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Some observations on fingerprint deposits

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Abstract. Measurements of refractive indices and droplet profiles of fingerprint deposits on flat solid surfaces have been made using transmitted light interference microscopy. Changes in the profiles with time and relative humidity have been determined. From these measurements inferences are made on the structure of the droplets. The absence of significant variation in contact angle for fingerprints on substrates of different surface energy is explained in terms of a contaminant film over the area of finger ridge contact. The thickness of this film corresponds closely to that expected for a monolayer of contamination.

1. Introduction

Little is known about the physical nature of fingerprints and few physical techniques for developing fingerprints have emerged since the widely used powdering method (Moenssens 1971). The major aim of this work is to obtain a better understanding of fingerprints and how they differ from their surroundings. Results on the electrical properties of fingerprints have been reported elsewhere (Scruton and Blott 1973, Thomas 1975) and progress in this field has been recently reviewed (Thomas 1973).

Fingerprints on reflecting surfaces can often be seen by the naked eye. To understand their interaction with the substrates on which they are placed magnification is necessary. In general any substance which can be transferred tactually by the papillary ridges can form a fingerprint. The primary component of fingerprints is eccrine sweat from the glands on the finger ridges. This sweat is usually accompanied by sweat that originates from finger contact with other parts of the body. Sebum, the secretion of the sebaceous glands, is the other major constituent, and aprocrine sweat is also present but to a lesser degree. Pure eccrine sweat is an aqueous solution of inorganic and organic (non-lipid) compounds (Kuno 1956), whereas sebum is mainly composed of lipids (Heinz and van der Velden van der Ende 1973).

Because fingerprints are transparent, use is made of a dark ground, phase contrast or interference technique. Quantitative interference microscopy has been used to determine a refractive index distribution of finger deposits, the thickness variation, and also distributions of contact angles of fingerprints on high and low energy surfaces. The existence of a thin film of contamination that covers the whole area of ridge contact accounts for our observations.

2. Preliminary observations

Interference microscopy shows that (*a*) the thickness of the deposit varies widely within the region contaminated by the finger (figure 1, plate); (*b*) that the ridges are delineated by independent islands of material (Bridges 1942) ranging in diameter from about 1–50 μm; (*c*) that the maximum thickness of these structures ranges from that corresponding to the minimum phase change detectable, about 10 nm, to approximately 2 μm; (*d*) that there is a wide range of angle of contact between the finger deposit and the substrate, as can be seen from the variation in width of the interference fringes near the perimeter of the droplets.

Usually the region between these deposits appears uncontaminated but occasionally a continuous connecting film is apparent. An example of this is shown in figure 2 (plate) in which the continuous layer is approximately 30 nm thick. The thickness of this film may be increased to some 5–10 μm by deliberately coating the fingers with excessive sebum.

Sometimes sodium or potassium chloride crystals are observed in finger deposits. These appear soon after the deposition of the prints when the water has evaporated.

3. Refractive index measurements

As can be seen from figure 1 the distance between the droplets is often smaller than their diameters. For this reason we chose to use the interphako† method (Beyer 1967), rather than the more conventional shearing technique, for measuring phase changes.

Refractive indices of the droplets have been measured by comparing phase shifts in air with those obtained using an aqueous solution of barium mercuric iodide as the embedding medium. The sensitive purple was used as a colour index so the measured values refer to $\lambda = 550$ nm. The distribution of refractive index values is shown in histogram form in figure 3. The experimental error is $\pm 6 \times 10^{-3}$ (SD).

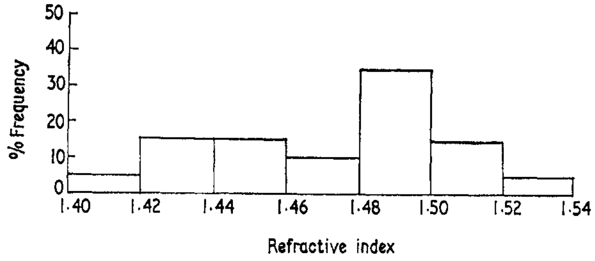

Figure 3. Refractive index distribution of fingerprint deposits of less than a day old for $\lambda = 551$ nm.

The refractive indices of most of the long chain fatty material found in finger deposits fall within our measured distribution. It should be noted that the refractive index of water lies well outside this range, indicating that water is not present in finger deposits to the extent that it is in sweat collected from the fingers after encouraging excessive perspiration (Kuno 1956).

4. Droplet profiles

4.1. Changes with time and relative humidity

We have studied the microscopic changes that occur in finger deposits with time and relative humidity. Fingerprints were stored in various environments for up to 3 months

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† The interference measurements were carried out using a Carl Zeiss (Jena) Amplival Interphako microscope.

