the reaction is expressed in eq. (5)) due to ECM. Fig. 4 shows the electrical parts on the PCBs of the tested devices after drying. White, grey, or green-colored contaminants were observed on each tested device. All the electrical components on PCBs were still intact with the board, despite the metal corrosion. On SM-1 and SM-2, battery connectors and components directly connected to the batteries are severely corroded. Removal of RF (Radio Frequency) covers revealed contaminants near every PMIC (Power Management IC) chips. Measurement with an electrical tester showed that the anode and cathode of the battery connector in each tested SM device was short circuited. Overall, more contaminants were observed on SM-2 than SM-1.

On the LG devices, overall, more white-colored contaminants were observed than dark-colored ones. Dark-colored contaminants were only found on LG-2.

Contaminants left on the PCBs of tested devices were collected and analyzed with EDX. The results are shown in Fig. 5. The detected intensity of different energy levels is plotted in the unit of counts per second. Note that the unlabeled spikes in Fig. 5 indicate rhodium (Rh) detection, which comes from the X-ray tube and can therefore be excluded from the components of the target. The main components of the contaminants collected from the SM devices are copper (Cu), nickel (Ni), and tin (Sn), making up 70 percent of the analyzed contaminants. Since those metals are used for manufacturing PCBs and solder, and were not present in water used for the submersion test, we conclude those colored contaminants are produced as the result of electrochemical reactions of metals on the PCBs, making short circuits.

Meanwhile, the contaminants on the LG devices are primarily composed of aluminum (Al), which made up more than 71 percent of the detected components. As noted earlier, aluminum is used in the housing case of the device. The content ratio of copper (Cu), nickel (Ni), and tin (Sn) in the analyzed contaminants is less than 1 percent in combination. We conclude, therefore, that galvanic corrosion on the LG devices greatly exceeded ECM based metal corrosion.

Since the EDX analysis results show that contaminants in water damaged devices contain metals, we conclude that contaminants in water damaged devices are conductive. Thus, unintentional short circuits can be created with the presence of the contaminants on those devices. Therefore, applying voltage to a PCB without removing contaminants can cause system failure. Note that EDX only detects metal compounds of the target sample, therefore, oxygen and other organic compounds are not included in the EDX composition analysis results.

5.2. Electrical condition of PCBs after submersion

As shown in the previous section, the corrosion products observed on the PCB after water submersion are conductive. Thus, after drying the devices, we first removed the contaminants by cleaning the PCBs with ethanol and a soft brush. After cleaning and confirming that no short circuit was created on the battery connector of the SM devices, the PCB of each SM device was connected to a DC power supply. Neither of the SM devices booted successfuly. Instead, a current flow of 70–80 mA was monitored on both devices as soon as the PCB was connected to the power supply, which is not the normal current value when the device is operating under regular conditions. When operating normally, no current flows until the switch button is pushed down. Current flow with the peak of 50 mA should be observed for only a few seconds after pushing down the button briefly. This means that abnormal circuits still existed on the tested SM devices even after cleaning their PCBs of contaminants. On the LG devices, on the other hand, normal current flows were monitored on both devices after cleaning and connecting the power source and pushing down the switch button. After connecting the cleaned PCB to the battery, display, and other peripheral devices, LG-1 successfully booted and operated normally. Meanwhile, though no abnormality was detected in the current flow on LG-2, nothing was displayed on the screen after attempting to boot LG-2.

