International Journal on Science and Technology (IJSAT)

E-ISSN: 2229-7677 ● Website: www.ijsat.org ● Email: editor@ijsat.org

Studies on Spectral, Absorbance and Transmittance Properties of Indian Automobile Paint Samples using UV-Vis Microspectrometer and its Forensic Significance

Mahantappa Limbitot[1], Chandarshekhara[2], Venkatesh G N[3], Sunagar Manjunath Gulappa[4]

[1, 2, 3, 4]Regional Forensic Science Laboratory, Hubballi, Karnataka, India

Corresponding author: Dr. Mahantappa Limbitot

Abstract

Paint samples are considered as most crucial types of trace evidence come across hit-and-run and vehicular accident cases. Particularly in establishing links between suspected vehicles and crime scenes, the forensic analysis and comparison of such paint samples play a vital role. The present work focuses on the spectral (S), absorbance (A), and transmittance (T) characteristic analysis of paint samples using a UV-vis microspectrometer instrument. The spectral characteristics of the paint samples were carried out in the wavelength range of 380–800nm to assess their optical properties. The absorbance spectra of the paint sample described distinct peaks responsible for the presence of particular pigments and binder materials. APF-4 displays the highest initial absorbance at approximately 0.56% at 400 nm, which gradually decreases toward the higher wavelengths, suggesting a high concentration of pigments absorbing in the blue region of the spectrum. Simultaneously, the transmittance characteristic of the samples illustrated variation across different paint types, which can aid in distinguishing similar-looking paints of different origins. . APF-3 exhibits the highest transmittance overall, reaching values exceeding 120% at wavelengths above 600 nm. The findings highlight the usefulness of UV-vis microspectroscopy as a non-destructive, rapid, and reliable technique for characterizing automobile paint samples.

Keywords: Automobile Paint Flakes, Spectral Characteristics, Absorbance, Transmittance, MSP, *Microspectroscopy*

1. Introduction:

One of the most important types of trace evidence that is frequently found in criminal investigations, particularly in hit-and-run and auto accident cases, is paint evidence [1]. Automotive paint offers a high degree of distinctiveness because of its multilayered structure and intricate chemical makeup, which makes it an invaluable instrument in forensic science for trace evidence identification and comparison [2–3]. Tiny pieces of paint may transfer to the affected surface when cars collide with people, objects, or other cars, providing vital evidence for connecting suspects, cars, and crime scenes [4].

Out of all the analytical methods that are accessible, UV-visible (UV-vis) microspectroscopy has become well-known as a potent, non-destructive instrument for analyzing paint samples [5–6]. Precise spectral analysis is made possible by this method, which yields data on the optical characteristics, transmittance, and absorbance of paint layers—information crucial for forensic comparison, color differentiation, and pigment identification [7]. Specifically, the transmittance and absorbance properties in the visible and ultraviolet spectrums can highlight minute variations in paint composition that are otherwise hard to pick up on by eye alone [8].

Using UV-vis microspectrometry, the current study attempts to evaluate the forensic importance of Indian car paint samples by analyzing their spectrum, absorbance, and transmittance characteristics. In addition to making it easier to characterize car paints scientifically, this method helps build trustworthy techniques for forensic comparison and source attribution in criminal investigations.

2. Materials and method:

2.1 Collection of samples:

In the present study, total ten paint flakes of vehicles such as Hyundai cars, Maruthi, Ashok Leyland and Force including trucks and buses, were collected. The registration number, model number, name, and paint collecting points of the individual automobile were recorded for references. The different paint samples were further marked as follows for further reference.

Table No-01: Markings of paint flakes with automobile details

Sample code	Vehicle model	Color of the paint	Vehicle name	Sample code	Vehicle model	Color of the paint	Vehicle name
APF1	2021	White	Hero Destine 125 vx (se)	APF6	2018	White	Maruthi Swift Dzire
APF2	2015	White	Chevrolet Cruze LTZ	APF7	2014	Grey	Chevrolet Enjoy
APF3	2005	Silver Color	Hyundai Elantra	APF8	2020	White	Force Traveller
APF4	2016	Cream Color	Tata Ace Facelift Ht BS III	APF9	2018	Red	Ashok leyland ltd,
APF5	2020	Red	Maruthi Swift	APF10	2018	Green	Ashok leyland ltd

2.2 Experimental techniques:

2.2.1 Microspectrometry:

Microspectrometry is an advanced analytical technique that integrates optical microscopy with spectroscopic methods (such as Raman, infrared, or UV-Vis spectroscopy) for high-resolution chemical and structural analysis at the microscopic level. It is widely used in forensic science, materials research, and life sciences. The spectral characteristics, absorbance, transmittance as function of wavelength (nm) of all the paint samples were analysed.

