

***Importance of Open Discussion on  
Adversarial Analyses for Mobile Security  
Technologies  
--- A Case Study for User Identification ---***

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*Security Architecture*

*Operating Systems Security*

*Software Tamper Resistance*

*Mobile Code Security*

*Physical Tamper Resistance*

*Communications Security*

*Cryptographic Protocol*

*User Identification*

.....

*Security assessment of biometric user identification systems should be conducted not only for the accuracy of authentication, but also for security against fraud.*

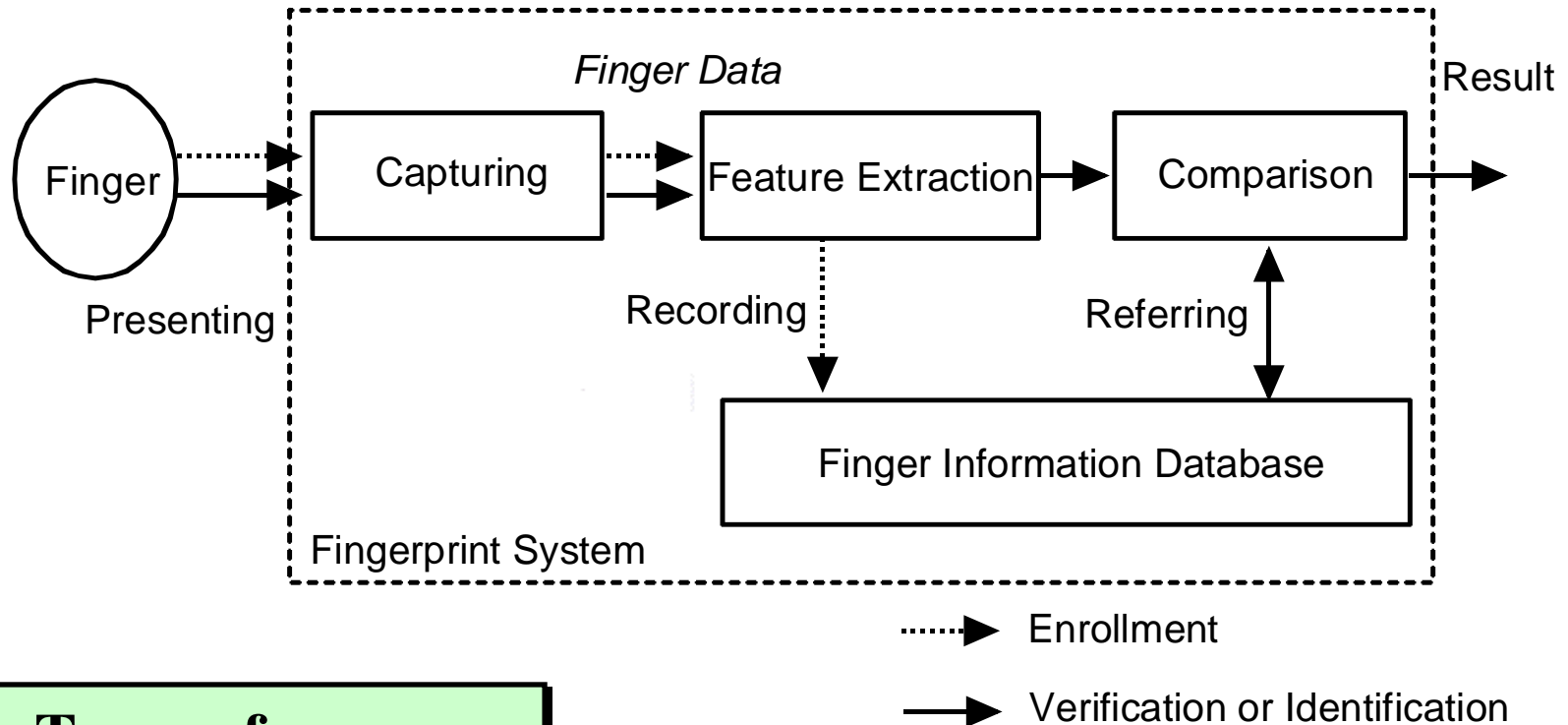


*In this presentation we focus on Fingerprint Systems which may become widespread for Mobile Terminals.*

## *Examine Adversarial Analysis as A Third Party*

- *Can we make artificial fingers that fool fingerprint systems?*
- *What are acceptance rates?*

## Typical structure of a fingerprint system



## Types of sensors

- Optical sensors
- Capacitive sensors
- Thermal sensors, Ultrasound sensors, etc.

*“Live and Well” Detection*

# *A Risk Analysis for Fingerprint Systems*

*Attackers may present*

- 1) the registered finger,  
by an armed criminal, under duress, or with a sleeping drug,*
- 2) an unregistered finger (an imposter's finger),  
i.e., non-effort forgery,*
- 3) a severed fingertip from the registered finger,*
- 4) a genetic clone of the registered finger,*
- 5) an artificial clone of the registered finger, and*
- 6) the others,  
such as a well-known method as a “fault based attack.”*

# *Fraud with Artificial Fingers*

Part of patterns of dishonest acts with artificial fingers against a fingerprint system.

|            | Verification / Identification |      |      |      |      |
|------------|-------------------------------|------|------|------|------|
| Enrollment | L(X)                          | A(X) | L(Y) | A(Y) | A(Z) |
| L(X)       | (1)                           | (2)  | – *  | –    | –    |
| A(Y)       | –                             | –    | (3)  | (4)  | –    |
| A(Z)       | –                             | –    | –    | –    | (5)  |

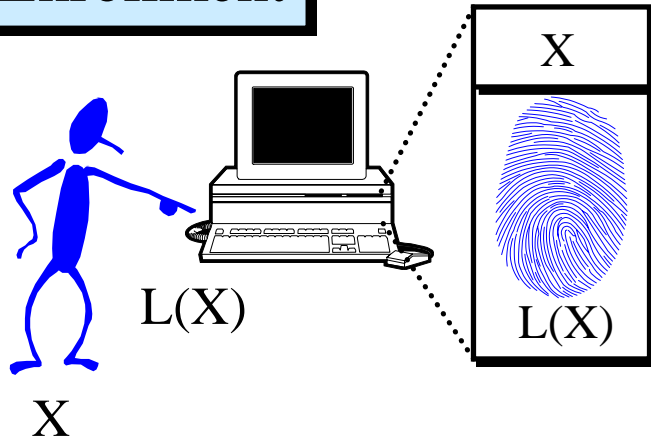
**L(X): A Live Finger corresponding to Person X**

**A(Y): An Artificial Finger corresponding to Person Y**

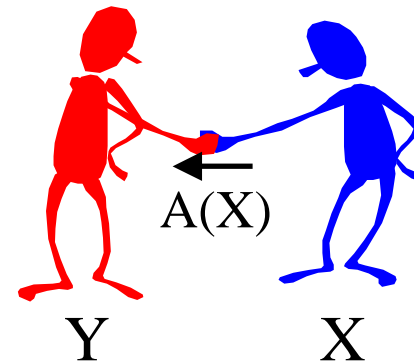
**A(Z): An Artificial Finger corresponding to Nobody**

