

On the characterization and differentiation of clearcoats in automotive paint using UV-Visible microspectrophotometry, FTIR spectroscopy, and Raman spectroscopy

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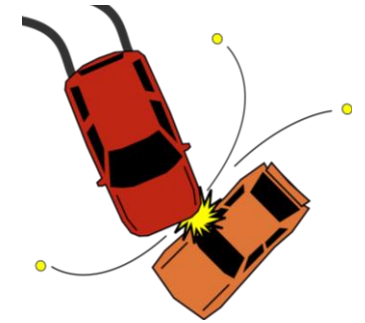
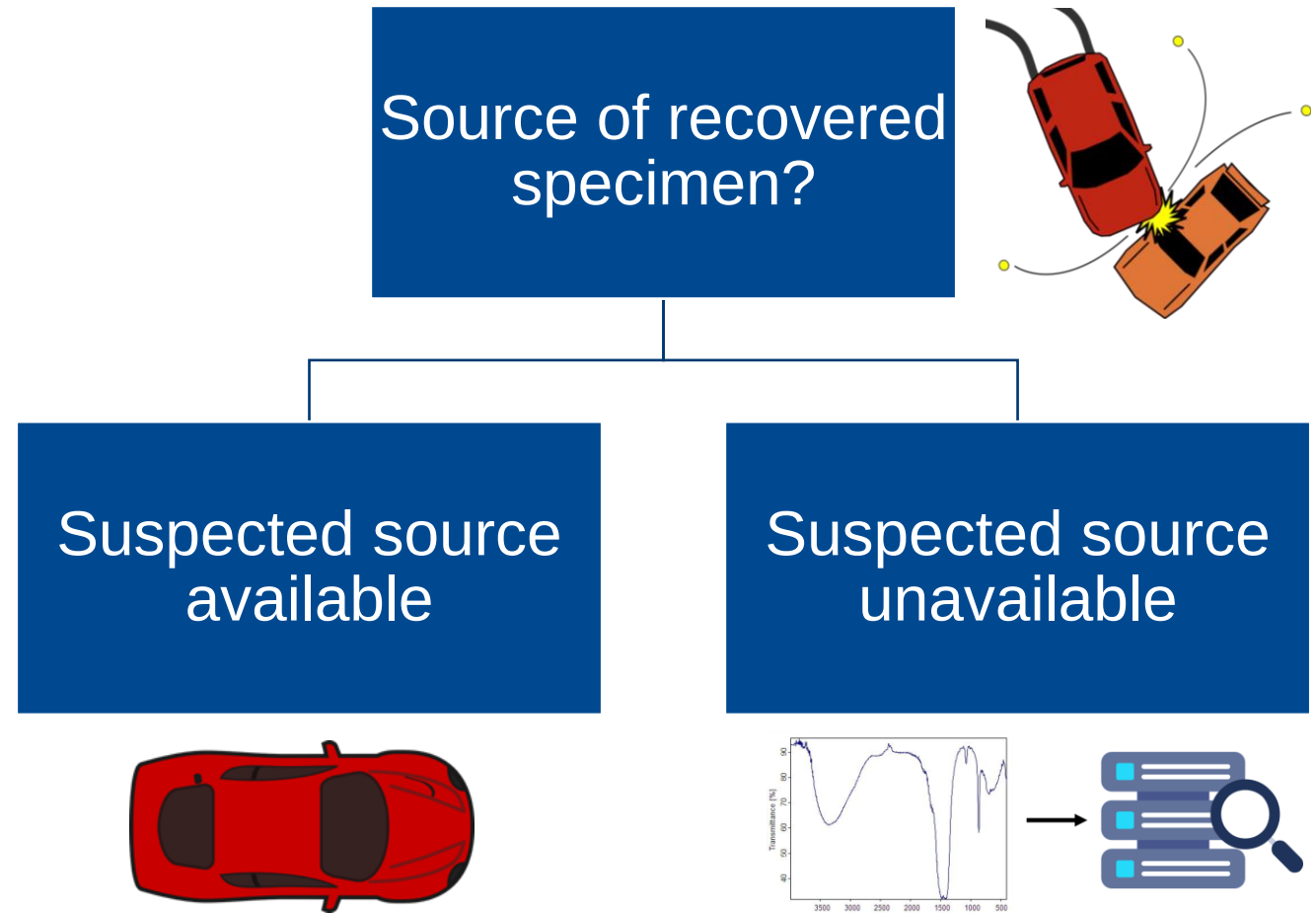
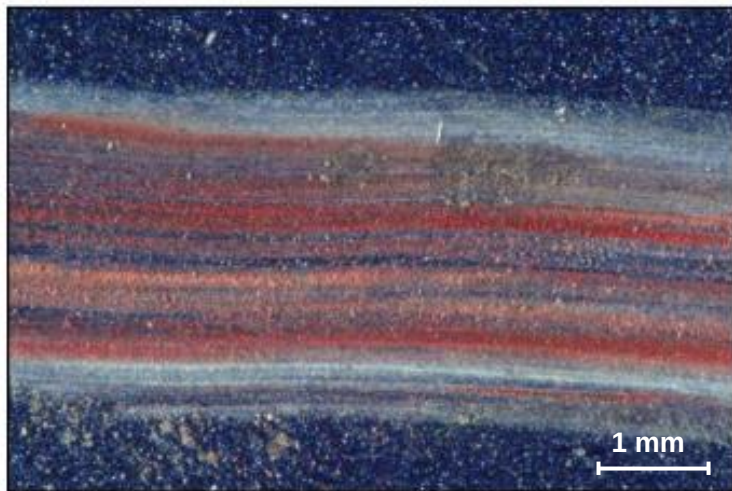