3. Result and discussion:

3.1 Spectral analysis of paint samples:

The figure-1 represents the spectral characteristics automobile paint sample in the wavelength range of 400 to 800 nm. The spectral analysis of the samples from APF-1 to APF-5 shows shown in figure-1(a). In this set of analysis, the APF-3 sample describe highest intensity at 612 nm peak with 13,969 counts suggesting dense pigment or high reflectivity, possibly due to metallic or inorganic pigment components such as iron oxides or titanium dioxide [3]. In contrast, APF-4 sample indicating lower spectral intensity, suggesting a less pigment load or altered binder composition. Similarly, APF-5 paint sample having peak at wavelength 628 nm, reflects a pigment system with higher wavelength reflective properties, often associated with red-shifted colorants or metallic flakes designed to enhance appearance and durability [9].

The spectral analysis of the samples from APF-6 to APF-10 shows shown in figure-1(b).In this set of analysis reveals even more pronounced spectral diversity. The APF-6 paint sample exhibits a peak at wavelength 500nm with an intensity of 14,242 counts suggesting the shortest wavelength among all samples and a strong reflective response in the blue-green region. Conversely, APF-7 representing attenuated intensity with peak at 580 nm with only 3,317 counts suggesting low pigment load and high translucency. The APF-8 sample exhibits the highest intensity among all samples with peak at 596 nm suggesting highly pigmented, optically reflective coating layer. The spectral profiles of APF-9 and APF-10 with peak positions at 628 nm and 596 nm respectively, indicating variation in the pigment employed across the paint samples [10].

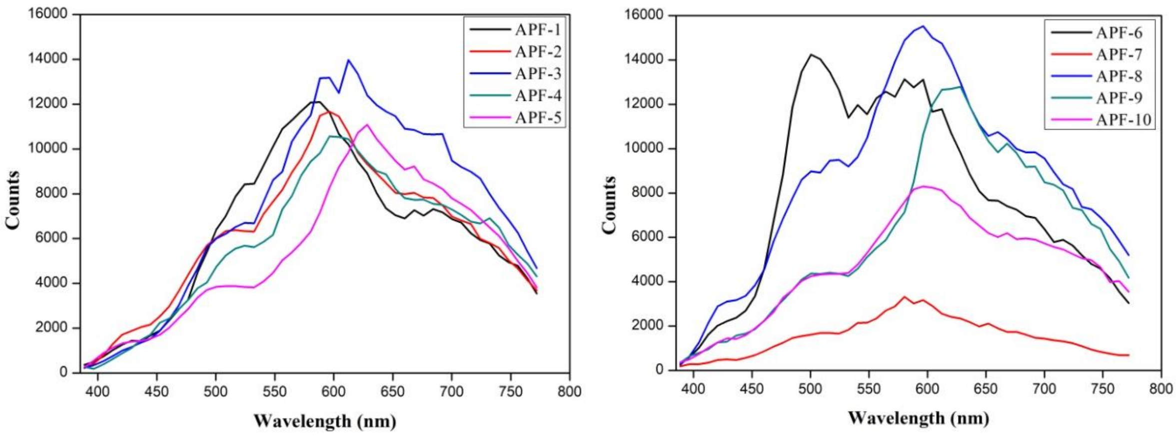

Figure-1: Spectral characteristics of paint samples

The differences wavelength of the peak from 500 nm (APF-6) to 628 nm (APF-5, APF-9) represents the variation in the pigment load, such variation is indicative of presence of iron oxides, titanium dioxide, and organic colorants often used in automobile paints samples [1,4]. The APF-3, APF-6, and APF-8 with higher intensity values, suggesting either a more pigment load or enhanced reflectivity [5, 8]. The APF-7 with low intensity may due to the less pigment concentration or the presence of a translucent coating layer [10].