# Fraud with Artificial Fingers I

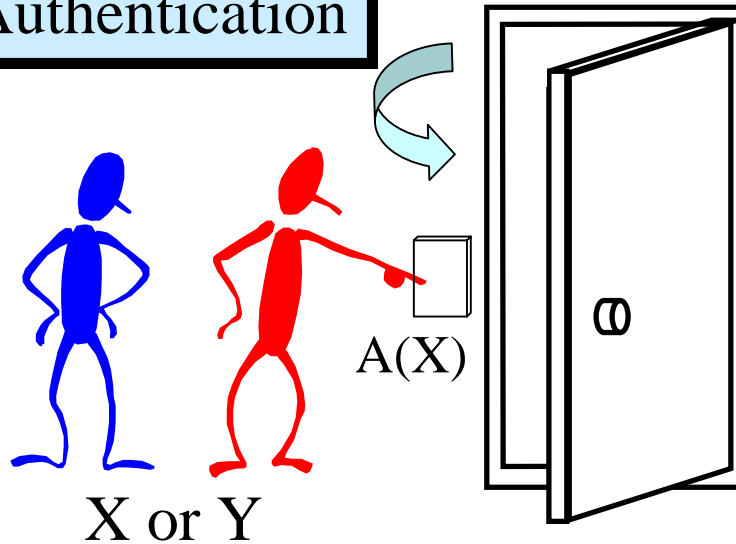
Enrollment



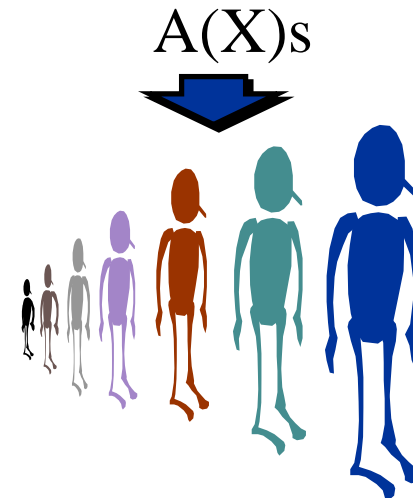
$Y$  obtains  $A(X)$ .



Authentication

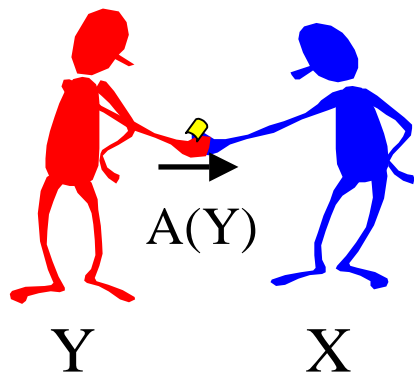


Distribution of  $A(X)$ s

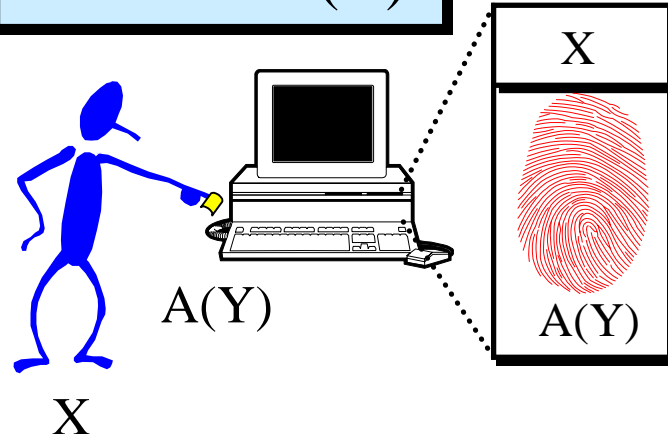


# Fraud with Artificial Fingers II

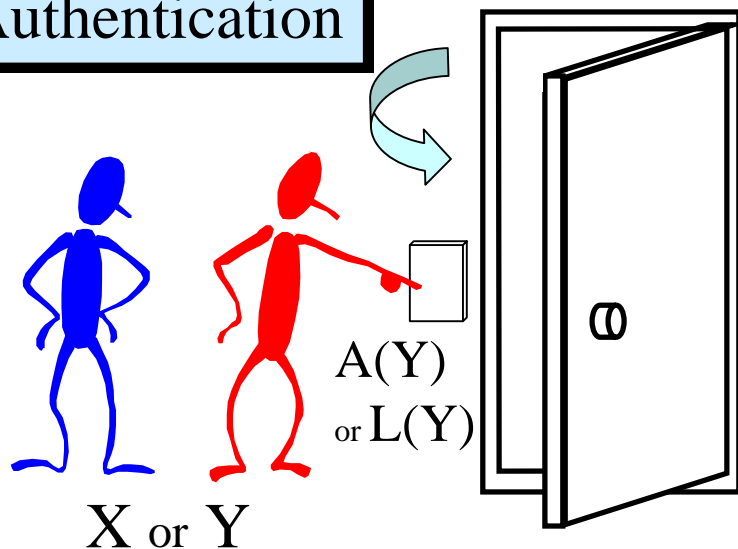
X obtains A(Y).



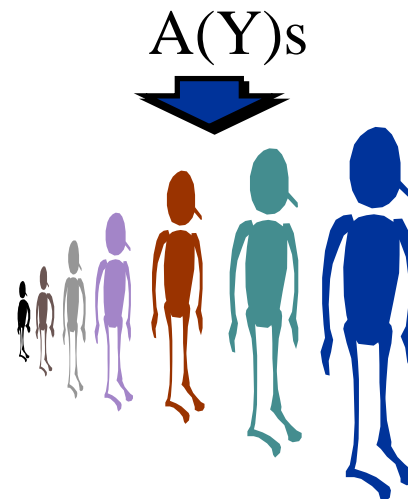
X enrolls A(Y).



