Article type: Article

Title

Impact of "anti-fingerprint" coatings on the detection of fingermarks

Authors

Sandra Forchelet

Andy Bécue *

Affiliation

École des Sciences Criminelles

University of Lausanne – Building Batochime

CH-1015 Lausanne

Switzerland

Contact information (*corresponding author)

Tel: +41 (0)21 692 46 30

Fax: +41 (0)21 692 46 05

e-mail: andy.becue@unil.ch

Introduction

Our current lifestyle is characterized by an increasing use of devices based on touchscreen interfaces, such as mobile phones, computers, tablets, or smartwatches. The development of coatings preventing fingermark deposition has logically followed. These coatings are referred to as "anti-fingerprint" (AFP), "easy-to-clean", or "self-cleaning", with commercial claims referring to the reduction of oily components left (upon contact) and/or the easiness of cleaning. AFP coatings are either integrated in the purchased device or can be added afterwards (*e.g.*, repellent liquid, plastic film, or replacement glass). From a forensic point of view, the development of AFP coatings should raise the question of their impact on the deposition and on the detection of fingermarks. Given that fingermark detection is a procedure that is highly dependent on the nature of the surface to process [1], it is crucial to know if detection techniques commonly applied on smooth (non-porous) surfaces are still applicable and efficient on AFP coatings. This appears particularly relevant considering that most scientific publications on AFP coatings refer to their morphology and their physico-chemical properties [2], but nothing so far regarding forensic issues. Given that AFP-coated items are now commonly encountered in our lifestyle, it is anticipated that their processing for fingermark detection will increase, leaving the practitioners with un-answered questions.

From a physico-chemical point of view, the engineering of AFP surfaces is mostly based on the development of coatings presenting amphiphobic properties (*i.e.*, hydrophobic and oleophobic), meaning that they repel both water and oily components. The need for amphiphobicity is mostly due to the composition of a fingermark, particularly of the hydrolipidic film composing the secretion residue. AFP coatings are consequently engineered to reduce the affinity of secretion residue for the surface, which should affect the transfer of material upon contact with a fingertip or ease its cleaning. To reach that goal, engineers can rely on the chemical composition, roughness and morphology of the coatings [2, 3]. The first parameter consists in using chemical groups with low surface energy (*e.g.*, fluorinated groups composing the Teflon) to minimize the surface wettability against water and oil.

The second parameter is directly linked to the fact that textured surfaces promote the formation of air/solid interfaces improving the non-wetting behavior of the surface. The third parameter finds its origin in the observation of natural structures presenting nano-/micro-structures on their surface, which result in enhanced hydrophobic properties (*e.g.*, lotus effect [4]). If user-oriented requirements are taken into consideration (*e.g.*, transparency, durability, smooth touch), it becomes obvious that the engineering of efficient AFP coatings constitutes an industrial challenge. Nevertheless, it is quite surprising to realize that most of the scientific literature dedicated to AFP coatings refers to a hypothetical anti-fingerprint effect, inferred from contact angles and wettability measurements. Moreover, most of the efficiency studies are either based on the use of artificial sebum [5], contaminated cloth [6] or computational modelling [7]. Therefore, it appears crucial to conduct a study based on actual secretion residue left on AFP coated-surfaces combined with the application of conventional detection techniques.

Given that little is known about the behavior of AFP coatings in a forensic context, the study was focused on their potential impact on each step of a fingermark detection procedure. This typically includes the characterization of the surface (optical behavior, background luminescence), the early observation of latent fingermarks, the application of detection techniques, and the observation of the processed marks. From a methodological point of view, this study has been designed to provide answers to the following questions:

- Q1: "Do anti-fingerprint surface coatings prevent the deposition of secretion residue?"
- Q2: "Do anti-fingerprint surface coatings impact the optical observation of latent fingermarks?"
- Q3: "Do anti-fingerprint surface coatings impact the application of common fingermark detection techniques?"

It is anticipated that such information will provide preliminary but helpful information to practitioners, as well as identify issues that should be further addressed.

Materials and methods

Anti-fingerprint (AFP) coatings

Eight commercially-available AFP coatings were considered: two liquids, three plastic films, and three glasses (Table 1). One product of each category is illustrated in Figure 1. Each coating was applied to as many glass slides (microscopy slide, VWR) as required by the fingermark sampling (see below). The application of the AFP coatings was performed by strictly following the recommendations of the providers (Table 1). The reference substrate considered in this study was uncoated glass (microscopy slides, VWR).

< INSERT TABLE 1 HERE >

< INSERT FIGURE 1 HERE >

Fingermark collection

For this study, one donor was asked to provide eccrine, sebum-rich, and natural fingermarks [8]. Eccrine and sebum-rich secretions were obtained by following the published recommendations [9]. Natural secretions were obtained by asking the donor to act normally before depositing fingermarks (hand washing was prohibited 30 minutes before the deposition). Depletion series composed of three successive fingermarks were considered for each set of deposition. To assess the impact of an AFP coating, each fingermark was left astride two substrates: uncoated glass (left half) *vs* AFP-coated glass (right half), as illustrated in Figure 2. This approach allows for the comparison of how two substrates differ in behavior as they both bear comparable secretion residue (quantitatively and qualitatively). Finally, the fingermarks were stored at room temperature in the dark, in a way that prevented friction, before being characterized and processed. Two categories of ages were considered: fresh (≤ 1 week) and old (≥ 1 month).

< INSERT FIGURE 2 HERE >

Fingermark detection techniques

Three different fingermark detection techniques were applied: cyanoacrylate fuming (CA), small particle reagent (SPR), and gold/zinc vacuum metal deposition ($VMD_{Au/Zn}$). The techniques were applied as stand-alone processes. CA fuming was performed in an MVC-1000 cabinet (Foster+Freeman) using Lumicyano with 5% dye content (Crime Scene/Science Technology). SPR was based on molybdenum disulphide (MoS_2) and applied by immersion, as recommended the Home Office [10]. $VMD_{Au/Zn}$ was performed in an Edwards Identicoat 500 device. Unless specified, all techniques were applied by following the conventional/providers' recommendations.

Characterization of the AFP coatings

The AFP coatings were characterized for their optical properties (*e.g.*, color, transparency, background luminescence). Luminescence behavior was studied by observing the substrates under an alternate light source (Polilight PL500; Rofin; all excitation wavelengths) combined with different emission filters (green, yellow, orange, and red).

Characterization of the fingermarks

Latent and processed fingermarks were observed using stereomicroscopy (Leica), oblique and grazing light (Polilight PL500; Rofin), coaxial episcopy (Rofin), RUVIS (Arrowhead), and luminescence if applicable (Polilight PL500; Rofin). RUVIS observations were conducted using a 254 nm excitation source (Spectroline ENF-260). Observation in luminescence was conducted on CA-processed fingermarks only, considering both Lumicyano excitation domains: 300-400 nm (excitation) without observation filter, and 505 nm (excitation) combined with a 565 nm interferential observation filter. Each taken picture (half-mark) was characterized by a score based on ridge detail clarity, using the UK Home Office CAST scale (Table 2) [9]. Given that each of the ca. 430 fingermarks (864 half-marks) was observed before (latent) and after being processed with a detection technique, using different observation methods, a total of ca. 4,000 pictures were taken and rated. At the end of the scoring procedure, each half mark is consequently associated with different scores, one per observation method used when latent and then processed.

To provide a quick way to assess if an AFP coating had impacted the observation of fingermarks or the application of detection techniques, an original score was introduced: the *Impact Value*. This score is computed for each fingermark (considering both halves: uncoated and coated) by subtracting the clarity score associated to the uncoated half (glass, reference) from the clarity score associated to the coated half (AFP):

$$\text{Impact Value} = \text{Score}_{AFP} - \text{Score}_{glass}$$

By subtracting quality scores between both sides of a split mark, the so-defined *Impact Value* is meant to provide information about how AFP coating can promote the detection of ridge details (positive *Impact Value*; maximum value of +4), can be detrimental to the observation of ridge details (negative *Impact Value*; minimum value of -4), or has no apparent effect (null *Impact Value*). Even if they are actually calculated from clarity scores associated with half-marks, the *Impact Value* does not provide information about the intrinsic quality of the observed ridge patterns anymore.

< INSERT TABLE 2 HERE >

Results

Characterization of the anti-fingerprint (AFP) coatings

Using white light, seven out of the eight AFP treatments were transparent and colorless. These coatings were consequently visually undistinguishable from uncoated glass. The only exception was the *Anti-*

fingerprint Film from BrightonNET (AFP/F2) which appeared yellowish and translucent. When excited under UV, most AFP coatings presented background luminescence, especially the plastic films (Figure 3). Background luminescence under UV results in a loss of contrast for all the detection techniques requiring a UV excitation light source, such as Lumicyano. Fortunately, a second excitation domain is available for this reagent (centered at 515 nm), which minimizes the background issue. The only two exceptions were the liquid solutions (AFP/L1 and /L2), which presented no particular optical behavior under UV (Figure 3).

< INSERT FIGURE 3 HERE >

Characterization of the latent fingermarks

All the half-marks were characterized when they were latent (before the application of a fingermark detection technique). Coaxial episcopy was the most suitable technique to observe latent marks on glass and AFP coatings. The *Impact Values* were consequently computed from the scores associated with this observation technique (Table 3). Overall, eccrine and natural secretions were associated with *Impact Values* close to zero (similar ridge quality on both sides). It should be noted that latent eccrine secretions were hardly visible on both sides, meaning that no or few ridge details were observed (scores and *Impact Values* close to zero). Sebum-rich secretions led to positive *Impact Values* (higher ridge clarity on the AFP-coated side), especially on the glass-based coatings (AFP/Gx). This is mostly noticeable with one-month-old marks, due to the absence of secretion residue diffusion with time on the coated side (Figure 4). *Fusso SmartPhone* from Crystal Armor (AFP/L1) is the only AFP coating leading to noticeable positive *Impact Values* with all three kinds of secretions, mostly due to the good quality of the one-month-old marks. *OK Display Anti-Trace* from CellularLine (AFP/F3) is the only one leading to a noticeable negative *Impact Value* with natural secretions, seemingly due to a reduced residue deposition (Figure 5).