3.2 Absorbance Characteristics of Paint Samples Using UV-Vis Microspectrometry:

The figure-2 represents the absorbance characteristics automobile paint sample in the wavelength range of 400 to 800 nm. The absorbance analysis of the samples from APF-1 to APF-5 shows shown in figure-

2(a). In this group of samples, the values of absorbance decreasing with increasing in wavelength. The absorbance of the sample APF-4 is about 0.56% at 400nm found to be initial highest and, which gradually decreases toward the higher wavelengths, indicating a absorption of high pigments in the blue region of the spectrum. Similarly, for APF-5 paint samples exhibits an initial absorbance of about 0.35% at 400 nm, preserving higher absorbance across the other samples, suggesting existence of high pigments load. The APF-3 shows the lowest absorbance among all the compared samples with 0.15% at 400 nm initially and which decreasing higher wavelengths. The other samples, APF-1 and APF-2, representing intermediate absorbance with peak at around 0.3% in the lower wavelength region which decreasing higher wavelengths [11].

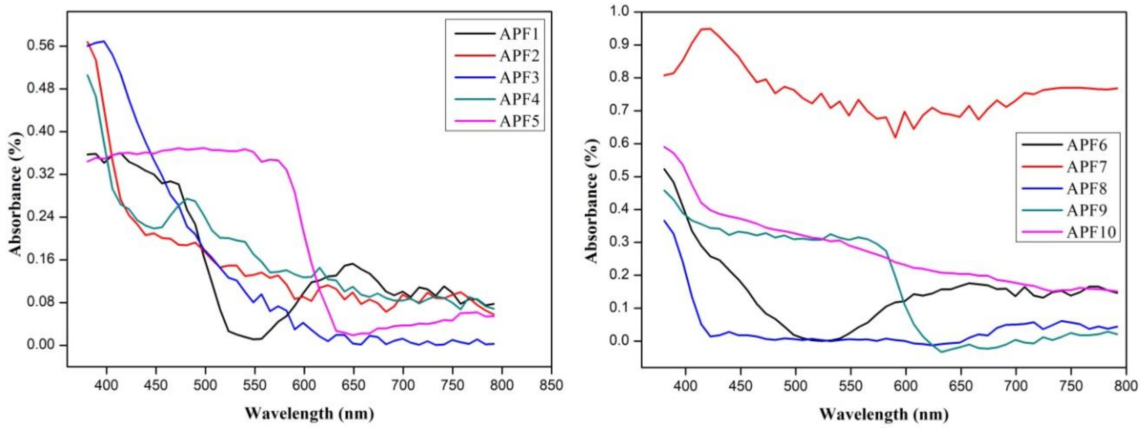

Figure 2. UV-visible absorbance spectra of Indian automobile paint samples (APF-1 to APF-10) showing variations in absorbance (%) as a function of wavelength (nm) across the visible region

The absorbance analysis of the samples from APF-6 to APF-10 shows shown in figure-2(b).In this set of samples exhibiting even higher spectral diversity. APF-7 exhibits high absorbance value among all the samples reaching nearly 0.9% at 400 nm and maintaining relatively higher absorbance levels which usually suggesting presence of high pigment. In contrast, APF-8 describe lower absorbance values initially from 0.2% at 400 nm and which is decreasing suggesting lower pigment load concentration or more translucent layers. The show intermediate behavior was observed for absorbance profiles of APF-6, APF-9, and APF-10 with peak values ranging between 0.25% and 0.5% at 400 nm and which is decreasing toward higher wavelengths. Such variations in absorbance magnitude and spectral slope are primarily attributed to differences in pigment type, layer composition, and surface properties, all of which are critical parameters for distinguishing between visually similar paint samples in forensic casework [3,6, 12].