Authentication



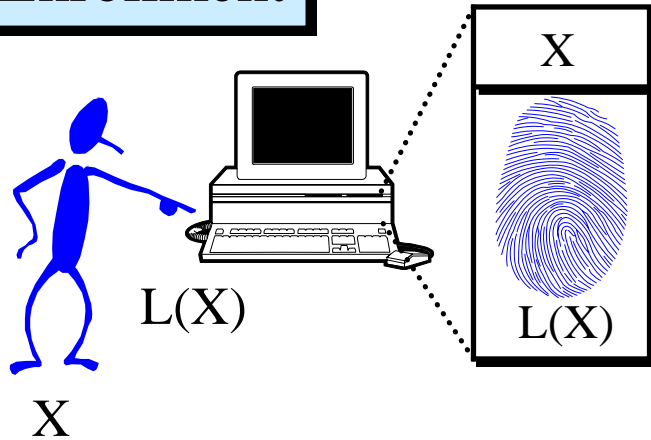
Distribution of A(Y)s



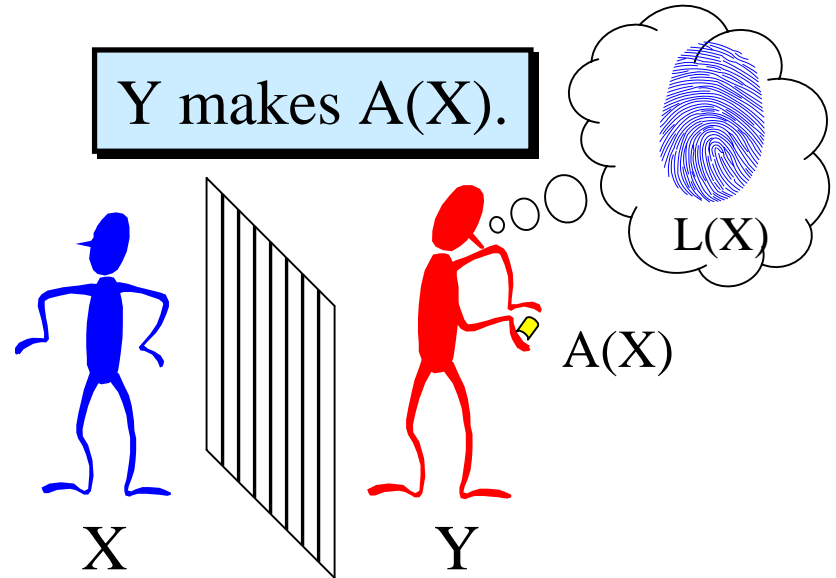


# Fraud with Artificial Fingers III

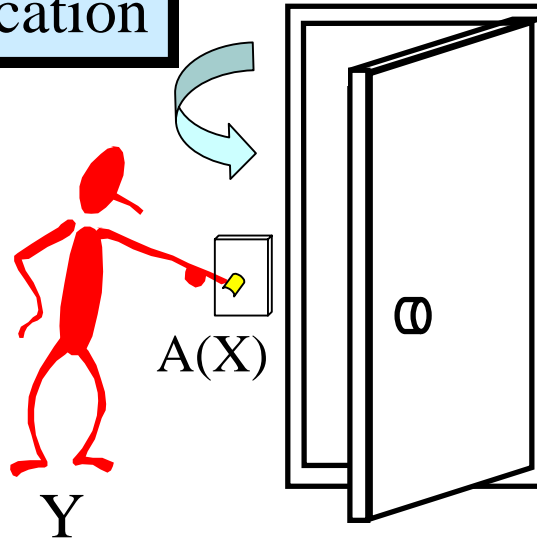
Enrollment



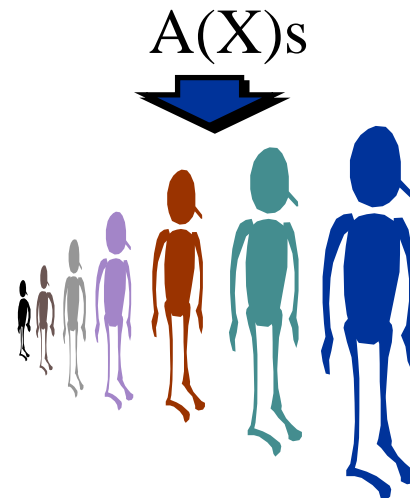
Y makes  $A(X)$ .



Authentication



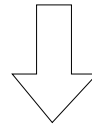
Distribution of  $A(X)$ s



# *Mapping a Fingerprint onto Artificial Fingers*

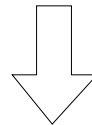
**Fingerprint**

*e.g., Live Fingers, Generators, ...*



**Impression**

*e.g., Molds, Residual Fingerprints, ...*



**Artificial Finger**

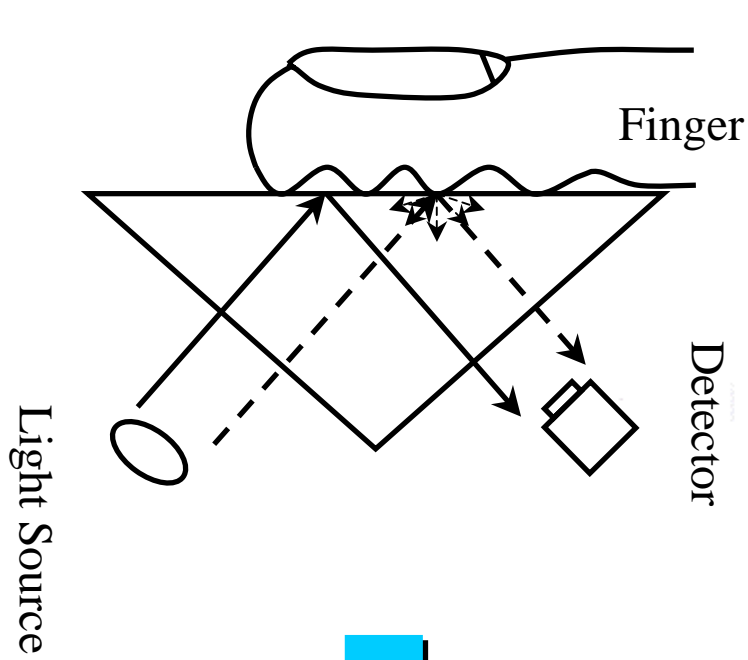
# *Process 0*

*(1) Finger*

*(2) Mold*

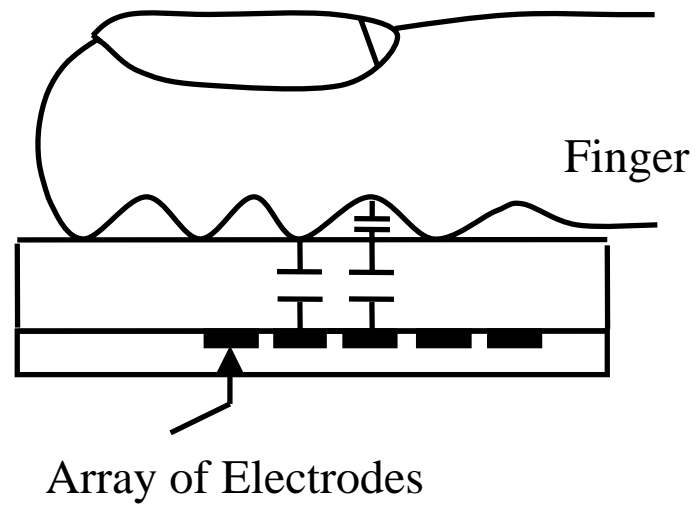
*(3) Silicone Rubber Finger*

### Optical Sensor



Often Accepts  
Silicone Rubber Fingers

### Capacitive Sensor



Usually Rejects  
Silicone Rubber Fingers

# *Our Result*

## *Process 1*

*(1) Finger*

*(2) Plastic Mold*

*(3) Gummy Finger*



# Making an Artificial Finger **directly** from a Live Finger

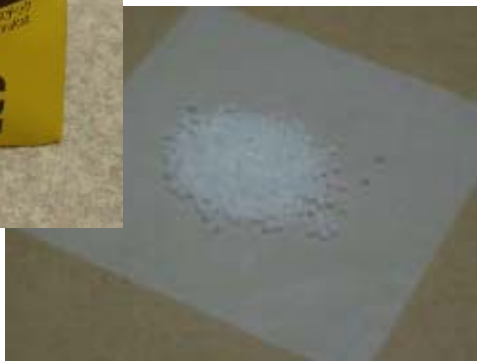
## Materials

**Free molding plastic**  
“FREEPLASTIC”

by Daicel FineChem Ltd.



350JPY/35grams

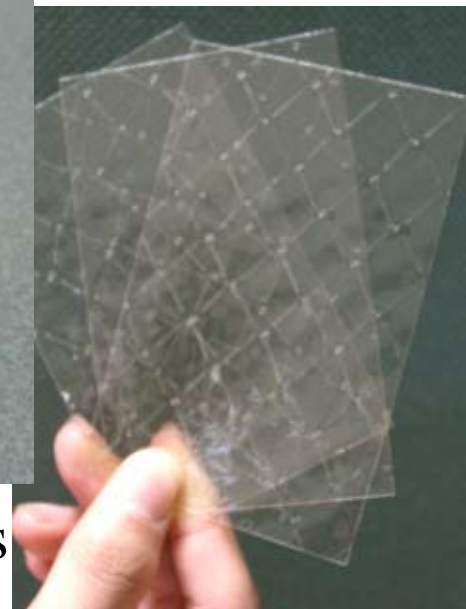


**Solid gelatin sheet**  
“GELATINE LEAF”

by MARUHA CORP



200JPY/30grams



**Making an Artificial Finger *directly* from a Live Finger**

**How to make a mold**



**Put the plastic into hot water to soften it.**



**Press a live finger against it.**



**The mold**

**It takes around 10 minutes.**

## Making an Artificial Finger **directly from** a Live Finger

### Preparation of material

- A liquid in which immersed gelatin at 50 wt.% .