< INSERT TABLE 3 HERE >

< INSERT FIGURES 4 and 5 HERE >

These preliminary observations are relevant from a forensic point of view: (1) AFP coatings do not prevent secretion residue from leaving the fingertips towards the surface, and (2) by preventing the diffusion of sebum-rich secretions with time, they may act to preserve ridge morphology. About the first statement: early observations of secretion residue interaction with various surfaces (including polytetrafluoroethylene – PTFE, also known as Teflon) were reported by Scruton *et al.* in 1975 [11]. In their study, the authors observed that sebum-rich secretions do adhere to PTFE, despite their preliminary thoughts. The authors concluded about the unlikeliness of existence of a surface preventing the deposition of secretion residue from a contact with a fingertip. In other words: it is extremely difficult to prevent secretion residue from leaving a fingertip once a contact is established. The only noticeable effect in favor of lesser material deposition has been observed with *OK Display Anti-Trace* from CellularLine (AFP/F3). Without any detailed information about the composition and the structure of this coating, it is difficult to explain why AFP/F3 succeeds partially in preventing natural secretion deposition. About the second statement: once transferred, the secretion residues are in contact with amphiphobic surfaces (AFP coatings). The combined hydrophobicity and oleophobicity properties may consequently prevent the diffusion of water or sebaceous material towards the inter-ridge area, preserving by the same way the topology of the ridge pattern. A closer look at sebum-rich secretions illustrates well the impact of oleophobicity on the morphology and distribution of the secretion residue components (Figure 4). On a conventional substrate, material diffusion may be observed with time [12, 13], as shown here with uncoated glass. The only AFP treatment that goes against this trend is the liquid solution *DeviceNet Smartphone Coating* (AFP/L2) which is characterized by *Impact Values* close to zero and by secretion residue diffusion with time (Figures 6 and 7). Its efficiency as an AFP treatment could be questioned as it behaves similarly to the reference surface. A possible explanation is found in the product instructions which state that the coating does not prevent the deposition of fingermarks but eases their cleaning. About that: resistance to friction was not assessed in this study and will constitute a logical perspective, for most providers claim that their product offers "easy-to-clean" properties.

< INSERT FIGURES 6 and 7 HERE >

Characterization of the fingermarks after detection

In terms of visualization performance, CA-processed marks were better-visualized using coaxial episcopy and luminescence (exc. 505 nm), SPR using coaxial episcopy, and $VMD_{Au/Zn}$ using oblique observation. The illustrated *Impact Values* were consequently calculated from the scores associated with these observation techniques. Figure 8 provides an overview of the impact of all eight AFP coatings after the application of the detection techniques, considering natural secretions only. The most relevant observation is that AFP coatings did not hinder the application of the detection techniques, with *Impact Values* mostly positive or of limited impact ($-0.5 \leq$ *Impact Value* ≤ 0.5). The only exception is *OK Display Anti-Trace* from CellularLine (AFP/F3) which resulted in negative *Impact Values* with SPR and $VMD_{Au/Zn}$. Finally, as already emphasized during preliminary examinations, detection performance on *DeviceNet Smartphone Coating* (AFP/L2) is indistinguishable between both sides (coated and uncoated), with all the considered detection techniques.

< INSERT FIGURE 8 HERE >

To provide a more specific look at how AFP coatings behave with each kind of secretion residue, the *Impact Values* were charted for eccrine (E), sebum-rich (S), and natural (N) secretions processed with CA (Figures 9 and 10), SPR (Figure 11), and $VMD_{Au/Zn}$ (Figure 12). Eccrine secretions resulted mostly in negative *Impact Values*, meaning that the ridge quality was less on the coated sides after the application of the detection techniques. This is due to the fact that the application of the detection techniques resulted in the detection of the eccrine secretions on glass (mostly by reverse detection) but not on the AFP coatings. No explanation can be provided so far to explain the lack of detection for eccrine secretions left on AFP coatings. Sebum-rich and natural secretions behave quite similarly overall, with *Impact Values* mostly positive or of limited impact ($-0.5 \leq$ *Impact Value* ≤ 0.5). This is not surprising as both these secretions share a lipid-based fraction, which may be preserved from migrating due to the amphiphobic nature of the coatings and constitute hence optimal conditions of development.

< INSERT FIGURES 9 to 12 HERE >

With regards to each detection technique, CA was mostly characterized by an absence of unwanted polymerization on the AFP substrate and in the inter-ridge area, leading to optimum clarity (Figure 13a). The reason for that may be found in the amphiphobic nature of the AFP coatings, which could prevent the coalescence of water droplets [14] and the migration of secretion residue on the AFP substrate, reducing by the same way the risks of unwanted polymerization. The only exception was observed with *Fusso SmartPhone* from Crystal Armor (AFP/L1), for which unwanted CA polymerization on the substrate led to the detection of secretions by reversed detection (Figure 13b). This could indicate a strong affinity of CA monomers for this particular coating. It should also be noted that the main excitation band of Lumicyano (UV range) could not be used optimally, for it led to strong background luminescence from most AFP coatings. This phenomenon was expected as the AFP coatings were optically characterized in the early stages of this study. Since most AFP coatings do luminesce under UV, the resulting contrast is inevitably reduced. It is consequently necessary to switch to the second excitation domain, centered at 515 nm.

The application of SPR on eccrine secretions led to no ridge detection or strong background staining on the AFP coatings (Figure 14a, right halves). *Premium Screen Protection Film* from Mission Ready

(AFP/F1) is the only exception, with good ridge clarity combined with an absence of background staining on the AFP coating. Film-based coatings (AFP/Fx) were characterized by negative *Impact Values*, or close to zero, with both sebum-rich and natural secretions. Conversely, glass-based coatings (AFP/Gx) led to noticeably positive *Impact Values*. Overall, the positive *Impact Values* are due to the absence of background staining on the coated sides (Figure 14b, left mark). On the contratry, *Anti-fingerprint Film* from BrightonNET (AFP/F2) and *OK Display Anti-Trace* from CellularLine (AFP/F3) led to strong and resistant background staining, resulting in noticeable negative *Impact Value* (Figure 14b, right mark). About the ability for SPR to detect secretion residue on the AFP coatings: it could be expected that the amphiphobic properties of the AFP coatings would weaken the residue adhesion to the substrate, resulting in material loss upon application of SPR (aqueous immersion). However, sebum-rich and natural secretions appeared quite undisturbed by the application of SPR. This is confirmed for AFP/L1 and all glass-based coatings (AFP/Gx), with better-defined ridges and less particle agglomeration compared to uncoated glass. In fact, most *Impact Values* were close to zero (performance equivalent to glass) or influenced by the presence/absence of background staining on the AFP coatings.

Observations similar to SPR can be found for $VMD_{Au/Zn}$: detrimental impact of AFP coatings on the detection of eccrine secretions, *Impact Values* superior or close to zero for sebum-rich and natural secretions, and beneficial impact of glass-based AFP coatings (AFP/Gx) compared to film-based ones (AFP/Fx) with regards to fingermark detection (Figure 14c). Similarly to SPR, *OK Display Anti-Trace* from CellularLine (AFP/F3) is characterized by a noticeable negative *Impact Value* for natural secretions, most likely due to the lesser quantity of material deposited on the coated side. A positive impact linked to AFP coatings has been observed with $VMD_{Au/Zn}$, in particular regarding empty marks. This phenomenon is often encountered with fresh and secretion-rich marks, for which the migration of material seems to prevent the deposition of zinc in the inter-ridge area [15]. In the case of AFP coatings, the amphiphobic nature of the substrate seems to prevent such migration, reducing the risk of empty marks.

< INSERT FIGURES 13 and 14 HERE >

Discussion

This study constitutes the first among the fingerprint community to study the behavior and influence of anti-fingerprint (AFP) coatings applied to fingermark detection. The scope of the research was to provide practitioners with preliminary results regarding how these coatings could positively or negatively affect a conventional fingermark detection procedure (from the optical characterization of the substrate to the observation of processed fingermarks). Eight AFP coatings were consequently considered, covering the three main kinds of products that can be purchased (*i.e.*, liquid, plastic film, and covering glass). With regards to the methodology, it may seem that the choice for only one donor is an unfortunate one, especially when referring to the International Fingerprint Research Group (IFRG) guidelines [8], which recommend to use several ones (from 3 to more than 20). However, the decision of considering one average donor in this study was made on purpose, with regards to the research plan and scope – which were not focused on the assessment of the performance of (new or optimized) detection techniques but rather on bringing preliminary information regarding the behavior of AFP coatings in a forensic context. The research effort was consequently focused on the optical characterization of AFP coatings, on their impact on the deposition of fingermarks and their observation when latent, and how they may hinder the application of conventional detection techniques. Regarding these aspects, most of the information gained from this study is independent from the number of donors. The key parameters in this context were consequently the number of AFP coatings, the different observation techniques, and the use of split marks which allowed for comparison of the behavior of AFP coatings and glass when comparable secretions (*i.e.*, both half marks) were exposed to the same conditions. To try assessing how AFP coatings may behave with regards to the composition of secretion residue, three kinds of secretion residues (i.e., eccrine, sebum-rich and natural ones) were considered. Finally, the introduction of an *Impact Value*, based on the clarity of the ridge details, aimed at obtaining a way to assess major influences that AFP coatings may have compared to glass. The aim was to determine if an AFP coating presented a noticeable effect or not (in that case, further studies including several donors would be required). Finally, if the observation of latent fingermarks on AFP coatings may seem surprising, it must however be recalled that these coatings are developed for casual use, using naked eyes but not forensic light sources or advanced optical techniques. Preliminary examination of latent marks through optical means (*e.g.*, coaxial episcopy or RUVIS) is consequently highly recommended.

Conclusion

This preliminary study aimed at assessing the impact of anti-fingerprint (AFP) coatings on a typical fingermark detection procedure. More specifically, it aimed at providing practitioners answers to the following three questions: "Do anti-fingerprint surface coatings prevent the deposition of secretion residue?", "Do anti-fingerprint surface coatings impact the optical observation of latent fingermarks?", and "Do anti-fingerprint surface coatings impact the application of common fingermark detection techniques?". It constitutes the first study on this topic among the fingerprint community.

Results showed that AFP coatings do not prevent the deposition of secretion residue on the coated surface, nor hinder the application of conventional detection techniques (*i.e.*, cyanoacrylate fuming, vacuum metal deposition, and small particle reagent). AFP coatings seem to offer favorable conditions for the detection and observation of natural and sebum-rich secretion residue. *OK Display Anti-Trace* from CellularLine (AFP/F3) was the only one characterized by a noticeable decrease of material upon deposition. The surface properties of AFP coatings (*i.e.*, hydrophobicity and oleophobicity) seem to prevent the migration of material with time, especially sebum-rich and natural secretions, preserving by the same way ridge detail sharpness. With regards to the detection techniques, cyanoacrylate fuming was shown to be the least impacted by most AFP coatings, especially due to the absence of unwanted polymerization on the background and in the inter-ridge area. The resistance to friction of fingermarks left on AFP-coated substrates will constitute a logical follow-up of this study.