The PCBs of SM-1 and SM-2 were then closely investigated

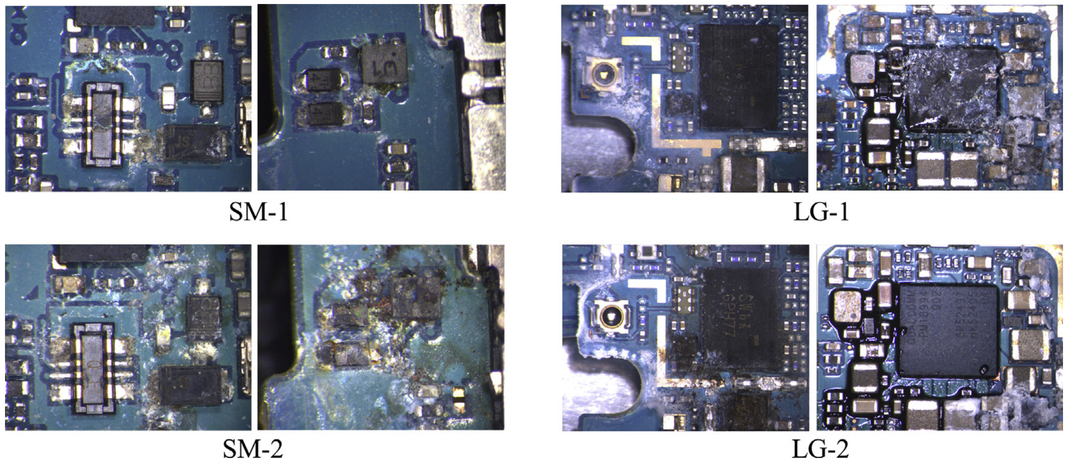

Fig. 4. Electrical parts on PCBs of tested devices after water submersion.

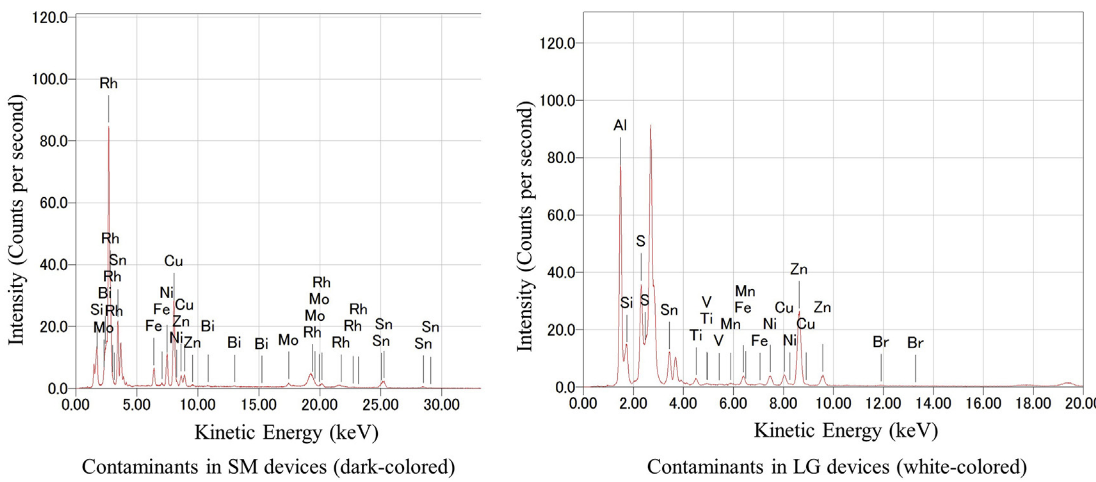

Fig. 5. EDX analysis results of the contaminants left on the PCBs of tested devices.

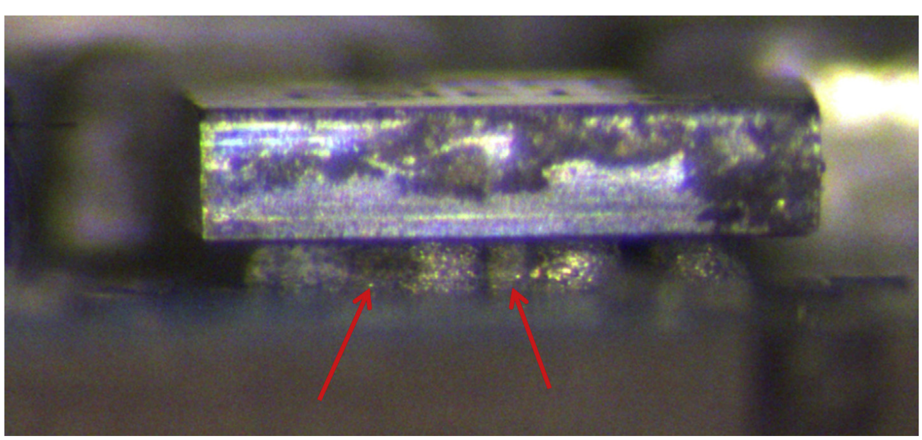

Fig. 6. Contaminants under a PMIC chip on SM-1 (indicated by red arrows). A short circuit is created by the contaminants.

under a microscope and with an X-ray inspection system, and we found solder abnormalities under some IC chips. Short circuits were created with what looks like ECM products under a PMIC chip (Fig. 6) on both SM-1 and SM-2. Additionally, investigation under X-ray system showed that solder balls were lost on several PMIC chips on SM-2. One example is shown in Fig. 7. The “healthy” solder bumps under ICs should appear as round objects when viewed under the X-ray system. We conclude that those solder balls were corroded due to ECM or galvanic corrosion caused by water submersion.