**Add boiling water (30cc) to solid gelatin (30g) in a bottle and mix up them.**

**It takes around 20 minutes.**



**Making an Artificial Finger *directly from* a Live Finger**

**How to make a gummy finger**



**Pour the liquid into the mold.**



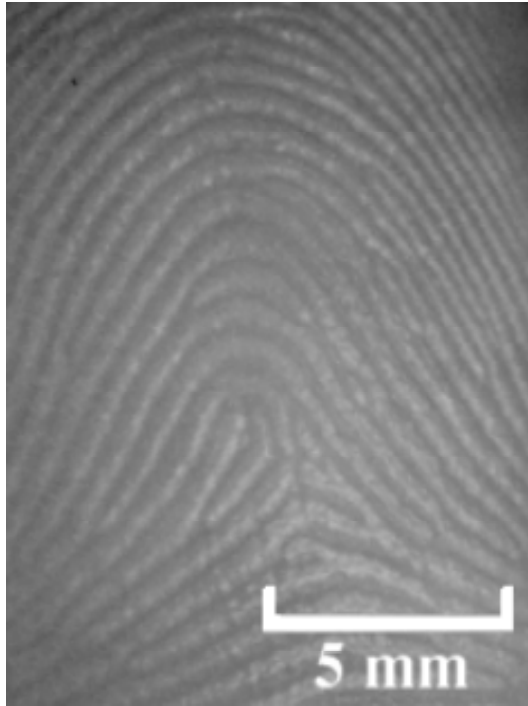
**Put it into a refrigerator to cool.**



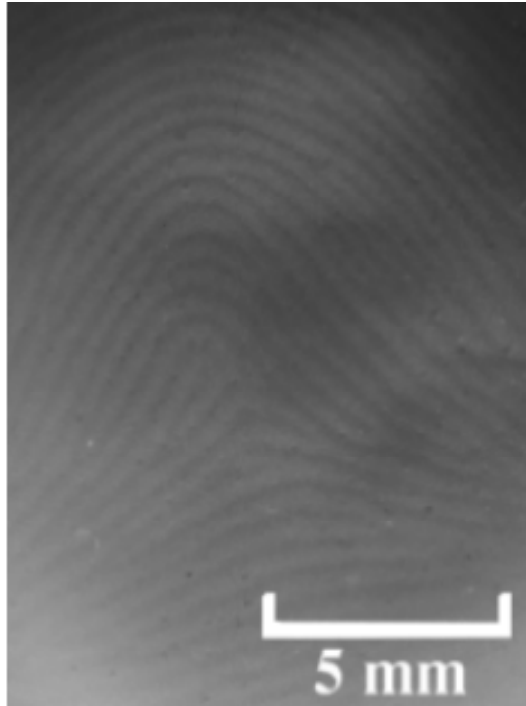
**The gummy finger**

**It takes around 10 minutes.**

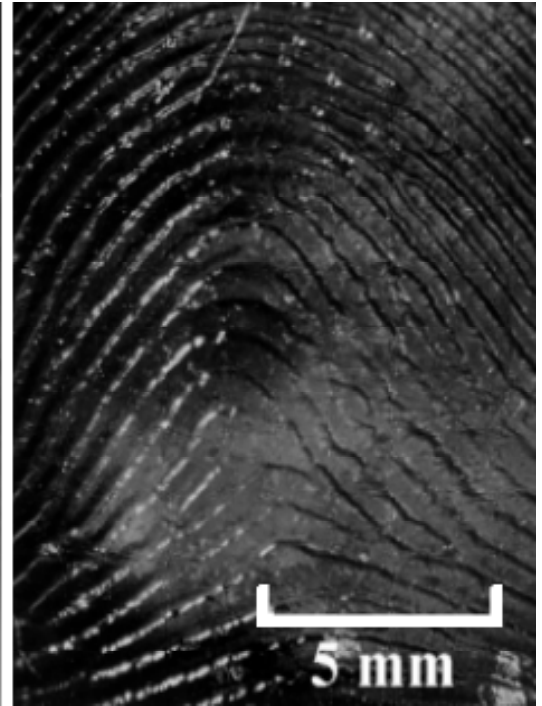
## The photomicrographs of fingers



**(a) Live Finger**



**(b) Silicone Finger**



**(c) Gummy Finger**

# Captured Images

Captured images with the device C (an optical sensor).



(a) Live Finger (b) Silicone Finger (c) Gummy Finger

Captured images with the device H (a capacitive sensor).



(a) Live Finger (b) Gummy Finger

**Subjects:** five persons whose ages are from 20's to 40's

**Fingerprint systems:** 11 types

We attempted one-to-one verification 100 times counting the number of times that it accepts a finger presented.

## Types of experiments

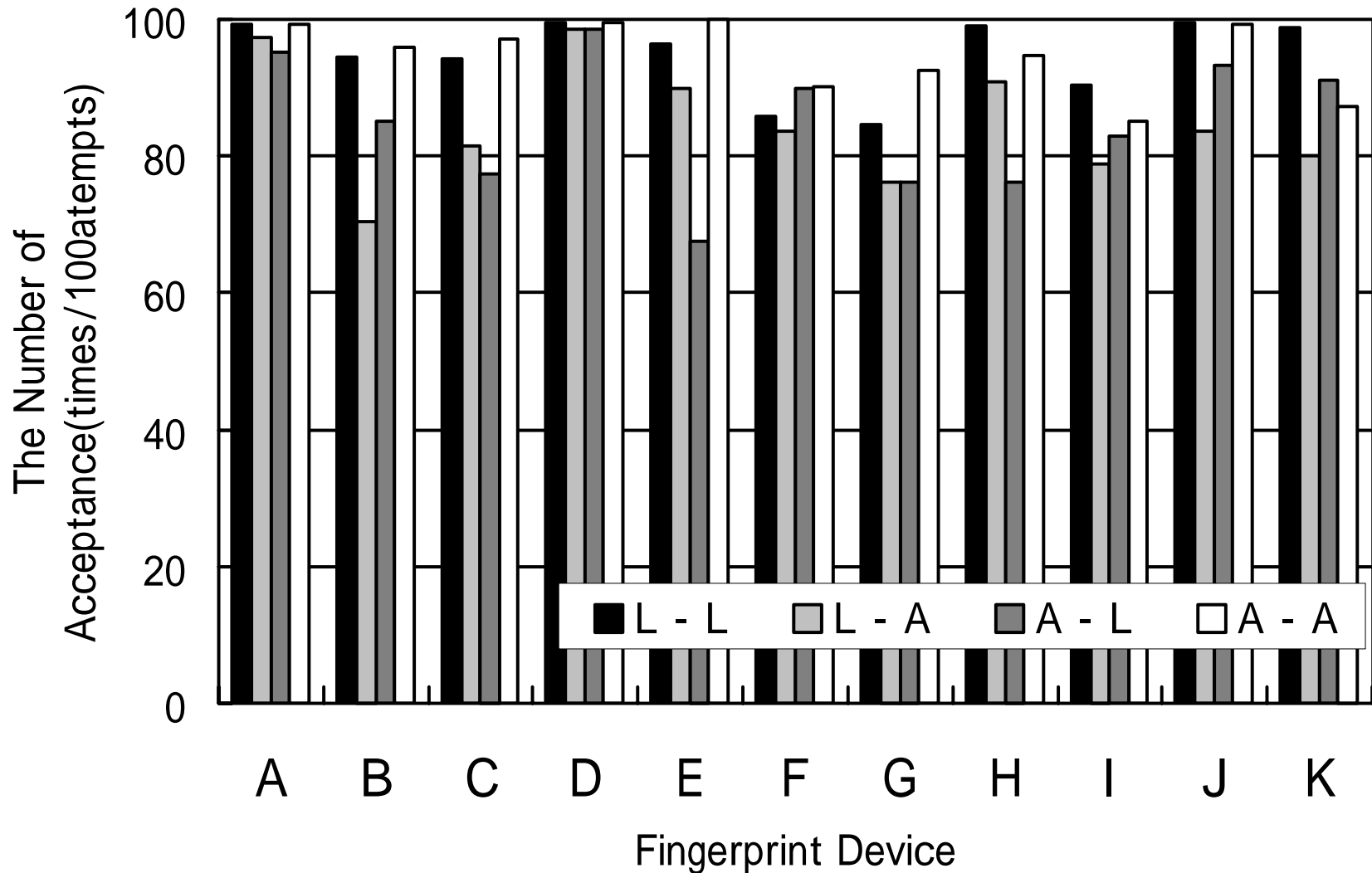
| Experiment | Enrollment   | Verification |
|------------|--------------|--------------|
| Type 1     | Live Finger  | Live Finger  |
| Type 2     | Live Finger  | Gummy Finger |
| Type 3     | Gummy Finger | Live Finger  |
| Type 4     | Gummy Finger | Gummy Finger |