References

1. Champod C.; C. Lennard; P. Margot; M. Stoilovic. *Fingerprints and Other Ridge Skin Impressions - Second Edition*; Boca Raton, Florida: CRC Press LLC. 2016; 427.

2. Belhadjamor M.; M. El Mansori; S. Belghith; S. Mezlini. Anti-fingerprint properties of engineering surfaces: a review. *Surface Engineering* **2016**, 1-32.

3. Milionis A.; I.S. Bayer; E. Loth. Recent advances in oil-repellent surfaces. *International Materials Reviews* **2016**, *61* (2), 101-126.

4. Feng L.; S. Li; Y. Li; H. Li; L. Zhang; J. Zhai; Y. Song; B. Liu; L. Jiang; D. Zhu. Super-Hydrophobic Surfaces: From Natural to Artificial. *Advanced Materials* **2002**, *14* (24), 1857-1860.

5. Wu L.Y.L.; S.K. Ngian; Z. Chen; D.T.T. Xuan. Quantitative test method for evaluation of anti-fingerprint property of coated surfaces. *Applied Surface Science* **2011**, *257* (7), 2965-2969.

6. Bhushan B.; P. Muthiah. Anti-smudge screening apparatus for electronic touch screens. *Microsystem Technologies* **2013**, *19* (8), 1261-1263.

7. Belhadjamor M.; S. Belghith; S. Mezlini; M. El Mansori. Effect of the surface texturing scale on the self-clean function: Correlation between mechanical response and wetting behavior. *Tribology International* **2017**, *111*, 91-99.

8. International Fingerprint Research Group (IFRG). Guidelines for the Assessment of Fingermark Detection Techniques. *Journal of Forensic Identification* **2014**, *64* (2), 174-200.

9. Sears V.G.; S.M. Bleay; H.L. Bandey; V.J. Bowman. A Methodology for Finger Mark Research. *Science & Justice* **2012**, *52*, 145-160.

10. Home Office - Centre for Applied Science and Technology (CAST). Fingermark Visualization Manual, Bandey H., Editor. 2014.

11. Scruton B.; B.W. Robins; B.H. Blott. The Deposition of Fingerprint Films. *Journal of Physics D: Applied Physics* **1975**, *8*, 714-723.

12. Popov K.T.; V.G. Sears; B.J. Jones. Migration of latent fingermarks on non-porous surfaces: Observation technique and nanoscale variations. *Forensic Science International* **2017**, *275*, 44-56.

13. Dorakumbura B.N.; T. Becker; S.W. Lewis. Nanomechanical mapping of latent fingermarks: A preliminary investigation into the changes in surface interactions and topography over time. *Forensic Science International* **2016**, *267*, 16-24.

14. Paine M.; H.L. Bandey; S.M. Bleay; H. Willson. The Effect of Relative Humidity on the Effectiveness of the Cyanoacrylate Fuming Process for Fingermark Development and on the Microstructure of the Developed Marks. *Forensic Science International* **2011**, *212*, 130-142.

15. Jones N.; D. Mansour; M. Stoilovic; C. Lennard; C. Roux. The influence of polymer type, print donor and age on the quality of fingerprints developed on plastic substrates using vacuum metal deposition. *Forensic Science International* **2001**, *124* (2-3), 167-177.

Figure 1


CRYSTAL ARMOR
Fusso
SmartPhone™
Fusso SmartPhone™
日本製
MADE IN JAPAN
cellularline
Ok Display Anti-Trace
Anti-fingerprints protective film
Pellicola protettiva anti-impronte
Samsung Galaxy S5 - S5 Neo
ECO FUSED
S4/i9500
10:15
PREMIUM TEMPERED GLASS
SCREEN PROTECTOR
Tempered
Anti Fingerprint
Anti Scratch
Real Glass

Figure 2

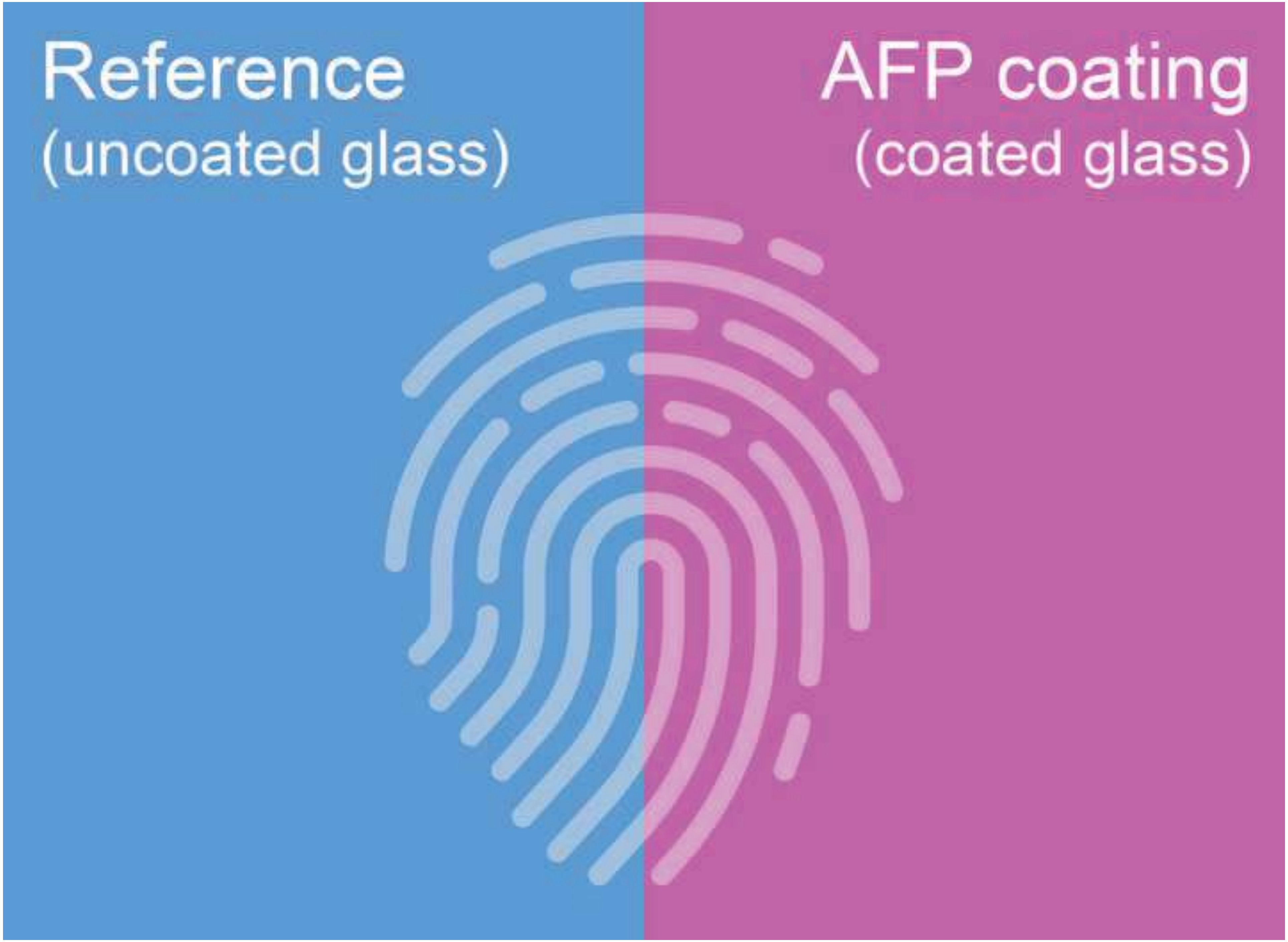


Figure 3

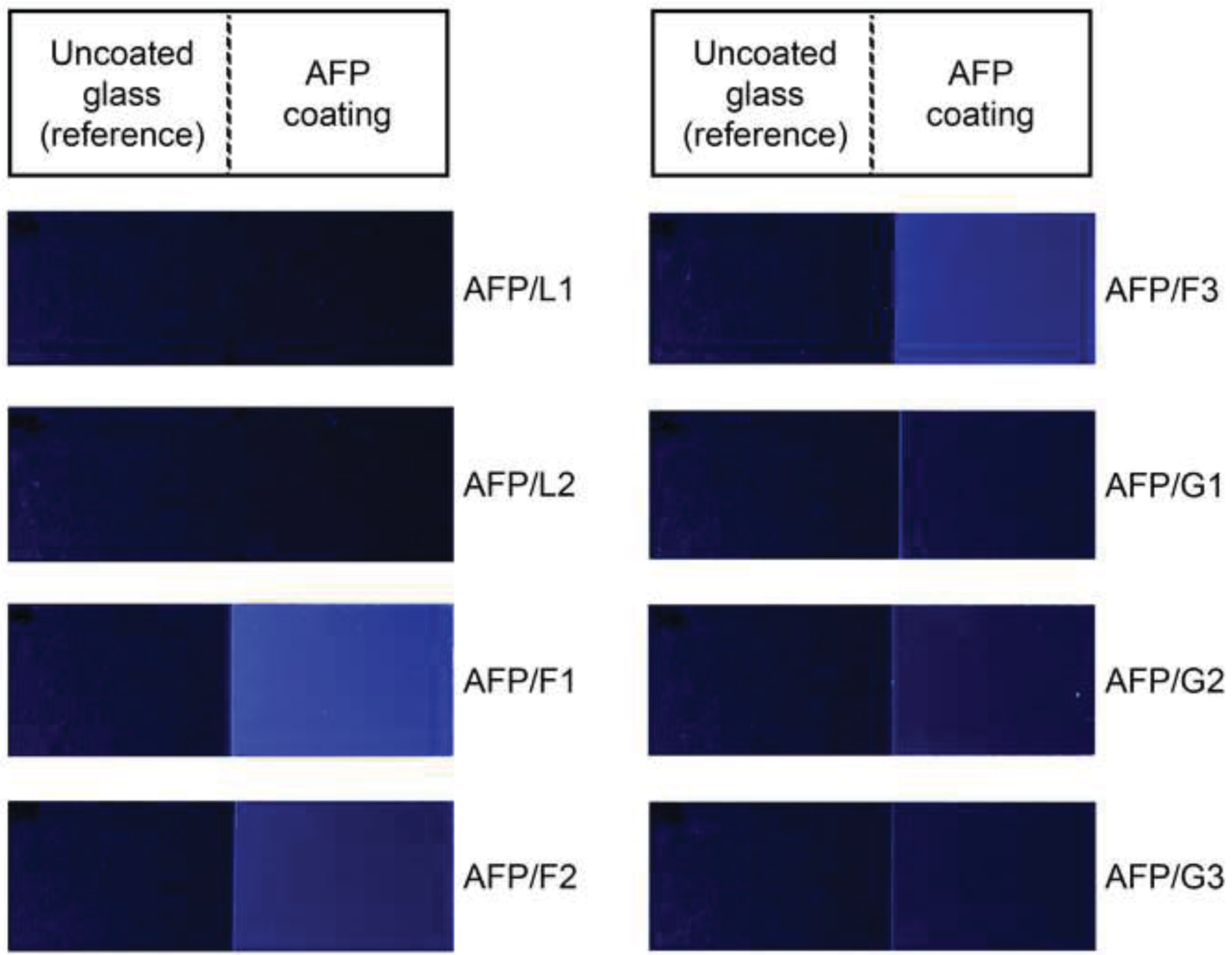

Uncoated glass (reference)
AFP coating
AFP/L1
AFP/L2
AFP/F1
AFP/F2
Uncoated glass (reference)
AFP coating
AFP/F3
AFP/G1
AFP/G2
AFP/G3