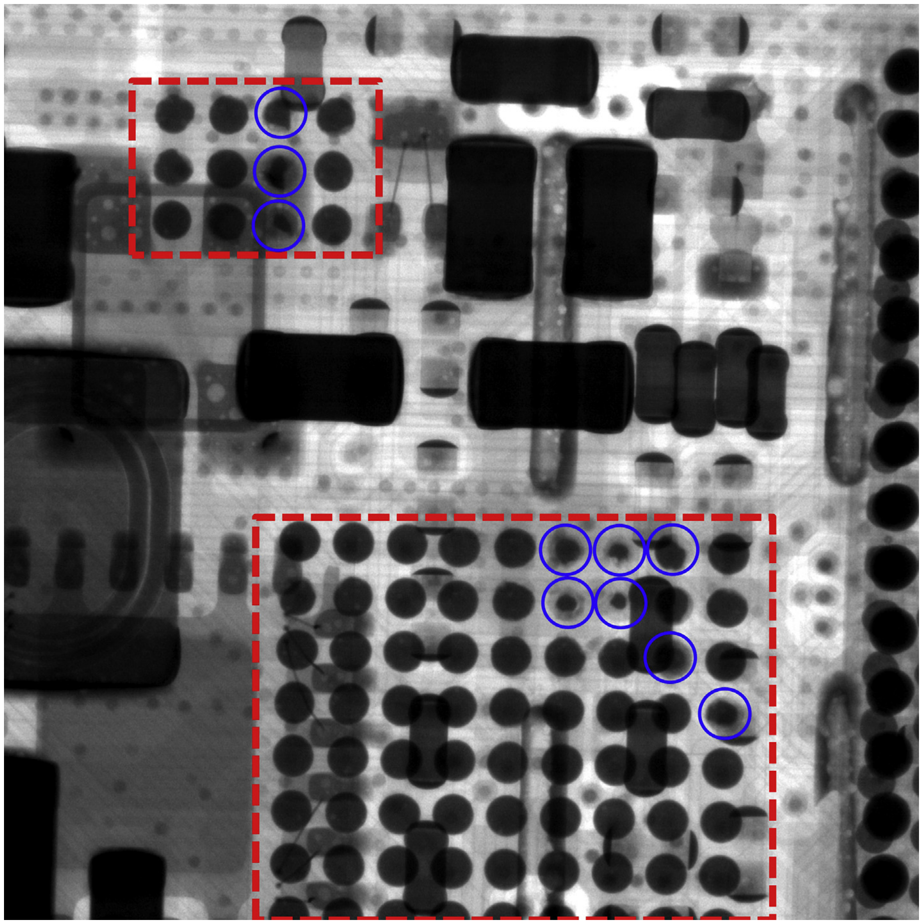

Fig. 7. X-ray inspection of solder balls under PMIC chips on SM-2. Mounted PMIC chips are indicated with dotted line. Abnormal solder balls are indicated with circles.

6. Repairing water submerged devices

Since SM-1, SM-2, and LG-2 did not boot properly after cleaning the PCBs, we moved forward to steps to repair the water damaged devices. The repair method for each device is introduced in this section.

6.1. SM devices

After determining the PMIC chips were no longer correctly mounted on the PCBs due to solder loss and short circuits, those IC chips were removed from the SM devices using a heat-gun. After the removal, one of the power management IC chips on SM-1 turned out to be electrically damaged due to internal short circuit. Typically, when an IC chip itself is damaged, it is impossible to repair it. Therefore, we acquired a working IC chip of the same model, and mounted it on the PCB of SM-1. This procedure allowed us to successfully repair the functions of SM-1. For removing and remounting of IC chips, we refer the reader to Heckmann et al. (2016) for detailed methodologies.

All the IC chips with solder abnormalities on SM-2 were removed from the PCB with a heat gun, and remounted after reballing the solder. After the procedure, SM-2 successfully booted with all functions working.