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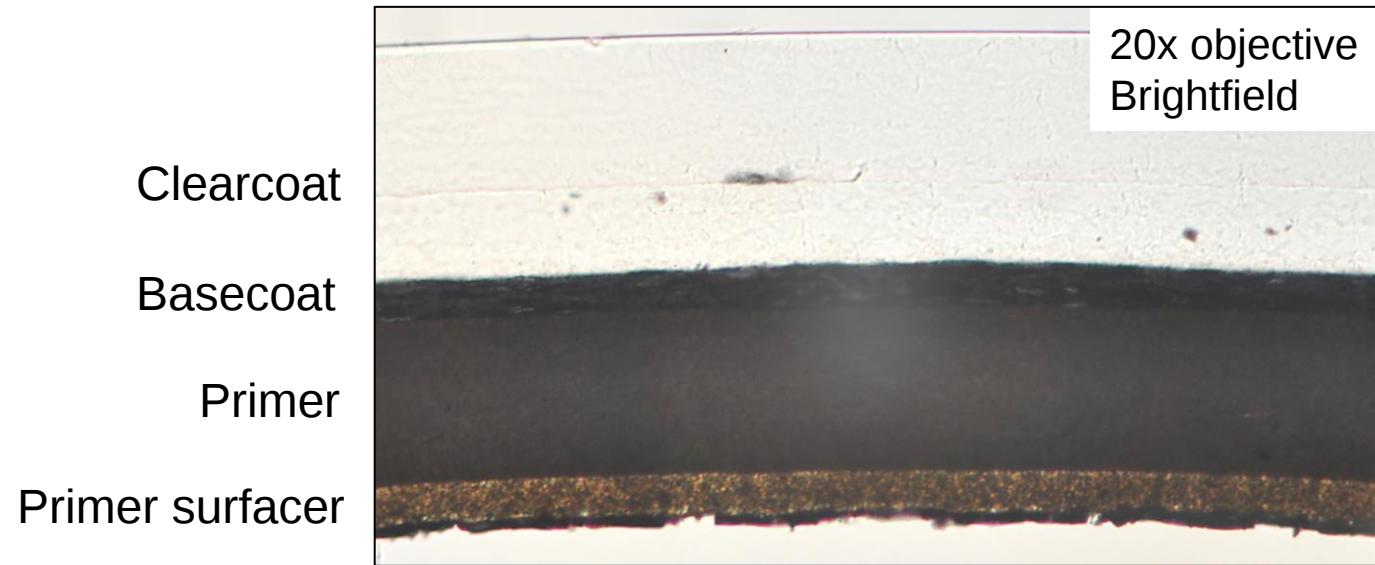
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Forensic Paint Analysis