Figure 4

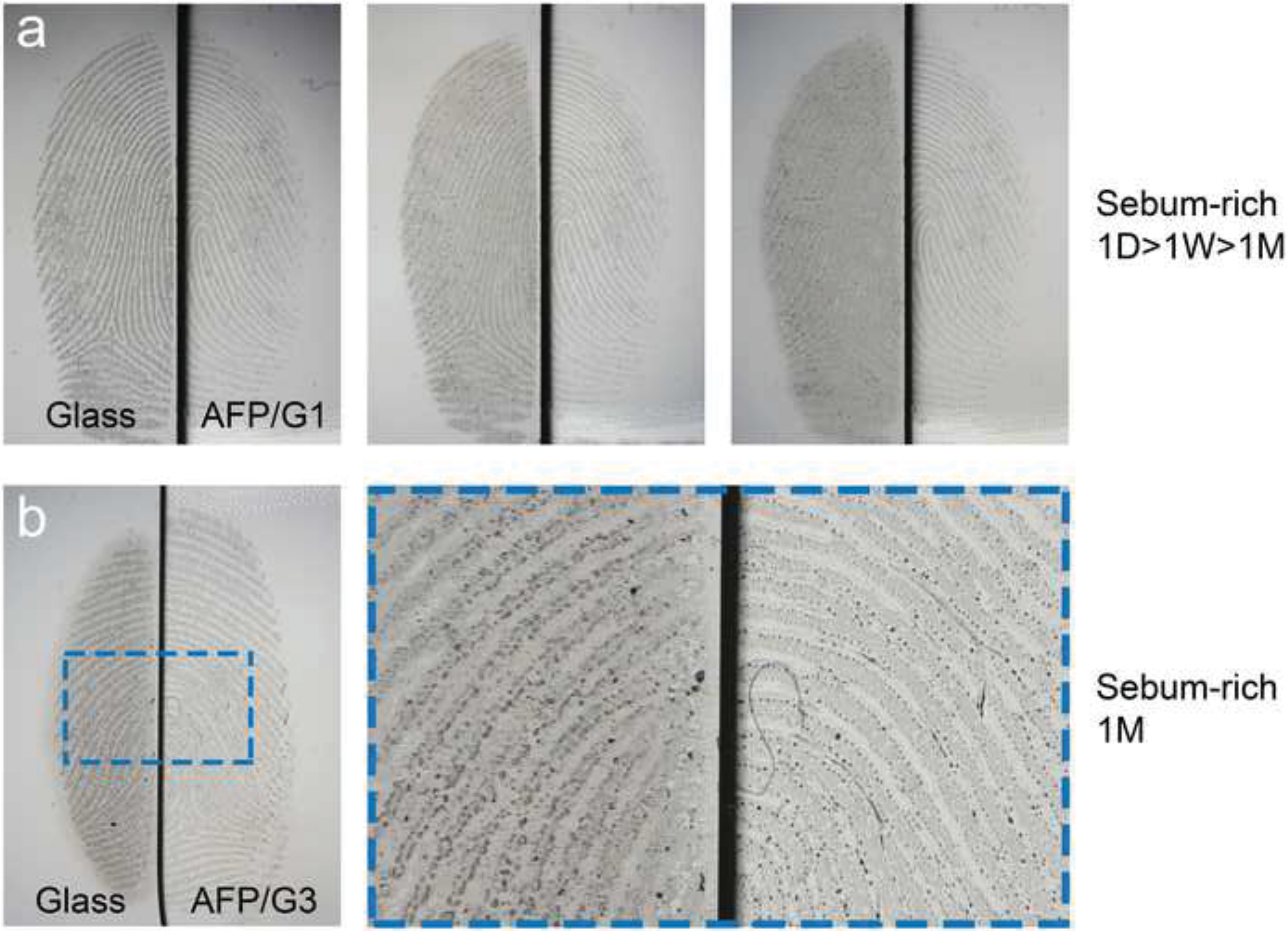
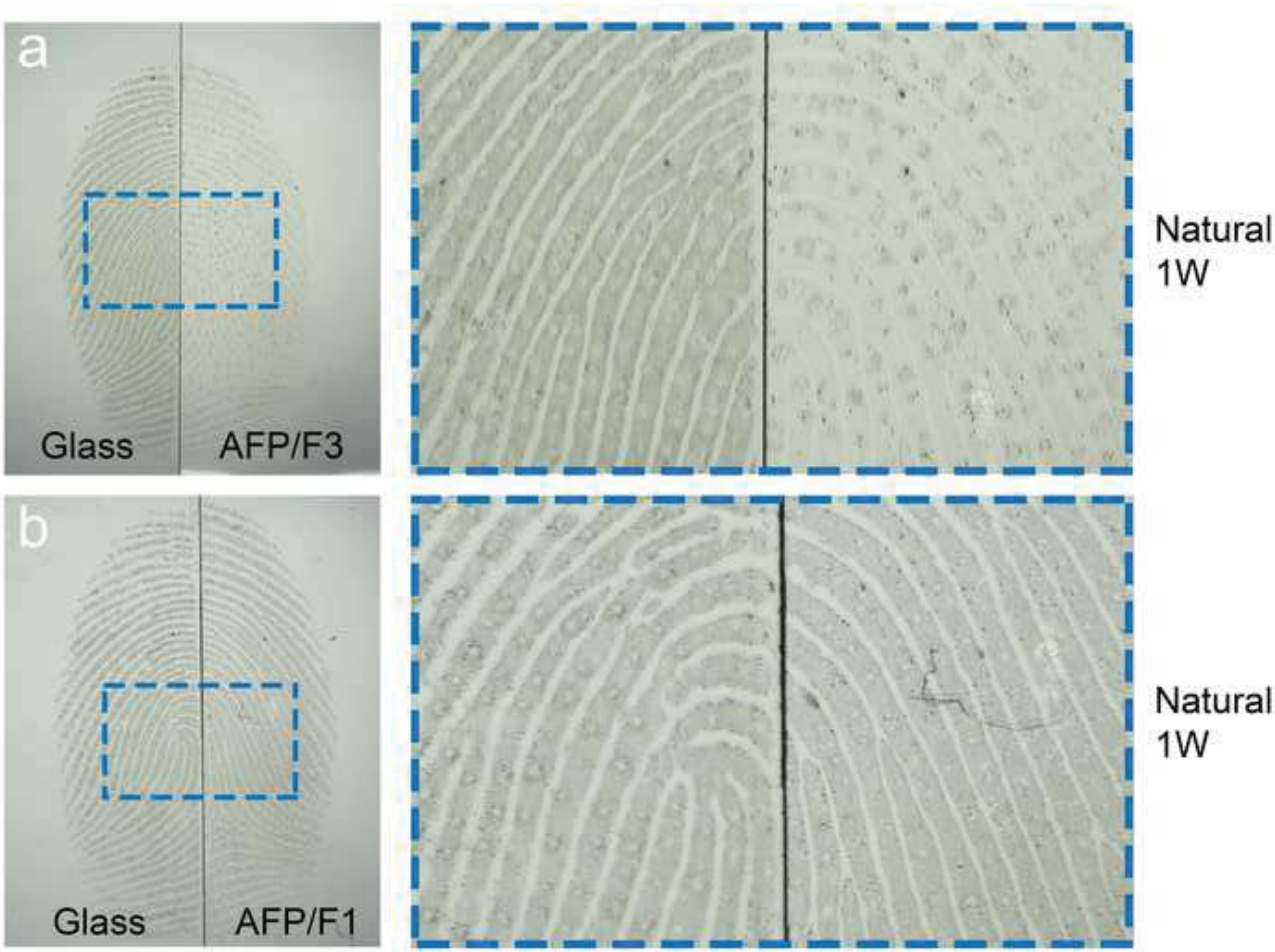
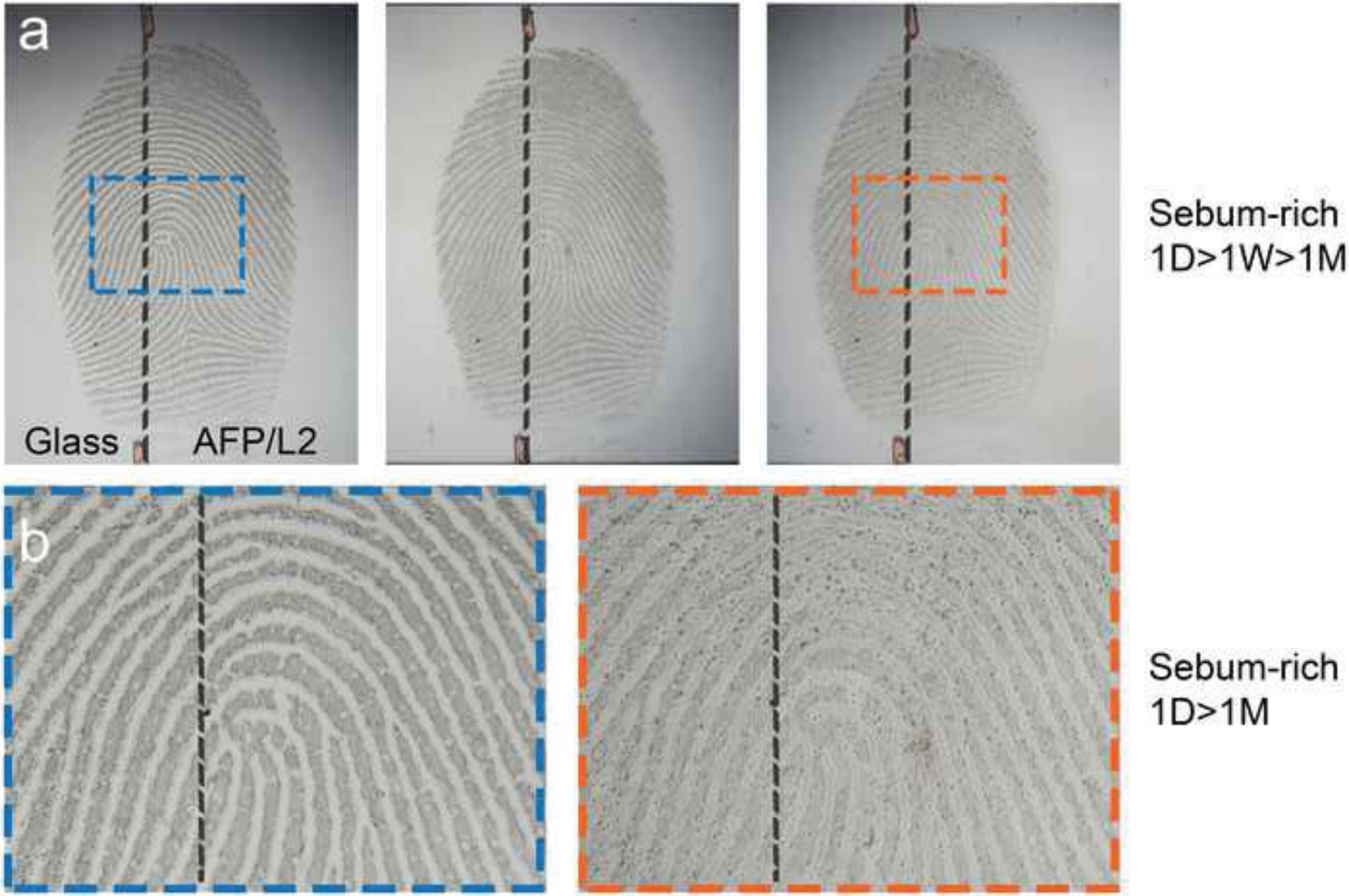