# The List of Fingerprint Devices

|          | Hardware Specifications               |                                                    |                       |                     |                   |                         | Software Specifications                 |                                                                                               |                   | Methods for Verification                 |
|----------|---------------------------------------|----------------------------------------------------|-----------------------|---------------------|-------------------|-------------------------|-----------------------------------------|-----------------------------------------------------------------------------------------------|-------------------|------------------------------------------|
|          | Manufacturer / Selling Agency         | Product Name                                       | Type                  | Product Number      | Sensor            | Live and Well Detection | Manufacturer / Selling Agency           | Product Name (Application)                                                                    | Comparison Levels |                                          |
| Device A | Compaq Computer Corporation           | Compaq Stand-Alone Fingerprint Identification Unit | DFR <sub>3</sub> -200 | E03811US001         | Optical Sensor    | unknown                 | Compaq Computer Corporation             | Fingerprint Identification Technology Software version 1.1                                    | 1 through 3       | Minutiae Matching                        |
| Device B | MITSUBISHI ELECTRIC CORPORATION       | Fingerprint Recognizer                             | FPR-DT mkII           | 003136              | Optical Sensor    | unknown                 | Sumikin Izumi Computer Service co. Ltd. | SecFP V1.11                                                                                   | Fixed             | Minutiae Matching                        |
| Device C | NEC Corporation                       | Fingerprint Identification Unit (Prism)            | N7950-41              | 9Y00003             | Optical Sensor    | unknown                 | NEC Corporation                         | Basic Utilities for Fingerprint Identification                                                | Fixed             | Minutiae Matching (Minutia and Relation) |
| Device D | OMRON Corporation                     | Fingerprint Recognition Sensor                     | FPS-1000              | 90500854            | Optical Sensor    | unknown                 | OMRON Corporation                       | "YUBI PASS" U.are.U <sub>3</sub> Fingerprint Verification Software                            | Fixed             | Minutiae Matching                        |
| Device E | Sony Corporation                      | Sony Fingerprint Identification Unit               | FIU-002-F11           | 00709               | Optical Sensor    | Live Finger detection   | TSUBASA SYSTEM CO.,LTD.                 | Fingerprint Identification Unit Windows <sub>3</sub> 95 Interactive Demo Version 1.0 Build 13 | 1 through 5       | Pattern matching                         |
| Device F | FUJITSU LIMITED                       | Fingsensor                                         | FS-200U               | 00AA000257          | Capacitive Sensor | unknown                 | FUJITSU LIMITED                         | Logon for Fingsensor V1.0 for Windows <sub>3</sub> 95/98                                      | Fixed             | Minutiae Matching (Correlation)          |
| Device G | NEC Corporation                       | Fingerprint Identification Unit (Serial)           | PK-FP002              | 0300529S            | Capacitive Sensor | unknown                 | NEC Corporation                         | Basic Utilities for Fingerprint Identification                                                | Fixed             | Minutiae Matching (Minutia and Relation) |
| Device H | Siemens AG (Infineon Technologies AG) | FingerTIP <sub>3</sub> EVALUATION KIT              | EVALUATION-KIT        | C98451-D6100-A900-4 | Capacitive Sensor | unknown                 | Siemens AG (Infineon Technologies AG)   | FingerTIP <sub>3</sub> Software Development Kit (SDK) Version: V0.90, Beta 3 "Demo Program"   | Fixed             | Minutia matching                         |
| Device I | Sony Corporation                      | Sony Fingerprint Identification Unit               | FIU-710               | 3000398             | Capacitive Sensor | Live Finger detection   | Systemneeds Inc.                        | Good-bye "PASSWORD"s                                                                          | 1 through 5       | Pattern matching                         |
| Device J | Secugen                               | EyeD mouse II                                      | SMB-800               | 9650172004          | Optical Sensor    | unknown                 | Secugen                                 | SecuDesktop 1.55 日本語版                                                                         | 1 through 9       | Minutia matching                         |
| Device K | Ethentica                             | ethenticator MS 3000 PC Card                       | MS 3000               | M300F20091          | Optical Sensor    | unknown                 | Ethentica                               | Secure Suite Release1.0                                                                       | Fixed             | Minutia matching                         |


# Experimental Results

## Making an Artificial Finger **directly** from a Live Finger



# *Our Result*

## *Process 2*

- (1) Residual Fingerprint*
  - (2) Digital Image Data*
  - (3) Printed Circuit Board*
  - (4) Gummy Finger*
- 

## Making an Artificial Finger from a Residual Fingerprint

### Materials

**A photosensitive coated Printed Circuit Board (PCB)**

“10K” by Sanhayato Co., Ltd .