3.3 Transmittance Characteristics of Paint Samples Using UV-Vis Microspectrometry:

The figure-3 represents the transmittance characteristics automobile paint sample in the wavelength range of 400 to 800 nm. The transmittance analysis of the samples from APF-1 to APF-5 shows shown in figure-3(a). In this set of samples, the values of transmittance exhibiting distinct trends with increasing wavelength. The higher transmittance was found to be for APF-3 sample at wavelengths 600 nm, suggesting presence of less pigment load or more transparent coating sample, such as clear coats or binders, that enables light transmission [3]. Similarly, the consistent up in the value of transmittance was observed for APF-4 samples, peaking near 96% beyond 600 nm. The intermediate transmittance values was observed for APF-1 and APF-2 paint sample ranging between 70% and 90% in the higher

International Journal on Science and Technology (IJSAT)
E-ISSN: 2229-7677 ● Website: www.ijsat.org ● Email: editor@ijsat.org

wavelength region which describes typical pigment concentrations and semi-transparent optical behavior. In contrast, the less transmittance values found for APF-5 samples peaking at approximately 84% around 650 nm, which may due to the more pigment density. All of these samples showed a progressive rise in transmittance with wavelength, which is consistent with how automotive paints should behave as pigments primarily absorb in the lower visible range while transmitting more effectively at higher wavelengths [13-15].
The transmittance analysis of the samples from APF-6 to APF-10 shows shown in figure-3(b). In this group of samples showing higher variation in the values of transmittance characteristics. The APF-6 sample having transmittance peak reaching nearly 160% around 500 nm and which decreases at higher wavelengths. The moderate transmittance were observed APF-8 and APF-9 profiles between 80% and 100% across most of the spectrum, suggesting reflecting the presence of semi-transparent layers. Due to the higher pigment density, the gradually increasing transmittance from 40% to 60% were observed for APF-10 samples. Due to the high pigmented or opaque coating sample, the APF-7 presents the lowest transmittance among all samples [6,7].

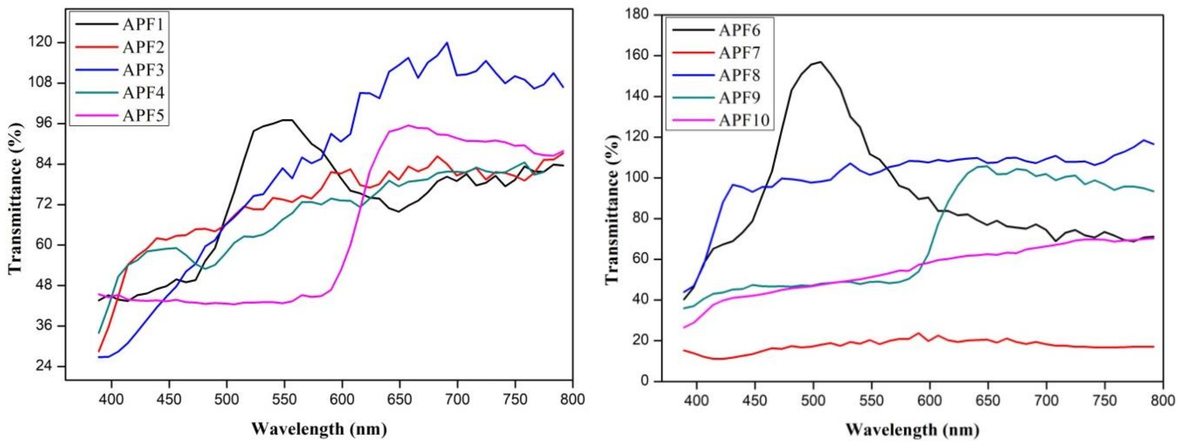

Figure 3. UV-visible transmittance spectra of Indian automobile paint samples (APF-1 to APF-10) showing the percentage transmittance as a function of wavelength (nm) in the visible region.