Figure 5




a
Glass
AFP/L2
b
Sebum-rich
1D>1W>1M
Sebum-rich
1D>1M

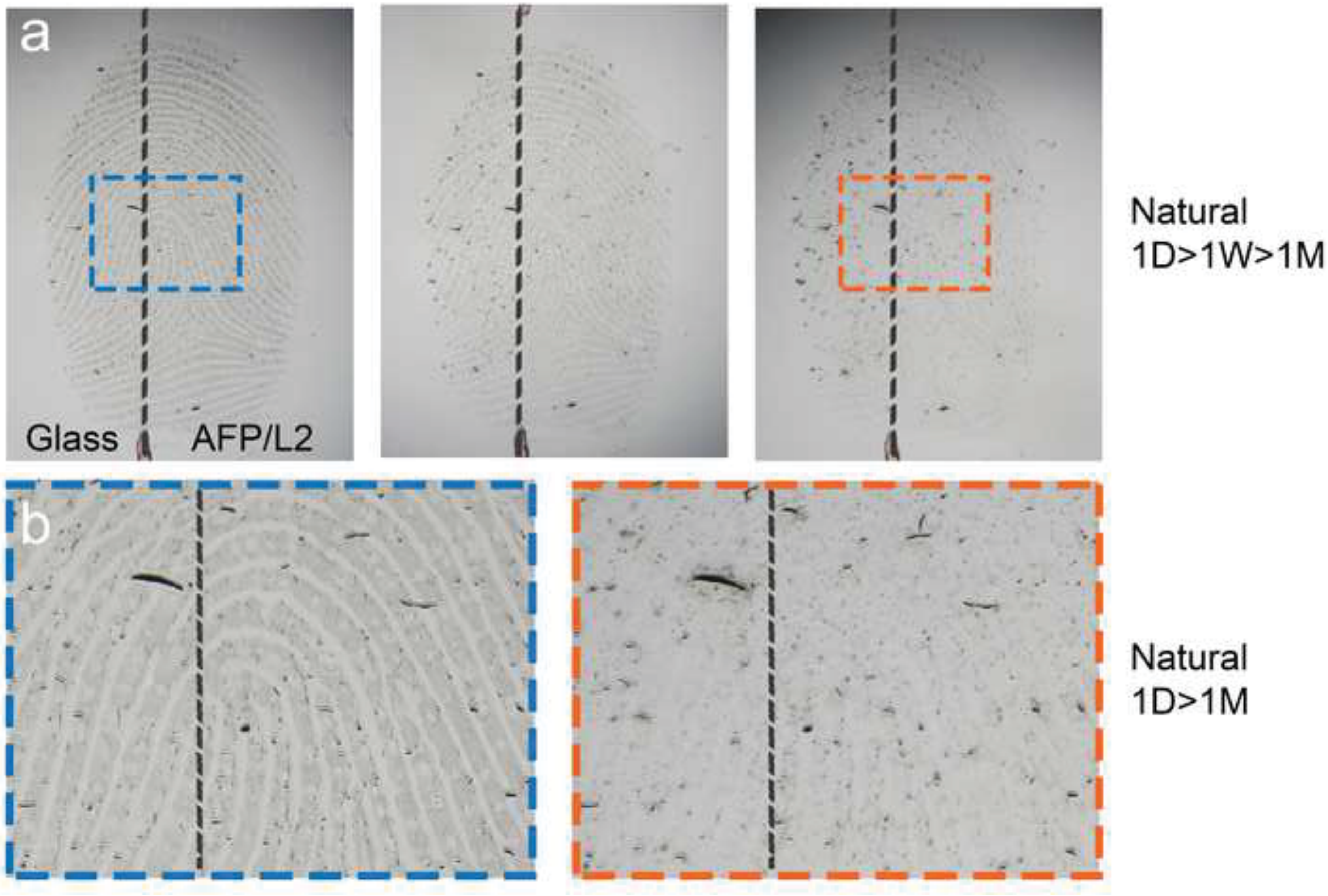

a
Glass
AFP/L2
b
Natural
1D>1W>1M
Natural
1D>1M

Figure 8

Click here to download Figure Figure 8.jpg

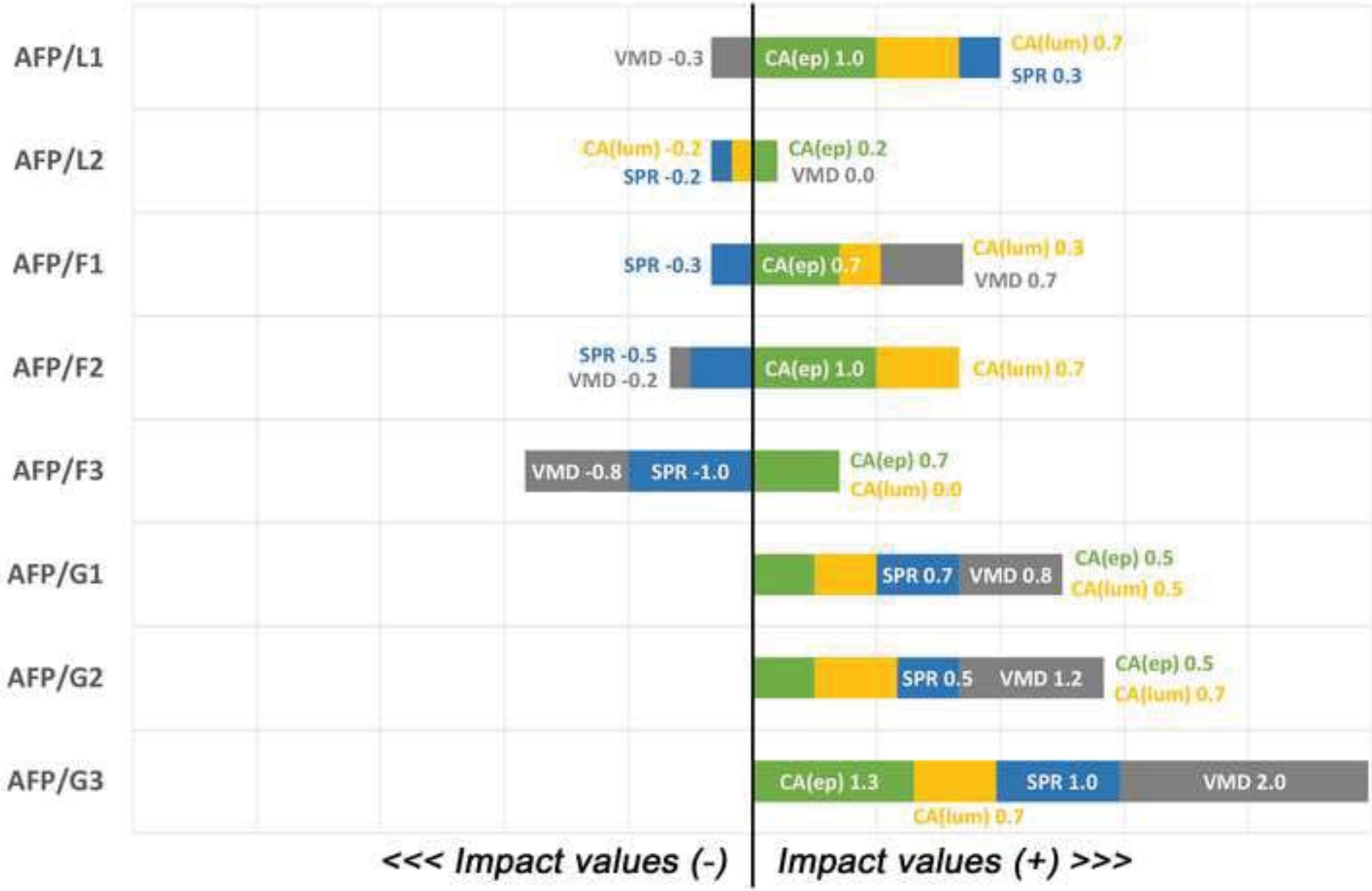
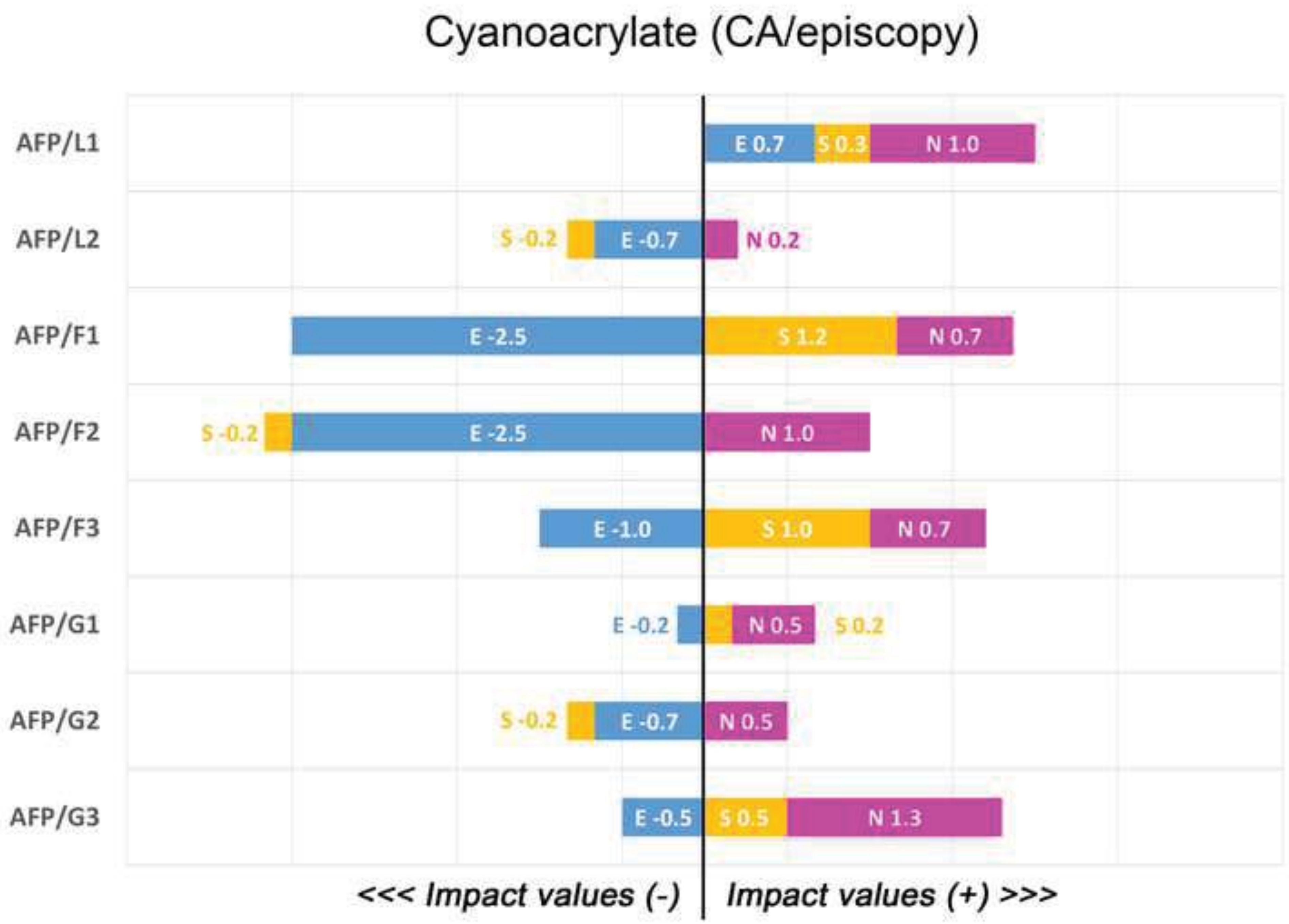
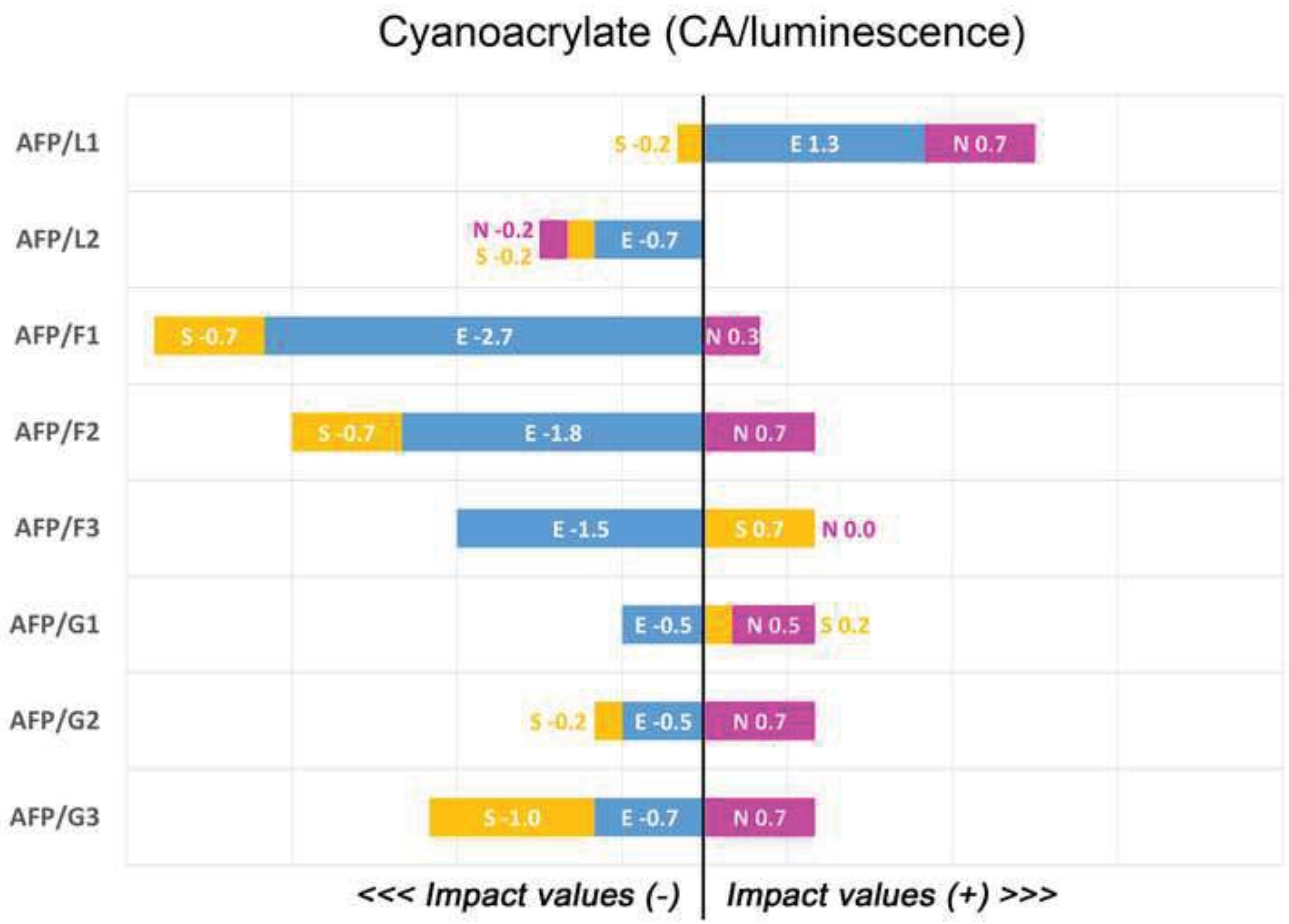


Figure 9

Click here to download Figure Figure 9.jpg




Cyanoacrylate (CA/luminescence)
AFP/L1
S -0.2
E 1.3
N 0.7
AFP/L2
N -0.2
S -0.2
E -0.7
AFP/F1
S -0.7
E -2.7
N 0.3
AFP/F2
S -0.7
E -1.8
N 0.7
AFP/F3
E -1.5
S 0.7
N 0.0
AFP/G1
E -0.5
N 0.5
S 0.2
AFP/G2
S -0.2
E -0.5
N 0.7
AFP/G3
S -1.0
E -0.7
N 0.7
<<< Impact values (-)
Impact values (+) >>>