- Class of polymers
- Forensic relevance:
 - Hit-and-run accidents
 - Traffic collisions



Automotive Paint Finish System



2011 Silver Dodge 1500

Clearcoat

- Transfer and subsequent recovery
- Binder dispersed with UV absorbers
 - Binder: FTIR and/or Raman spectroscopy
 - UV absorbers: UV-Vis MSP
- Limited studies on analysis of clearcoat
 - UV-Vis MSP analysis:
 - Stoecklein and Fujiwara (1999)
 - Liszewski et al. (2010)



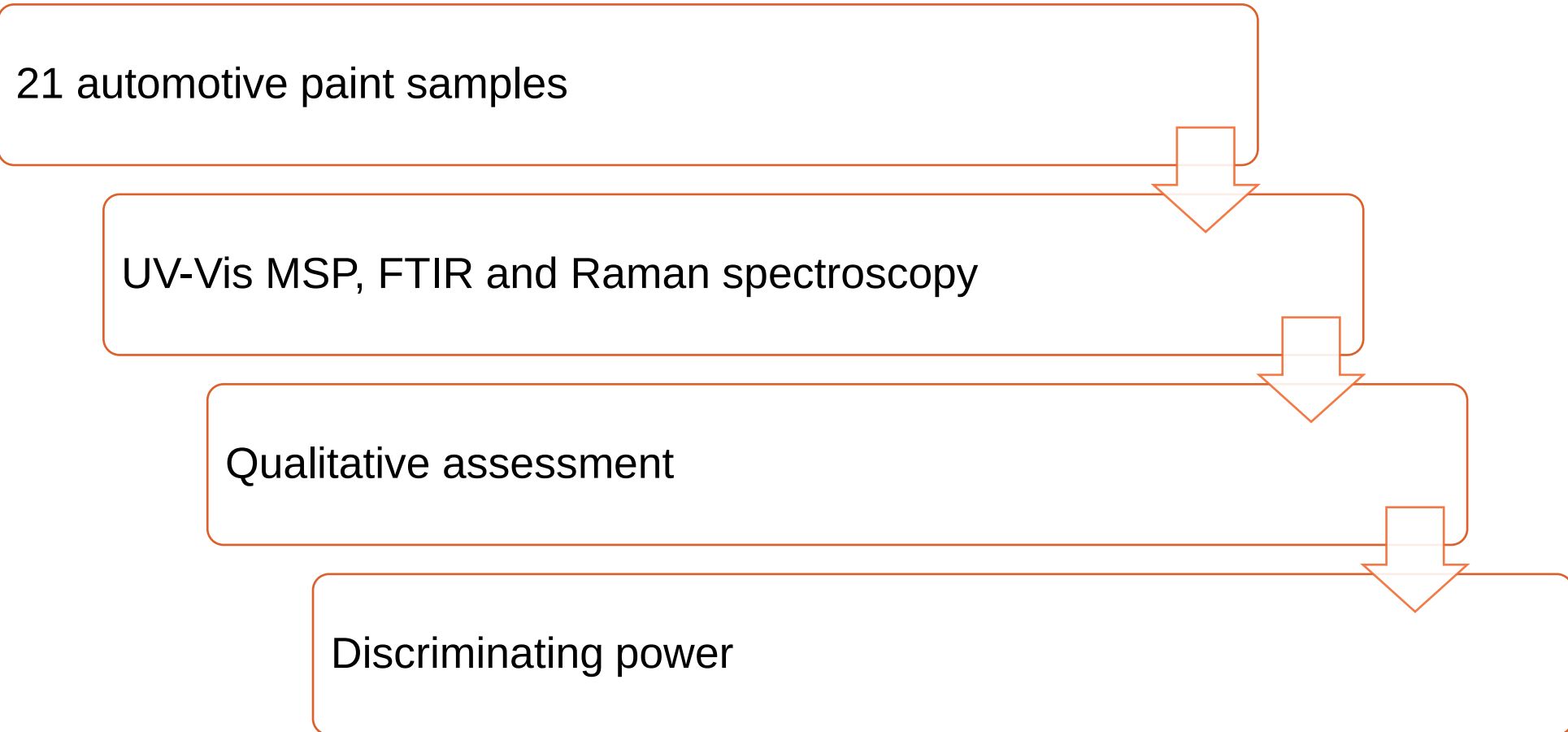
Sources: Stoecklein, W., & Fujiwara, H. (1999). The examination of UV-absorbers in 2-coat metallic and non-metallic automotive paints. *Science and Justice*, 39(3), 188–195.
[https://doi.org/10.1016/s1355-0306\(99\)72046-0](https://doi.org/10.1016/s1355-0306(99)72046-0).