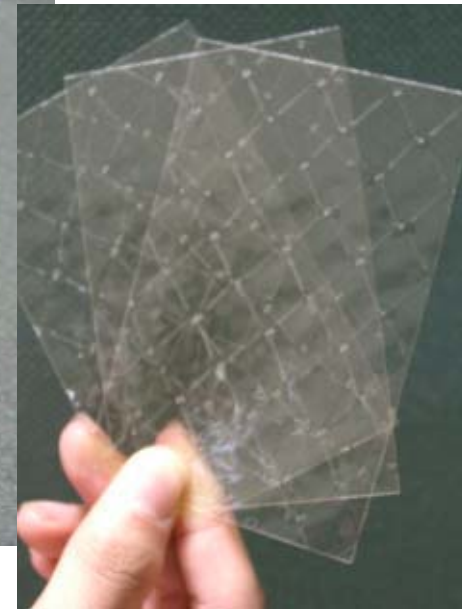
320JPY/sheet



**Solid gelatin sheet**  
“GELATINE LEAF”  
by MARUHA CORP

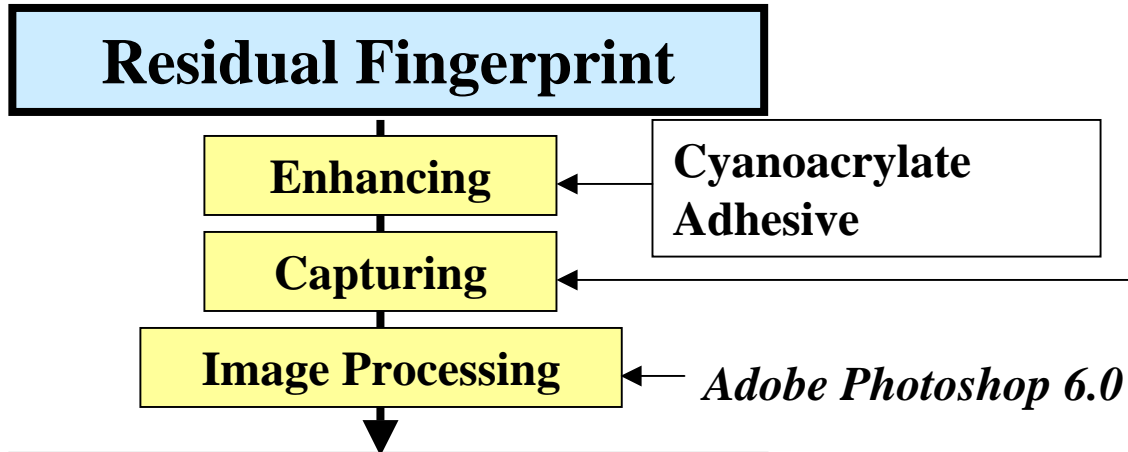


200JPY/30grams





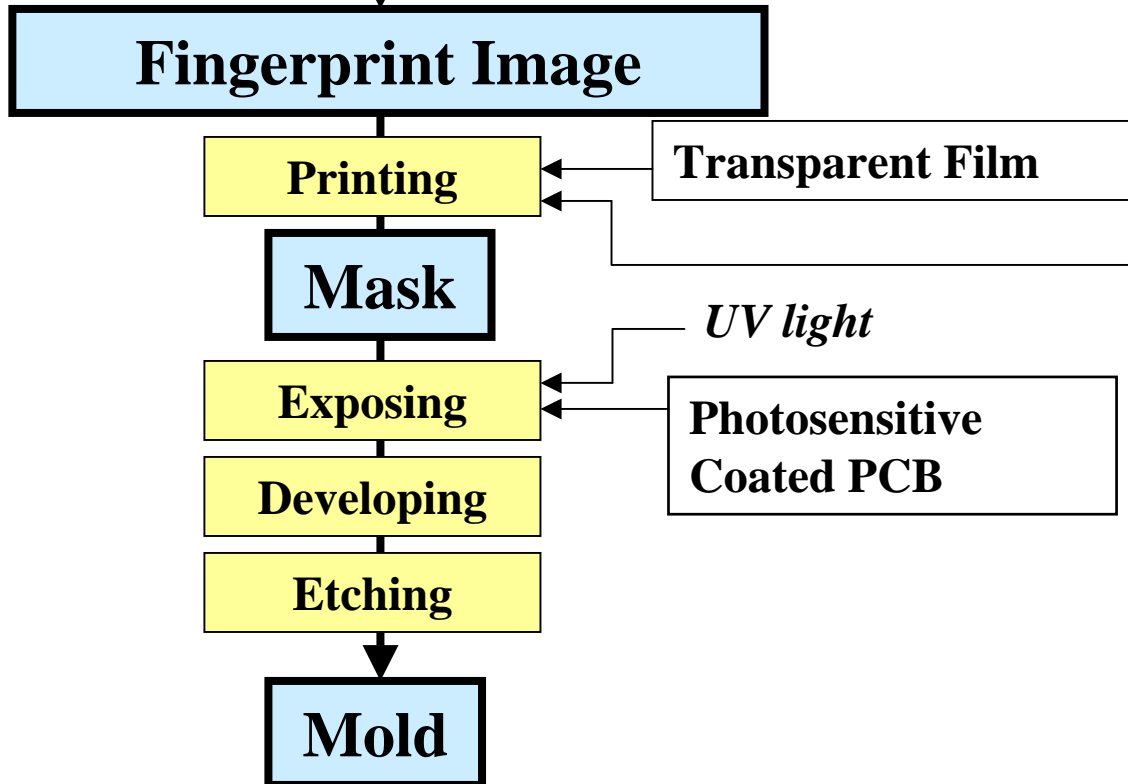
# Recipe 2-2



*Digital Microscope*



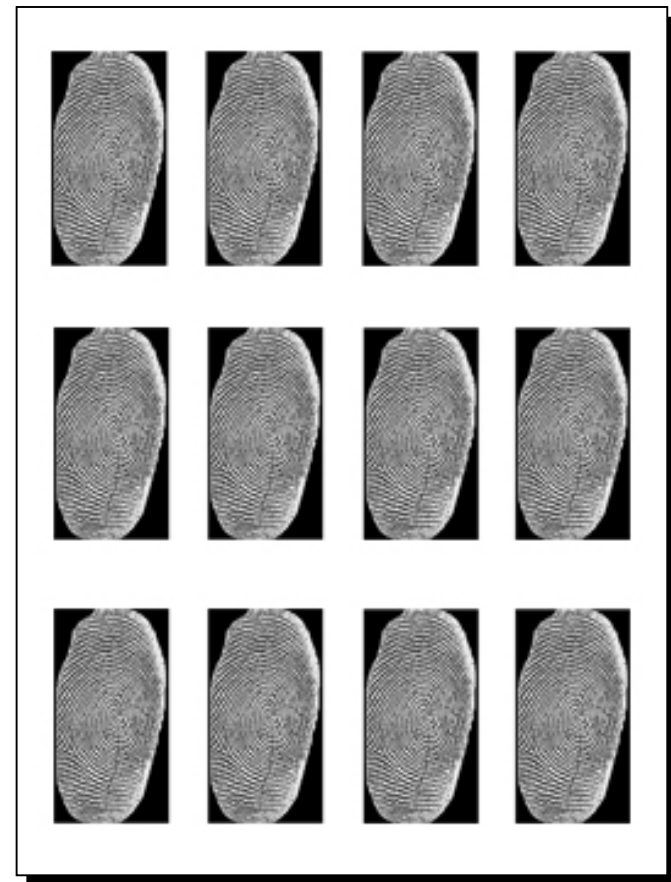
**KEYENCE VH6300: 900k pixels**



*Inkjet Printer*



**Canon BJ-F800: 1200x600dpi**

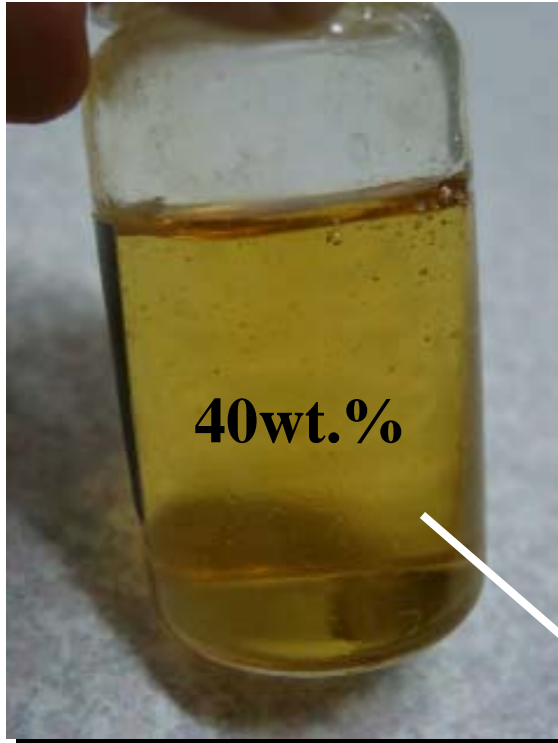


**A Mask with Fingerprint Images**

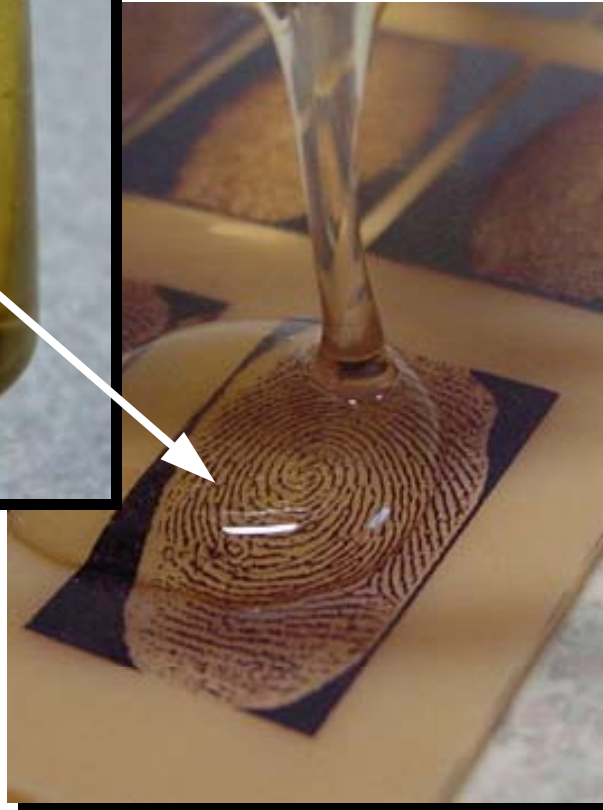