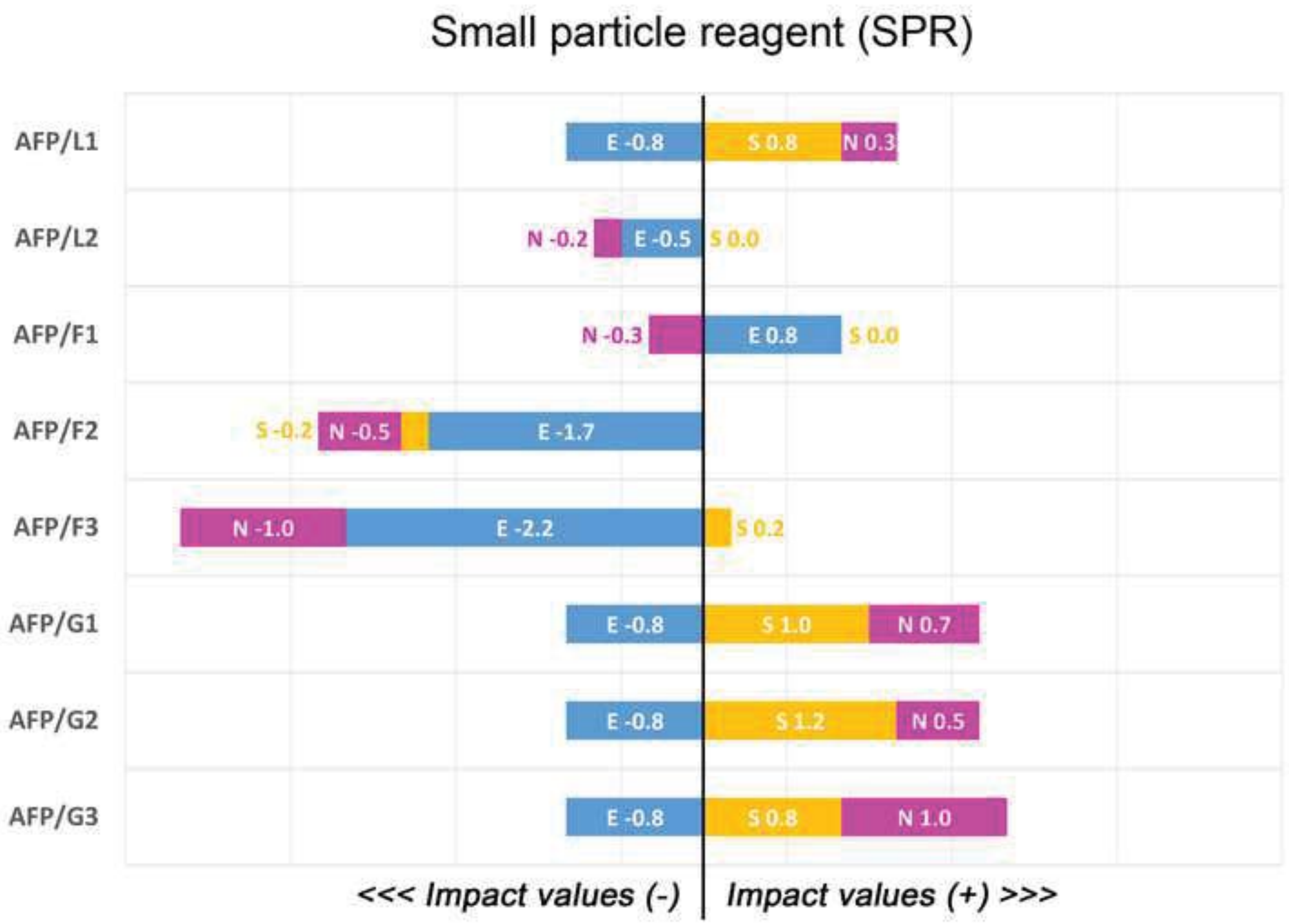

Small particle reagent (SPR)
AFP/L1
E -0.8
S 0.8
N 0.3
AFP/L2
N -0.2
E -0.5
S 0.0
AFP/F1
N -0.3
E 0.8
S 0.0
AFP/F2
S -0.2
N -0.5
E -1.7
AFP/F3
N -1.0
E -2.2
S 0.2
AFP/G1
E -0.8
S 1.0
N 0.7
AFP/G2
E -0.8
S 1.2
N 0.5
AFP/G3
E -0.8
S 0.8
N 1.0
<<< Impact values (-)
Impact values (+) >>>

Figure 12

Click here to download Figure Figure 12.jpg

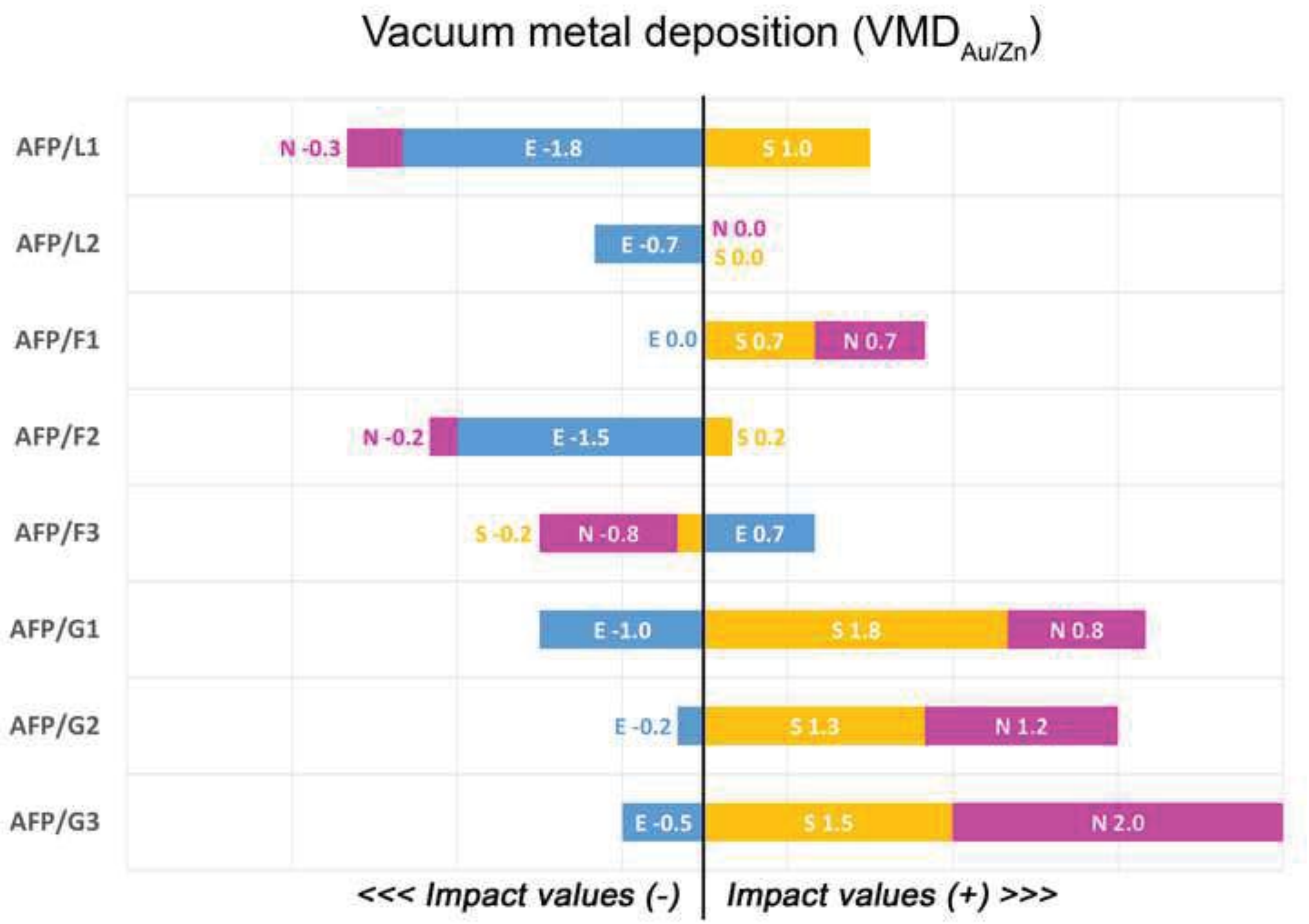
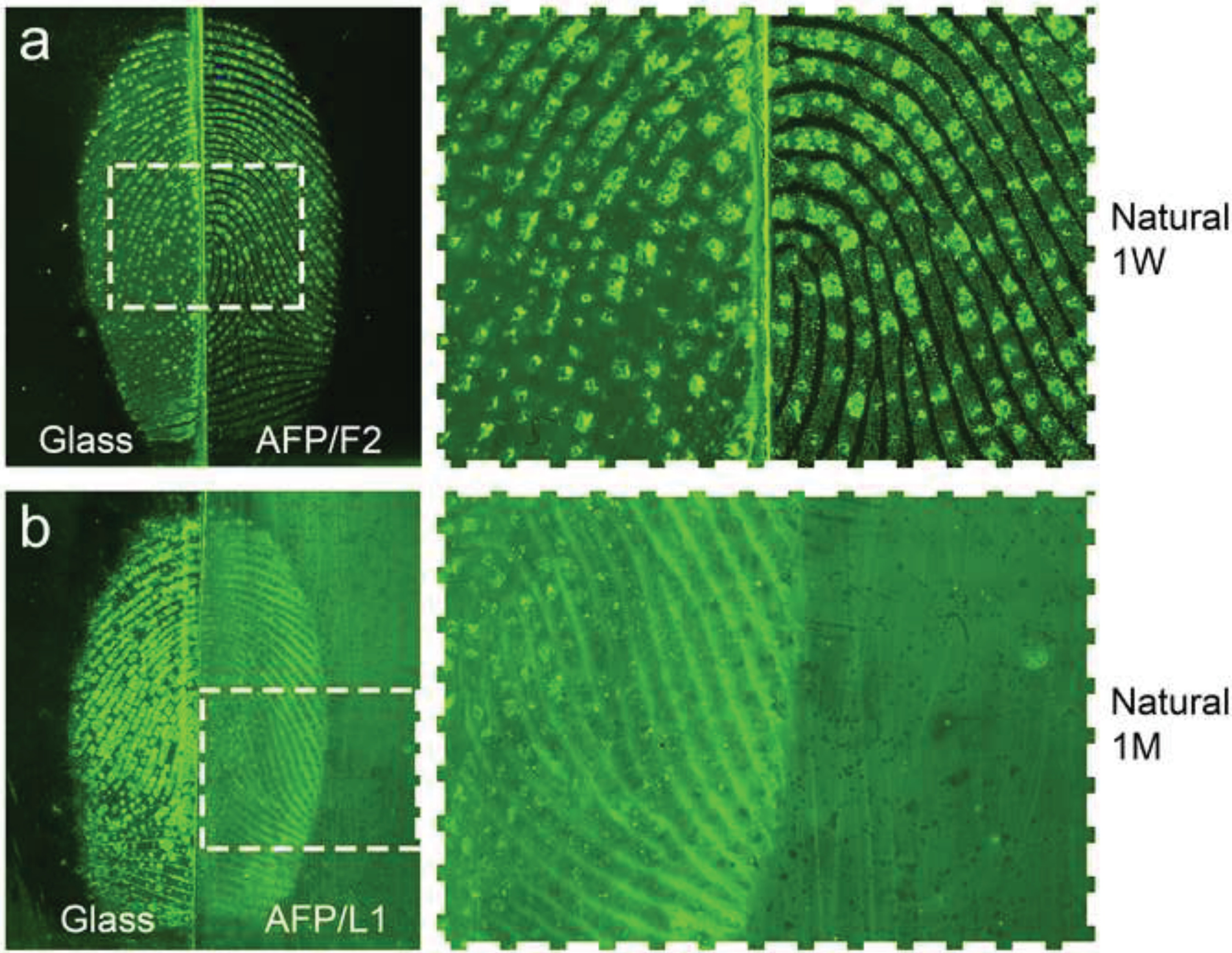