Liszewski, E. A., Lewis, S. W., Siegel, J. A., & Goodpaster, J. V. (2010). Characterization of automotive paint clear coats by ultraviolet absorption microspectrophotometry with subsequent chemometric analysis. *Applied Spectroscopy*, 64(10), 1122–1125. <https://doi.org/10.1366/000370210792973631>

Image source: <https://avalonking.com/blogs/tips-advice/causes-and-fixing-peeling-clear-coat> (Accessed on 2024/10/10).

Project Overview

To evaluate the discriminating capabilities of UV-Vis MSP, FTIR spectroscopy and Raman spectroscopy in the analysis of automotive paint clearcoats



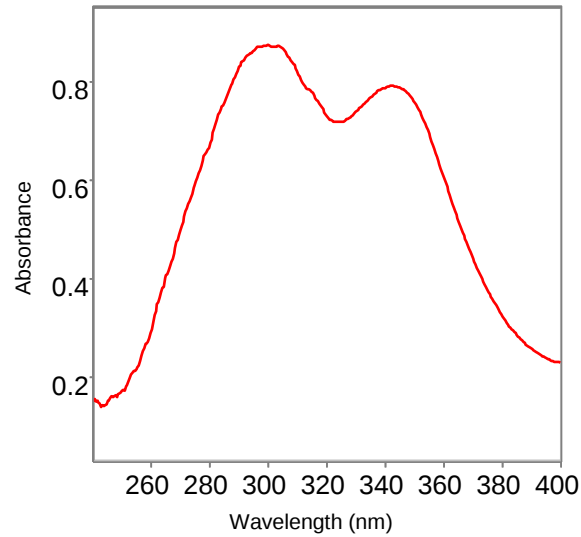
Results – UV-Vis MSP

- 8 groups:
 - Spectral differences
- Discriminating power ~ 86%

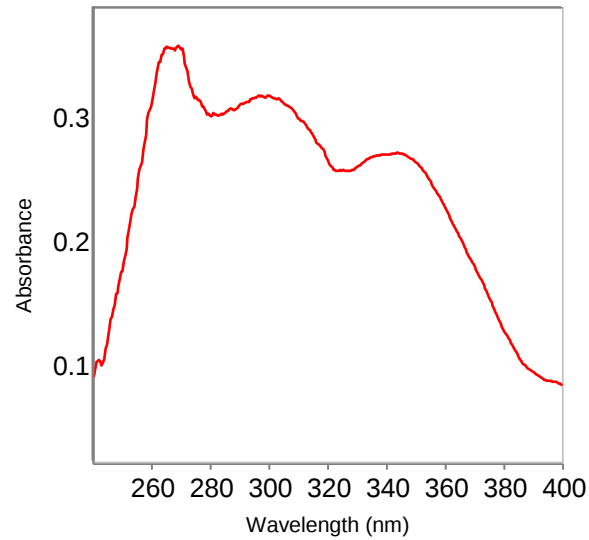


Results – UV-Vis MSP

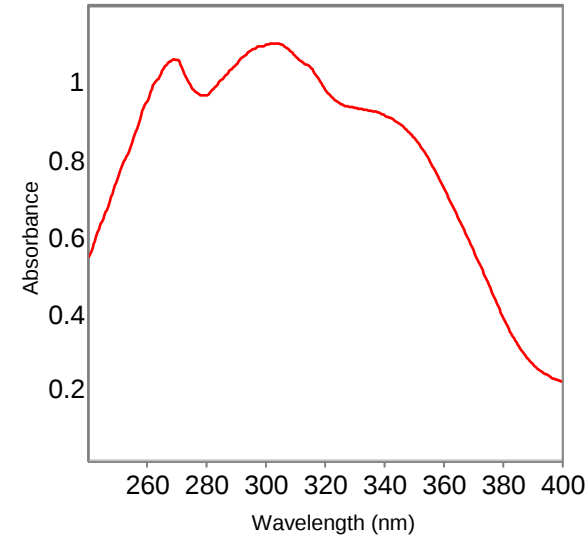
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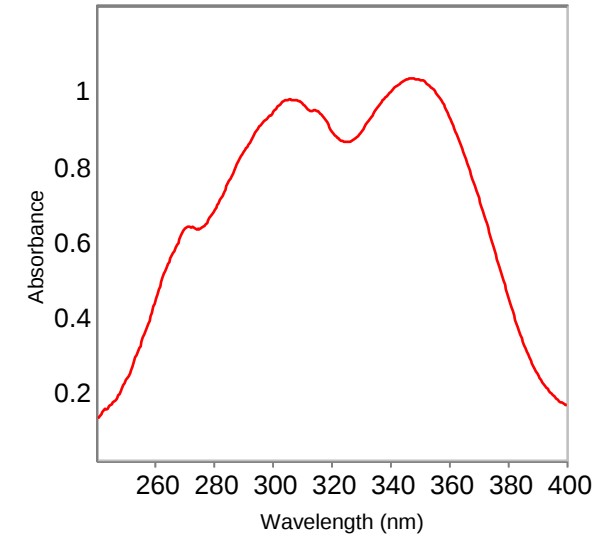
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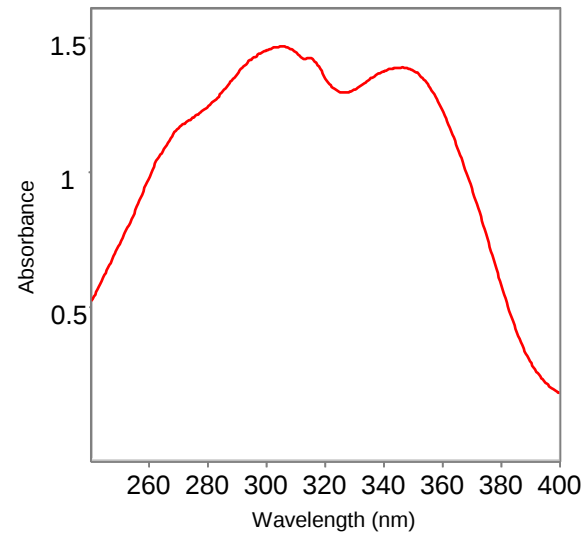
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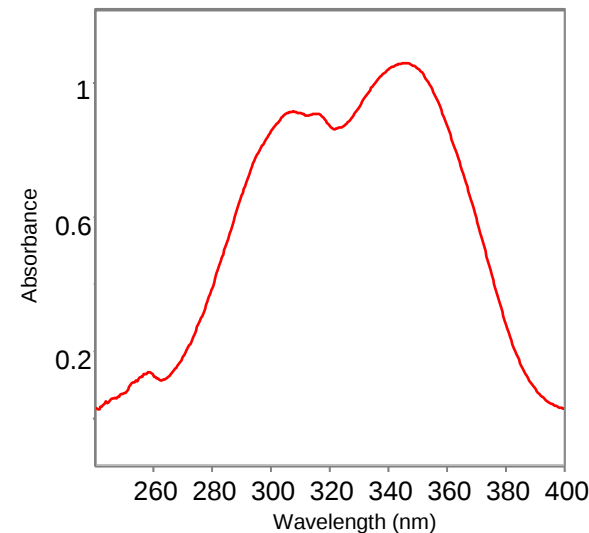
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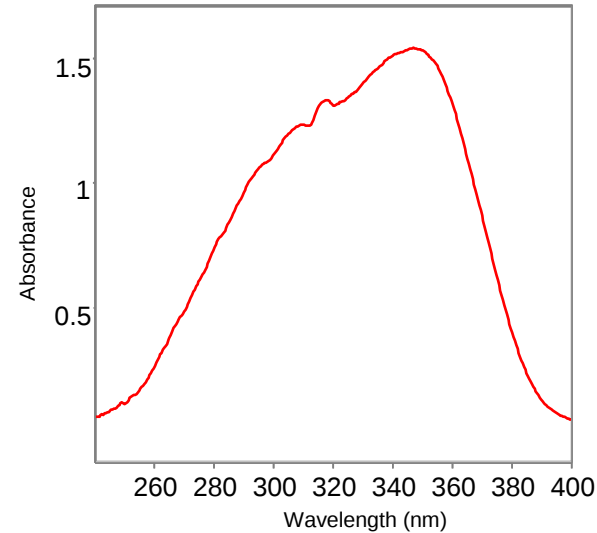
Group V