**An Enhanced Fingerprint**

**A Fingerprint Image**

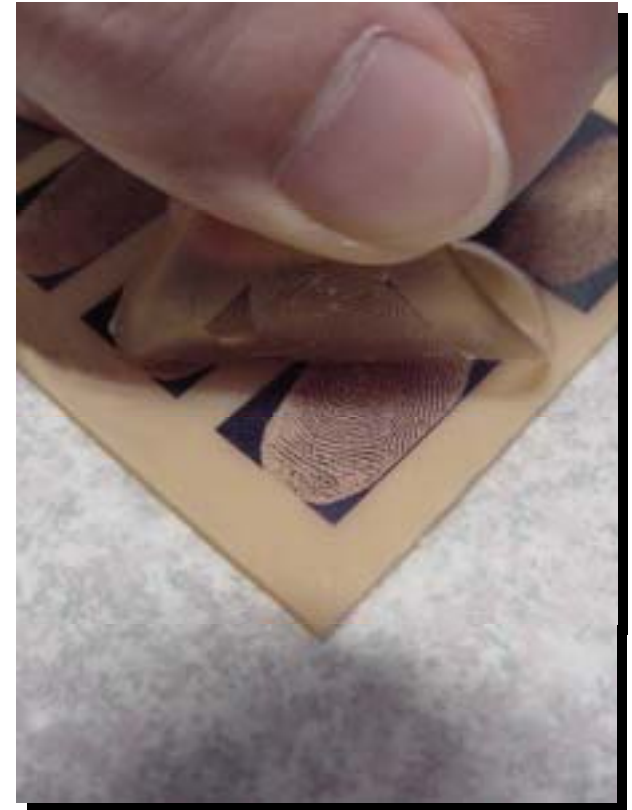
## Gelatin Liquid



**Drip the liquid onto the mold.**



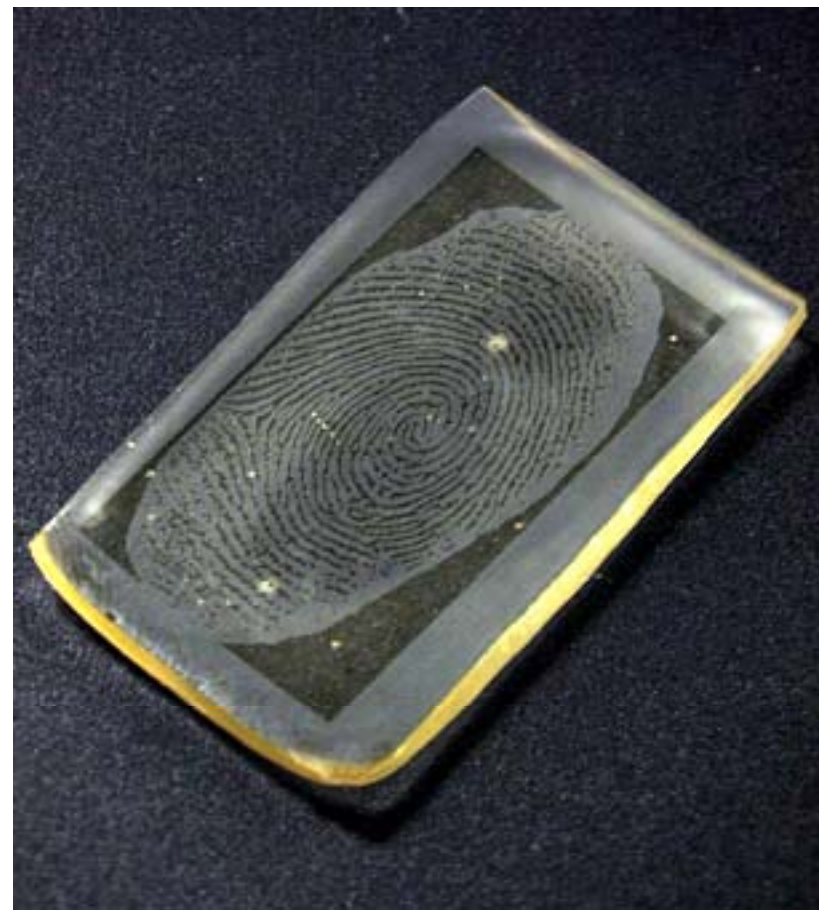
**Put this mold into a refrigerator to cool, and then peel carefully.**



# *The Mold and the Gummy Finger*



**Mold: 70JPY/piece**  
**(Ten molds can be obtained**  
**in the PCB.)**



**Gummy Finger: 50JPY/piece**

# *Resolution of Fingerprint Images*

Pores can be observed.