4. Conclusion:

The present study demonstrates the potential of UV-visible microspectrometry for the comprehensive characterization of Indian automobile paint samples through spectral, absorbance, and transmittance analysis. The observed variations in spectral peak positions, absorbance intensities, and transmittance profiles clearly reflect the compositional diversity of the analyzed samples, attributed to differences in pigment type, concentration, and multilayer coating structures. The UV-vis microspectrometric analysis revealed significant variations in spectral peaks (500–628 nm), absorbance values (0.15%–0.9% at 400 nm), and transmittance levels (40%–160%), highlighting its forensic utility in distinguishing automobile paint samples. The spectral peaks ranging from 500 nm to 628 nm and corresponding variations in absorbance and transmittance profiles provide crucial forensic markers for distinguishing visually similar paint samples of different origins. Notably, the absorbance and transmittance trends across samples, particularly those exhibiting higher pigment loads or semi-transparent coatings, underline the sensitivity of the technique in detecting subtle compositional differences. The results highlight the high discriminative potential of UV-Vis microspectrometry, offering a non-destructive, reliable, and sensitive approach for distinguishing visually similar paint samples. Such detailed optical profiling is of significant forensic relevance, particularly for the comparison and identification of trace paint evidence recovered from crime scenes or vehicular accidents. Overall, the findings of this study reinforce the forensic utility of UV-visible microspectrometry as a valuable tool in the scientific examination and source attribution of automotive paint evidence.

5. References:

[1]. Caddy, B. (Ed.). (2001). *Forensic Examination of Glass and Paint: Analysis and Interpretation*. CRC Press.

[2]. Suzuki, E. M. (2012). Forensic analysis of automotive paint: Scientific approaches and challenges. *Analytical and Bioanalytical Chemistry*, 402(5), 1741–1754. https://doi.org/10.1007/s00216-011-5605-8.

[3]. Vickerman, J. C., & Gilmore, I. S. (2011). *Surface Analysis: The Principal Techniques* (2nd ed.). John Wiley & Sons.

[4]. Zieba-Palus, J., & Trzcinska, B. (2000). Examination of paint evidence in hit-and-run accidents. *Forensic Science International*, 108(2), 121–130. https://doi.org/10.1016/S0379-0738(99)00161-6

[5]. Buzzini, P., & Massonnet, G. (2010). The use of microspectrophotometry for the forensic analysis of textile fibers. *Spectroscopy*, 25(2), 26–33.

[6]. Grieve, M., & Robertson, J. (1999). An assessment of the UV-visible microspectrophotometer for the forensic examination of dyed textile fibers. *Journal of Forensic Sciences*, 44(6), 1197–1202. https://doi.org/10.1520/JFS14601J

[7]. Helmus, R., et al. (2011). The application of UV-visible microspectrophotometry in the forensic analysis of colored materials. *Forensic Science Review*, 23(2), 123–136.

[8]. Roux, C., et al. (2001). The detection of differences in similar paint samples using UV-visible microspectrophotometry. *Journal of Forensic Sciences*, 46(4), 820–826. https://doi.org/10.1520/JFS15091J.

[9]. Buzzini, P., & Massonnet, G. (2010). The use of microspectrophotometry for the forensic analysis of textile fibers. *Spectroscopy*, 25(2), 26–33.

[10]. Grieve, M., & Robertson, J. (1999). An assessment of the UV-visible microspectrophotometer for the forensic examination of dyed textile fibers. *Journal of Forensic Sciences*, 44(6), 1197–1202. https://doi.org/10.1520/JFS14601J.

[11]. S. L. Morgan, B. S. Frye, "Analysis of Automotive Paints by UV-Visible Spectrophotometry," *Journal of Forensic Sciences*, 48(2), 2003, pp. 265-272. DOI:10.1520/JFS2002213.

[12]. Ropret, P., & Centeno, S. A. (2018). Identification of pigments and paint layers in cultural heritage using UV-Vis and Raman microspectroscopy. Microchemical Journal, 137, 352–362. https://doi.org/10.1016/j.microc.2017.11.011

[13]. D. J. Tobin, "UV-Visible Spectrophotometry in Forensic Paint Analysis," Forensic Science Review, 17(2), 2005, pp. 107-123.

[14]. R. S. Khandekar, "Automotive Coatings: Fundamentals and Applications," Progress in Organic Coatings, 52(3), 2005, pp. 296-310. DOI:10.1016/j.porgcoat.2004.07.004.

[15]. M. P. Seubert, "Characterization of Clearcoats and Basecoats in Automotive Paint Systems Using Spectroscopic Techniques," Journal of Coatings Technology and Research, 9(2), 2012, pp. 169-178. DOI:10.1007/s11998-011-9360-2.