6.2. LG-2

For LG-2, close investigation of the device revealed that some pins on the display connector were corroded, as well as the electrodes on the PCB connected to the pins. Fig. 8 shows the condition of the display connector after being cleaned. The corrosion was creating an open circuit and the required power to the display was therefore not properly supplied. In addition, missing conductive metal on the PCB prevented us from re-applying solder. Therefore, we traced the wiring of the PCB and repaired the circuit connection using thin copper wires in order to re-create the electrical paths between the PCB and the display. After the procedure, LG-2 turned on successfully.

7. Discussion

Through the test results, we found that water caused less damage to the LG devices than the SM devices. Since solder abnormalities under IC chips were frequent occurrences in the SM devices, while similar corrosion was not detected on the LG devices, we carefully compared the PCBs between the two device models. Multiple power management IC chips are mounted on both LG and SM devices. The biggest difference between those two models is that on LG devices power management IC chips are protected with *underfill*, which is an epoxy glue filling the gap between a PCB and IC chips, as well as solder balls. Underfill is typically used in digital devices to increase the mechanical strength of the interconnects (Chiang, 1998). We assume that water did not make contact with solder balls of IC chips in LG devices because of underfill, thereby avoiding ECM on those devices.

In all the water submerged devices we tested, contaminants

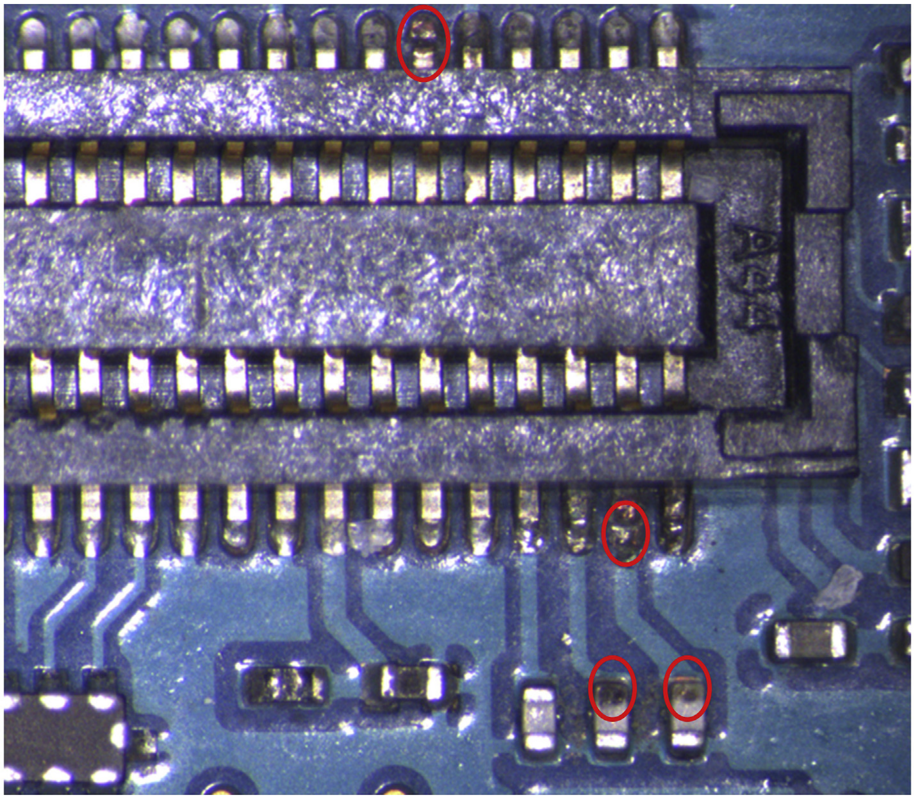

Fig. 8. Display connector of LG-2 after water submersion and cleaning. Marked electrodes are corroded and making open circuits.

from corrosion were found on the PCB surface where potential bias existed. Since a mobile device PCB is connected to a battery, constant voltage is applied to the PCB until the battery level becomes empty or the battery is disconnected. Therefore, the state of charge of the battery in a digital device when it makes contact with water is one of the factors critical to the level of water damage. Suppose that a mobile device is connected to a fully-charged Li-ion battery which has 2500mAh capacity. If ECM creates a short circuit on some ICs and current of 50 mA keeps flowing, then ECM keeps happening on the device for 50 h. If a device is kept in water during this time, metals in the device continue corroding. If the corrosion continues, the risk of losing connections between components and PCBs increases over time. Once the conductive metals of PCB electrodes are corroded and lost, repairing the electrical circuits becomes critically difficult, making chip-off (Breeuwsma et al., 2007; Fukami et al., 2017) or chip transplantation (Heckmann et al., 2018) the only options for recovering the original function of the device. Therefore, removing the battery and moisture from a water damaged device is critical to stopping corrosion reactions on its PCB.