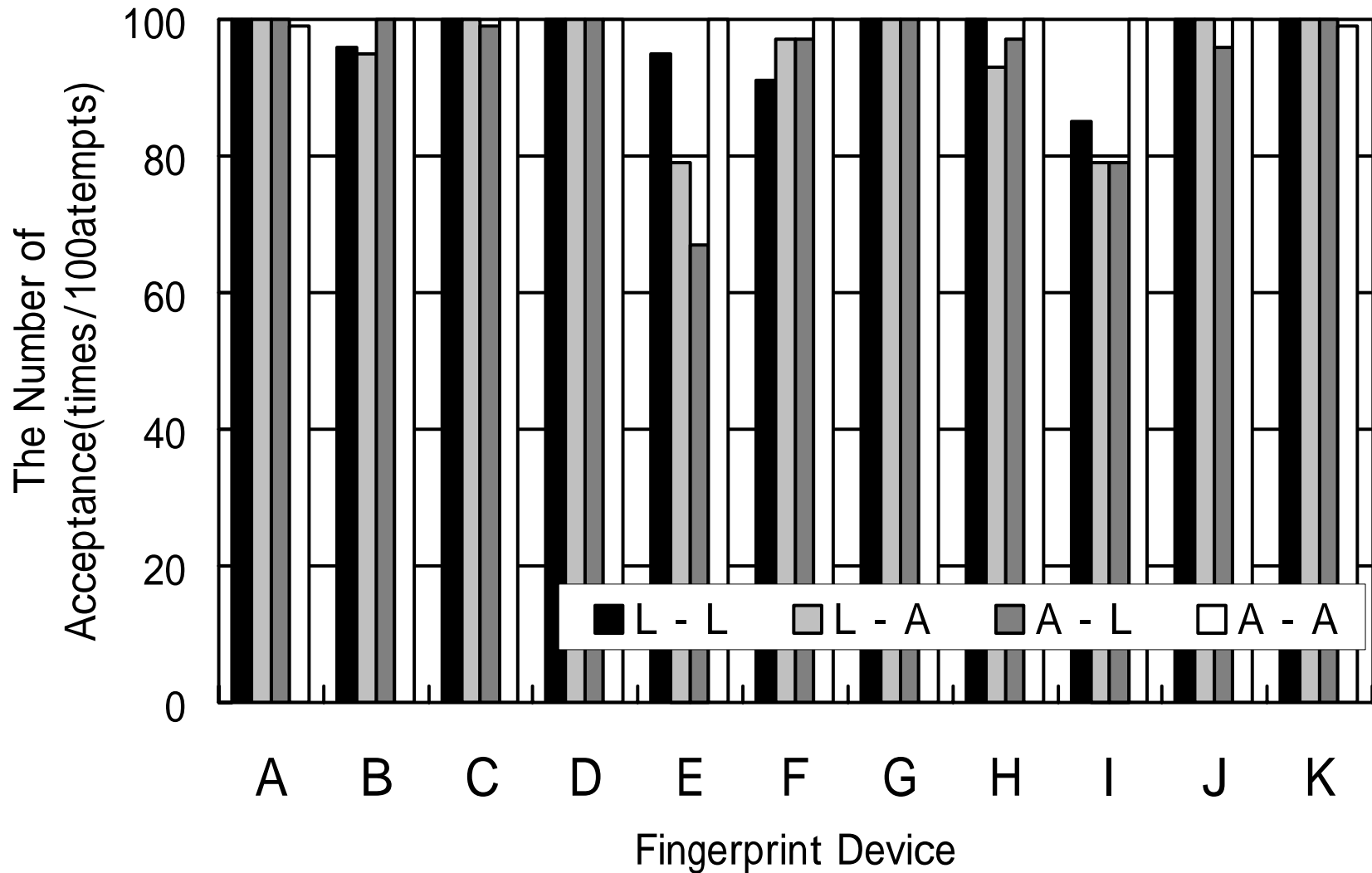
**Enhanced Fingerprint**



**Captured Fingerprint Image of  
the Gummy Finger  
with the device H (a capacitive sensor)**

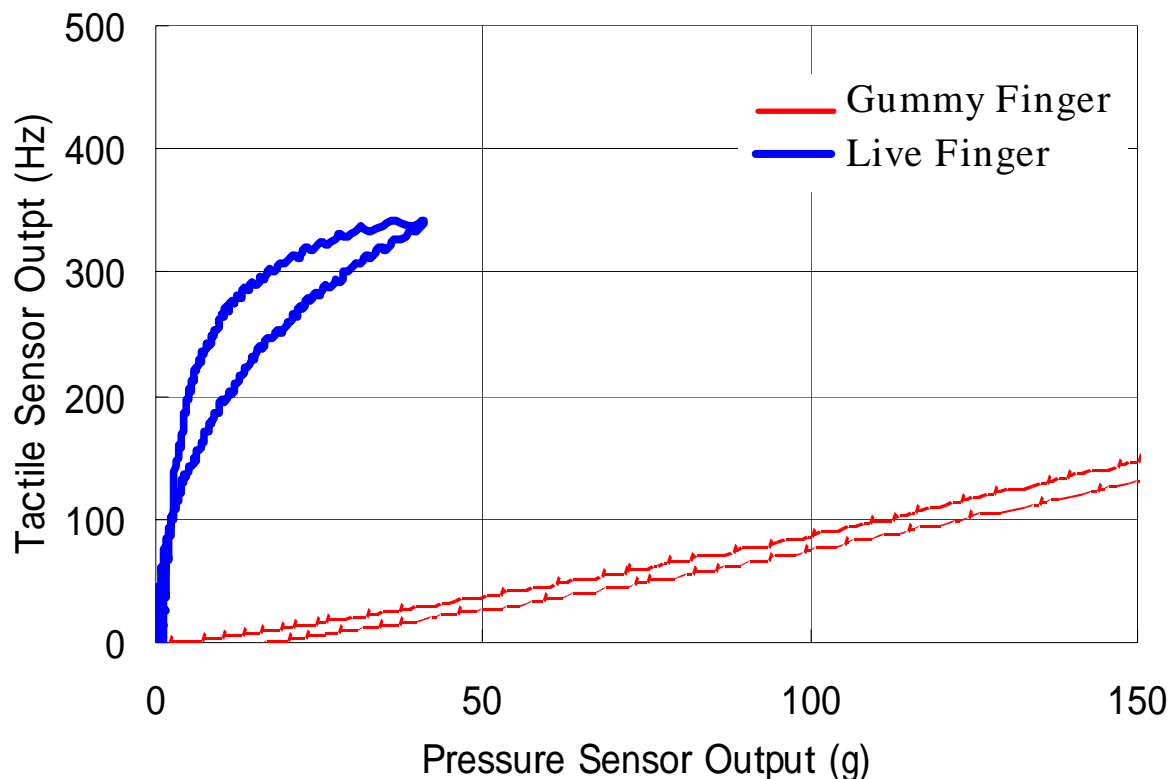
# Experimental Results

*from Residual Fingerprints (for 1 subject)*



# Characteristics of Gummy Fingers

|                 | Moisture              | Electric Resistance   |
|-----------------|-----------------------|-----------------------|
| Live Finger     | 16%                   | 16 Mohms/cm           |
| Gummy Finger    | 23%                   | 20 Mohms/cm           |
| Silicone Finger | impossible to measure | impossible to measure |



The compliance was also examined for live and *gummy* fingers.

- *There can be various dishonest acts using artificial fingers against the fingerprint systems.*
- *Gummy fingers, which are easy to make with cheap, easily obtainable tools and materials, can be accepted by 11 types of fingerprint systems.*
- *The experimental study on the gummy fingers will have considerable impact on security assessment of fingerprint systems.*
- *Manufacturers, vendors, and users of biometric systems should carefully examine security of their system against artificial clones.*
- *How to treat such information should be an important issue.*



- *Paper:*

*T. Matsumoto, H. Matsumoto, K. Yamada, S. Hoshino,  
“Impact of Artificial “Gummy” Fingers on Fingerprint  
Systems” Proceedings of SPIE Vol. #4677,  
Optical Security and Counterfeit Deterrence Techniques IV.*