Figure 13



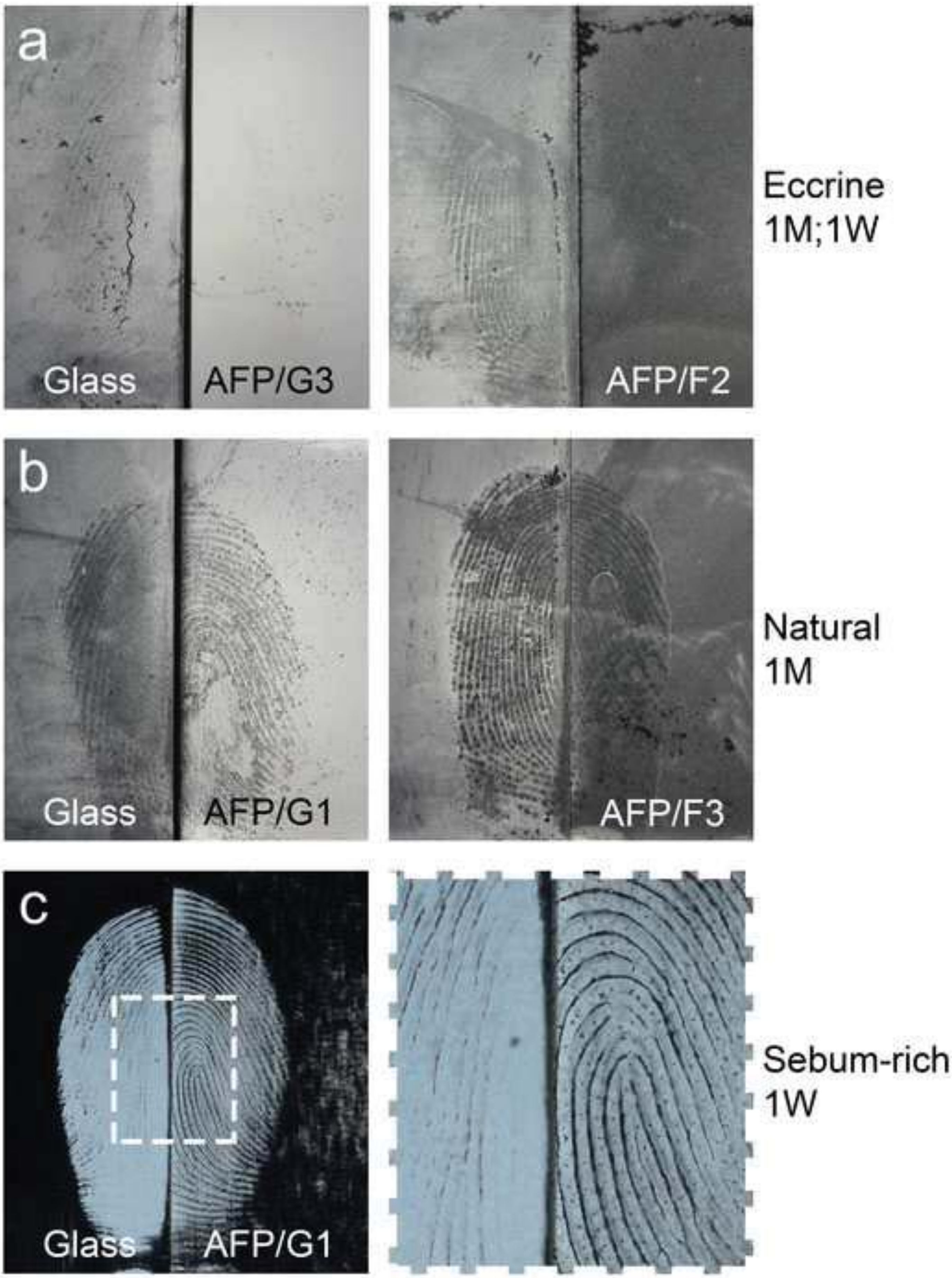

a
Glass
AFP/G3
AFP/F2
Eccrine
1M;1W
b
Glass
AFP/G1
AFP/F3
Natural
1M
c
Glass
AFP/G1
Sebum-rich
1W

Table 1

Product name (provider)	Form	Abbreviation
Fusso SmartPhone (Crystal Armor)	Liquid	AFP/L1
DeviceNet Smartphone Coating (DN-SC02BK/B)	Liquid	AFP/L2
Premium Screen Protection Film (Mission Ready)	Plastic film	AFP/F1
Anti-fingerprint Film (BrightonNET)	Plastic film	AFP/F2
OK Display Anti-Trace (CellularLine)	Plastic film	AFP/F3
Premium Tempered Glass – Mobilephone Screen Protector (PThink)	Glass	AFP/G1
Premium Tempered Glass – Screen Protector (Eco Fused)	Glass	AFP/G2
Second Glass (CellularLine)	Glass	AFP/G3

Table 2

Score	Ridge detail
0	No mark visible
1	No ridge detail, but indication of contact
2	Clear ridge details over one third of the mark
3	Clear ridge details over two thirds of the mark
4	Clear ridge details all over the mark, excellent quality

Table 3

		Averaged *Impact* values (latent marks)		
	Secretions >	**Eccrine (E)**	**Sebum-rich (S)**	**Natural (N)**
AFP coatings	**AFP/L1**	1.1 ± 0.8	0.8 ± 0.8	0.6 ± 0.7
	AFP/L2	0.1 ± 0.2	0.3 ± 0.5	-0.1 ± 0.2
	AFP/F1	0.1 ± 0.7	0.2 ± 0.4	-0.1 ± 0.4
	AFP/F2	-0.4 ± 0.6	0.4 ± 0.6	-0.2 ± 0.6
	AFP/F3	0.0 ± 0.0	-0.1 ± 0.6	-0.8 ± 0.5
	AFP/G1	-0.1 ± 0.2	0.5 ± 0.5	0.0 ± 0.0
	AFP/G2	-0.2 ± 0.5	0.9 ± 0.6	0.1 ± 0.2
	AFP/G3	0.2 ± 0.7	0.8 ± 0.7	0.1 ± 0.3

Figure captions

Figure 1 – Illustration of three categories of AFP coatings that were considered in this study: liquids (*e.g.*, *Fusso Smartphone* from Crystal Armor – AFP/L1), plastic films (*e.g.*, *OK Display Anti-Trace* from CellularLine – AFP/F3), and glasses (*e.g., Premium Tempered Glass - Screen Protector* from Eco Fused – AFP/G2).

Figure 2 – Schematic representation of the way fingermarks were left in this study: astride uncoated glass (reference) and AFP-coated glass. Note: fingermark icon made by Freepik from www.flaticon.com.

Figure 3 – Optical behavior of AFP coatings exposed to ultraviolet wavelengths (no observation filter). In each case, left halves correspond to uncoated glass (reference) and right halves to the AFP coatings.

Figure 4 – (a) Evolution with time (1 day → 1 week → 1 month) of a sebum-rich fingermark left on uncoated glass (left half; reference) and AFP/G1 (right half); (b) Overall and detailed views of a one-month-old sebum-rich fingermark left on uncoated glass (left half; reference) and AFP/G3 (right half). The observation technique is coaxial episcopy in both cases.

Figure 5 – One-week-old latent natural secretions left on AFP/F3 (a) and AFP/F1 (b), then observed using coaxial episcopy. In each case, left halves correspond to uncoated glass (reference) and right halves to the AFP coatings.

Figure 6 – (a) Evolution with time (1 day → 1 week → 1 month) of a sebum-rich fingermark left on uncoated glass (left half; reference) and AFP/L2 (right half); (b) Detailed views obtained from the above illustrations: one-day-old (left) and one-month-old (right). The observation technique is coaxial episcopy in both cases.

Figure 7 – (a) Evolution with time (1 day → 1 week → 1 month) of a natural fingermark left on uncoated glass (left half; reference) and AFP/L2 (right half); (b) Detailed views obtained from the above illustrations: one-day-old (left) and one-month-old (right). The observation technique is coaxial episcopy in both cases.

Figure 8 – Representation of the averaged *Impact Values* obtained after having processed fingermarks (natural secretions) with either cyanoacrylate fuming (CA; green and yellow), small particle reagent (SPR; blue), or vacuum metal deposition (VMD; dark grey). *Impact Values* were computed from the following observation modes: coaxial episcopy (green) and luminescence (exc. 505 nm; yellow) for CA, coaxial episcopy for SPR, and oblique observation for VMD. A positive (/negative) *Impact Value* means that ridge clarity is higher (/lower) on the AFP-coated half compared to glass (reference). A null *Impact Value* means that ridge clarity is similar on both sides. Details about AFP coating labels can be found in Table 1.

Figure 9 – Representation of the impact of AFP coatings on cyanoacrylate fuming (CA; Lumicyano 5%), applied to eccrine (E; blue), sebum-rich (S; orange) and natural (N; purple) secretions. The *Impact Values* were calculated from the clarity scores obtained with coaxial episcopy as the observation mode. Same additional remarks as for Figure 8.

Figure 10 – Representation of the impact of AFP coatings on cyanoacrylate fuming (CA; Lumicyano 5%), applied to eccrine (E; blue), sebum-rich (S; orange) and natural (N; purple) secretions. The *Impact Values* were calculated from the clarity scores obtained under luminescence (exc. 505 nm). Same additional remarks as for Figure 8.

Figure 11 – Representation of the impact of AFP coatings on small particle reagent (SPR), applied to eccrine (E; blue), sebum-rich (S; orange) and natural (N; purple) secretions. The *Impact Values* were calculated from the clarity scores obtained with coaxial episcopy as the observation mode. Same additional remarks as for Figure 8.

Figure 12 – Representation of the impact of AFP coatings on vacuum metal deposition ($VMD_{Au/Zn}$), applied to eccrine (E; blue), sebum-rich (S; orange) and natural (N; purple) secretions. The *Impact Values* were calculated from the clarity scores obtained with oblique light. Same additional remarks as for Figure 8.

Figure 13 – (a) Overall and detailed views of a one-week-old natural fingermark processed with CA and observed under luminescence (excitation: 505 nm). The mark was left astride uncoated glass (left half, reference) and AFP/F2 (right half). (b) Overall and detailed views of a one-month-old natural fingermark processed with CA and observed under luminescence (excitation: 505 nm). The mark was left astride uncoated glass (left half, reference) and AFP/L1 (right half). Details about AFP coating labels can be found in Table 1.

Figure 14 – Illustrations of fingermarks processed with SPR (a and b; observation: coaxial episcopy) and $VMD_{Au/Zn}$ (c; observation: oblique light). (a-left) One-month-old eccrine secretions left astride glass and AFP/G3, (a-right) one-week-old eccrine secretions left astride glass and AFP/F2, (b) one-month-old natural secretions left astride glass and AFP/G1 (b-left) or AFP/F3 (b-right), (c) overall and detailed views of one-week-old sebum-rich secretions left astride glass and AFP/G1. Details about AFP coating labels can be found in Table 1.

Table captions

Table 1 – Details regarding the commercially available anti-fingerprint coatings used in this study.

Table 2 – UK Home Office CAST scale used to characterize each half-fingermark by a quality score based on ridge clarity.

Table 3 – Averaged *Impact Values* and standard deviations obtained from the characterization of latent marks (not yet processed with a fingermark detection technique), for the three kinds of secretions and for all AFP coatings, using coaxial episcopy as the observation technique. Cells are colored in green or in red if the average value is greater than +0.5 or lower than -0.5, respectively.