In addition, the operating state of the device when it makes contact with water contributes to the metal corrosion level. As shown in Figs. 4 and 7, metal corrosion of electrical parts is more severe in operating devices than switched off ones. When multiple functions on a device are operating (e.g., playing music, taking pictures, display turned on), more components are supplied power and more current is flowing in the device compared to the turned off state. Therefore, when a digital device is submerged into water while it is operating, metal corrosion by ECM is promoted much quicker than while it is turned off, and open circuits are created at multiple locations.

Furthermore, while the standard procedure for a water damaged device calls for immediate transportation to a lab while keeping the device in the same liquid in which it was found (SWGDE, 2006), in reality, confiscated water damaged devices are left in the liquid for a long time before actual transportation happens. Given the nature of galvanic corrosion, this wait time could lead to more damage to a target device. We submerged the repaired PCB of SM-1 into seawater and left it for 14 days. Fig. 9 shows the condition of the PCB over time. White contaminants, which are clearly produced due to galvanic corrosion, are already visible on multiple parts of the PCB after one day of submersion. After two weeks, metal corrosion becomes severe and electrical parts are detached from the PCB. Once the critical electrical parts required for normal booting go missing from the PCB, repairing the device becomes almost impossible, again leaving chip-off or chip transplantation as the only options for recovering the original function of the device.

One question that arises now is how quickly it takes for the metal corrosion to create a complete open circuit that leads to system failure of a digital device after the device comes into contact with water. Though there is no clear answer to this question, as many different elements (e.g., mass of metal, applied voltage, liquid conductivity, etc.) contribute to the corrosion speed, it is worthwhile to simulate the circuit to measure the critical time interval before water creates an open circuit. For this purpose, we conducted an additional test using a PCB from a commercial digital device. A 0.40 mm pitch connector mounted on a commercial digital device was connected to a simple LED (Light Emitting Diode) circuit (Fig. 10). This is to simulate a display device connected to a mobile device PCB. Typically, a display backlight in a mobile device takes more than 15 V to light up, and it is connected to a PCB with a connector with small pitch (typically less than 0.4 mm). The shadowed area in Fig. 10 was submerged into water, and the time between water submersion and extinction of the LED light was measured under applied voltage of 15 V. As soon as the connector was covered with water, bubbles were generated as a result of the reaction expressed by eq. (5). At the same time, electrodes with

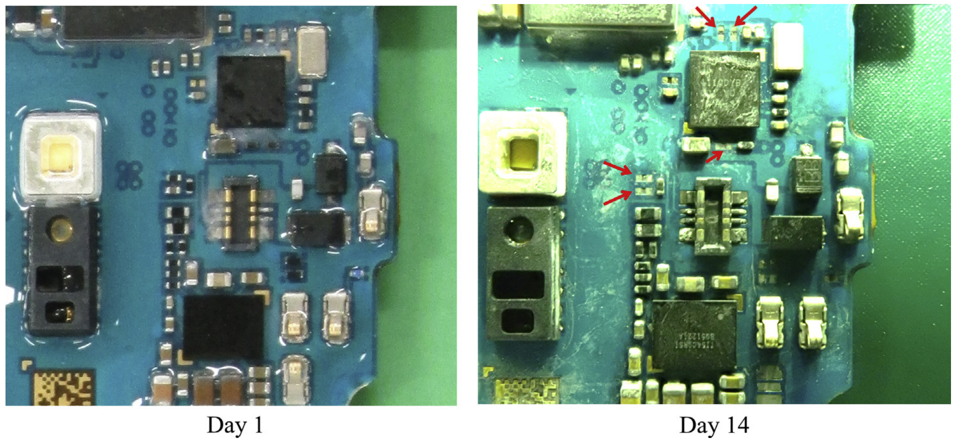

Fig. 9. Condition of the PCB of SM-1 after submersion into seawater. White contaminants are already visible around some components after 1 day of submersion. Multiple components are detached from the PCB after 14 days of submersion due to metal corrosion.