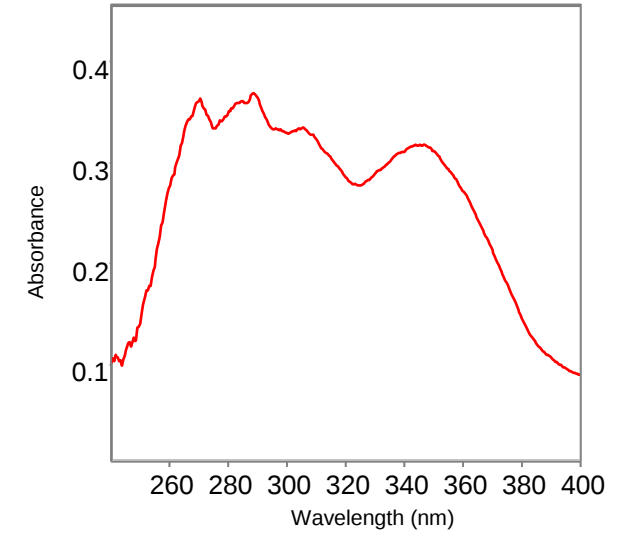
Group VI



Group VII



Group VIII



Results – UV-Vis MSP

Group I (n = 7)	Group II (n = 3)	Group III (n = 2)	Group IV (n = 2)
2017 Black Non Metallic Honda Civic 2015 Silver Metallic Honda Civic 2014 Red Non Metallic Ford F250 2012 White Non Metallic Ford F250 2004 Silver Metallic Chevy Silverado 2007 Red Metallic Jeep Compass 2005 Black Non Metallic BMW 350i	2009 Black Non Metallic Ford F150 2017 Blue Metallic Ford F150 2017 Blue Metallic Ford Fusion	2013 Black Metallic Hyundai Sonata 1994 White Metallic Mazda Millenia (Refinish)	2016 Black Non Metallic Ford Super Duty 2016 Red Metallic Toyota Corolla (Refinish)
Group V (n = 2)	Group VI (n = 2)	Group VII (n = 2)	Group VIII (n = 1)
2012 Silver Metallic BMW 528i (Refinish) 2007 Red Metallic Toyota Camry SE	2013 White Metallic Cadillac XTS 2014 Black Non Metallic Chevrolet Silverado	2007 Black Non Metallic GMC Sierra 2017 Silver Metallic Nissan Altima (Refinish)	2016 Black Metallic Toyota Camry