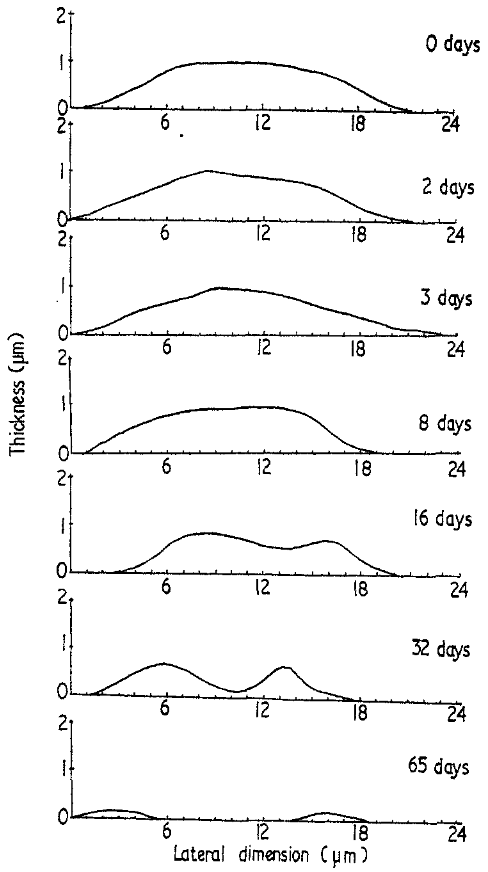

Figure 4. A cross section across a typical droplet of finger deposit and its temporal variation.

(see captions to figure 5). We noted that as aging proceeded the structures became quite irregular in topography and this was accompanied by an increase in viscosity of the deposit. A constant refractive index of 1·47 was used to calculate the thickness from the observed phase shifts and the variation of a typical profile is shown in figure 4. In figure 5 we show the variation of the mean of the maximum height of the droplets as a function of time and storage environment.

Presumably the large initial changes in thickness were due to evaporation of the more volatile constituents. The inhomogeneity of chemical composition of the droplets was apparent from the variation of drying rate within the droplets themselves (see for example figure 4). The lack of systematic dependence of drying rate with relative humidity indicates that the droplets have a low water content, at least near their surface. This is consistent with their measured refractive indices (see §3).

4.2. Contact angles

Our droplet profiles automatically give contact angles. We have extended these measurements to the observation of finger deposits on silicone polished glass (fingerprints are difficult to develop on silicone polished surfaces), Perspex and cellulose acetate. The distributions of measured contact angles are shown in figure 6 for the surfaces that we have examined. The error in the determination of θ_c is ±10% (SD). This includes the error due to the location of the edge of the droplet (±0·5 μm). It is apparent that the distribution of contact angles is more or less independent of the surface energy of the surface on to which the fingerprints have been placed. We noted that for about a third of the measurements the contact angles were zero and a definite point of inflexion in the droplet profile could be seen (see for example figure 4). Again this was independent of the surface energy. No significant time dependence in contact angles was observed over a 7 day period.

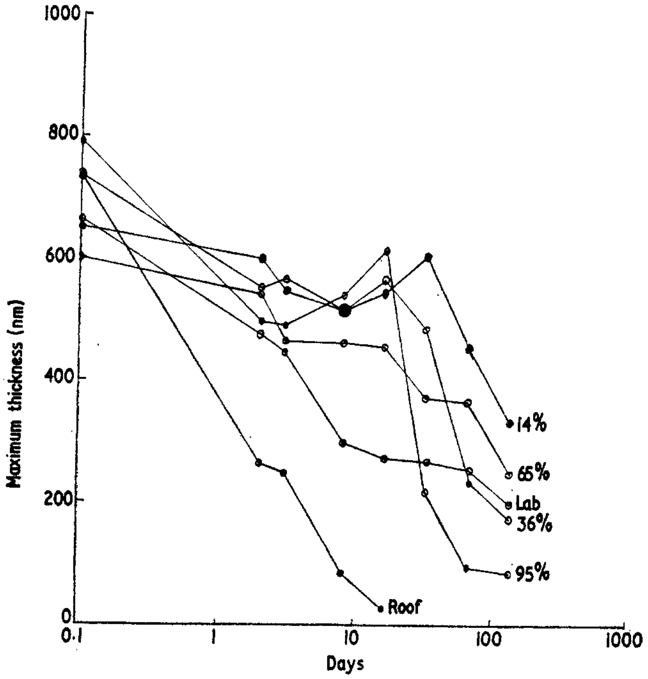

Figure 5. The variation of the mean of the maximum thickness of fingerprint droplets as a function of time and storage environment. One fingerprint on a clean microscope slide from each of four donors was stored in each of 6 environments for 3 months. The environments were: an open laboratory; 4 constant relative humidity cabinets (14%, 36%, 65% and 95% RH); outdoors with protection from direct rainfall in central London. Measurements were made on three droplets from each fingerprint.

The close similarity of contact angle distribution for the surfaces examined indicates that the contact angles are a characteristic, not of the clean surface on which the deposit has been placed, but of a layer of contamination produced by the retracting liquid as the droplets are formed. It is of course well known that oriented monolayers can be formed by retraction (Chapman and Tabor 1957). An area of liquid contact which is much larger than the area covered by the droplets has recently been observed (Scruton *et al* 1975). Since the droplets are presumably formed after the rupture of a liquid film the contact angles we have measured are largely receding angles. We might expect hysteresis in the contact angles due to the presence of the inferred contamination layer (Fowkes and Harkins 1940, Dettre and Johnson 1965). The observation of a concave meniscus indicates the presence of solid matter in the finger deposit, or at least material that becomes solid as the temperature of the deposit reaches that of the substrate. Some solid

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