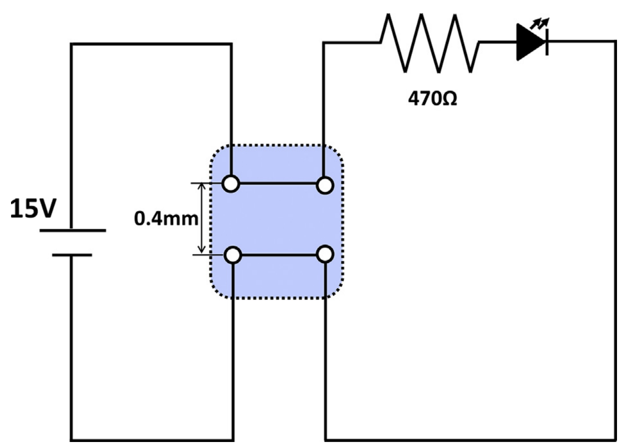

Fig. 10. Schematics of the LED circuit used for measuring the time between water submersion and the creation of open circuit. Shaded area was submerged into water.

positive bias were corroded and black contaminants were produced. After 1466 s, the LED light went off. Normally, the backlight of an LCD in a mobile device requires around 20 V in order to light up, meaning there is a high chance of display failure occurring when water contacts the display connector, due to quick metal corrosion. On a mobile device PCB, there are several components which require and/or produce high voltages. When handling water damaged devices, corrosion and the condition of those electrical parts need to be examined carefully. The authors have encountered multiple cases where the electrodes of a display connector in a water damaged device were completely missing as the result of metal corrosion. While re-establishing electrical paths between the PCB and the display requires advanced techniques, it is far less damaging than conducting chip transplantation analysis. Typically, the display requires the highest voltage of all the components in a digital device. Checking the condition of the display connector, therefore, can be listed as one of the first steps when analyzing a water damaged device.

The most troublesome case that the authors have encountered in handling water damaged devices is when the critical ICs are damaged internally. Sometimes, water infiltrates the IC chip which holds user data or encryption keys. Since an IC chip contains a PCB and other metal materials, metal corrosion occurs internally once water makes contact with them. Furthermore, short circuits created as a result of ECM can electrically damage those critical ICs in ways that are hard to detect and potentially unrecoverable.

Although we did not see CAF damage in the tested devices, through our casework we have seen devices where we diagnosed that a short circuit was created by CAF. When a short circuit is created inside the PCB because of CAF, repairing the board becomes impossible and forensic investigators need to turn to either chip-off or chip transplantation.

8. Related work

While multiple data recovery methods for water damaged digital devices have been suggested (Breeuwsma et al., 2007; Blackman, 2015; Bair, 2017; Heckmann et al., 2018), identification and repair procedures of faulty components on water damaged devices have not been addressed in any of those works. While Watson (2016, 2018) performed practical analysis of water damaged devices by submerging multiple devices into various liquids, and showed that the electrical components in a digital device absorb liquid over time, his research did not address the impact of metal corrosion, which is the most significant aspect of water damage to devices. Meanwhile, metal corrosion in digital devices in high humidity environments has been intensively researched from a device reliability perspective (Minzari et al., 2011; Li et al., 2017; Yip et al., 2017; Zhong et al., 2017), however, to our knowledge, methods to recover a device's operation after it has suffered metal corrosion are not addressed in those works.

9. Conclusion

While many devices arrive at digital forensics labs with water damage, to our knowledge, no comprehensive investigation of the device level effects of metal corrosion has previously been conducted. Through this study, we have documented the internal reactions that occur in digital devices when they have been in contact with water. ECM happens when potential bias and water coexist with digital devices. In order to minimize the continuing damage caused by ECM, the power supply, namely the battery, needs to be removed in a timely manner when handling a water damaged device. Additionally, it needs to be noted that longer submersion time creates more metal corrosion, which makes device recovery processes much more difficult.

When handling a water damaged device at a digital forensic lab, contaminants, namely the metal corrosion products in the device, need to be removed in order to avoid further damaging the device due to short circuits. In addition, close investigation of the PCB components, especially those that require continuous and/or high voltage, needs to be conducted in order to identify faulty components and open circuits. If the device is missing critical electrical components required for booting, or the corrosion is severe enough to cause the loss of conductive metals on the PCB at multiple locations, chip-off or chip transplantation would be the last options.

A clear understanding of metal corrosion can help ensure first responders and forensics investigators appropriately handle and analyze water damaged devices. Proper handling of water damaged devices during forensic analysis significantly improves the odds of successful data extraction.

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