Results – UV-Vis MSP

Group I (n = 7)	Group II (n = 3)	Group III (n = 2)	Group IV (n = 2)
2017 Black Non Metallic Honda Civic 2015 Silver Metallic Honda Civic 2014 Red Non Metallic Ford F250 2012 White Non Metallic Ford F250 2004 Silver Metallic Chevy Silverado 2007 Red Metallic Jeep Compass 2005 Black Non Metallic BMW 350i	2009 Black Non Metallic Ford F150 2017 Blue Metallic Ford F150 2017 Blue Metallic Ford Fusion	2013 Black Metallic Hyundai Sonata 1994 White Metallic Mazda Millenia (Refinish)	2016 Black Non Metallic Ford Super Duty 2016 Red Metallic Toyota Corolla (Refinish)
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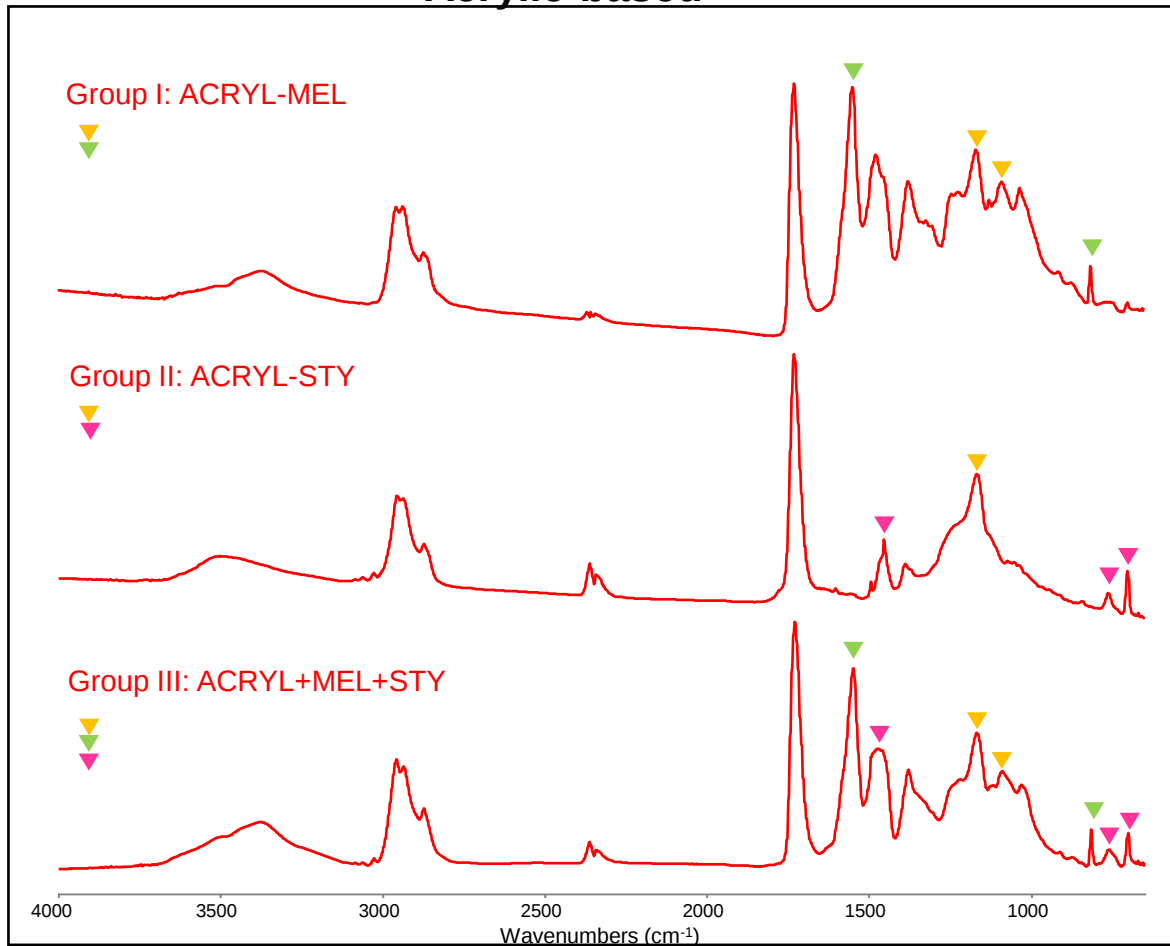
Results – FTIR spectroscopy

- 7 groups:
 1. Acrylic (ACRYL)
 2. Polyurethane (PUR)
 3. Melamine (MEL)
 4. Styrene (STY)
- Discriminating power ~ 87%

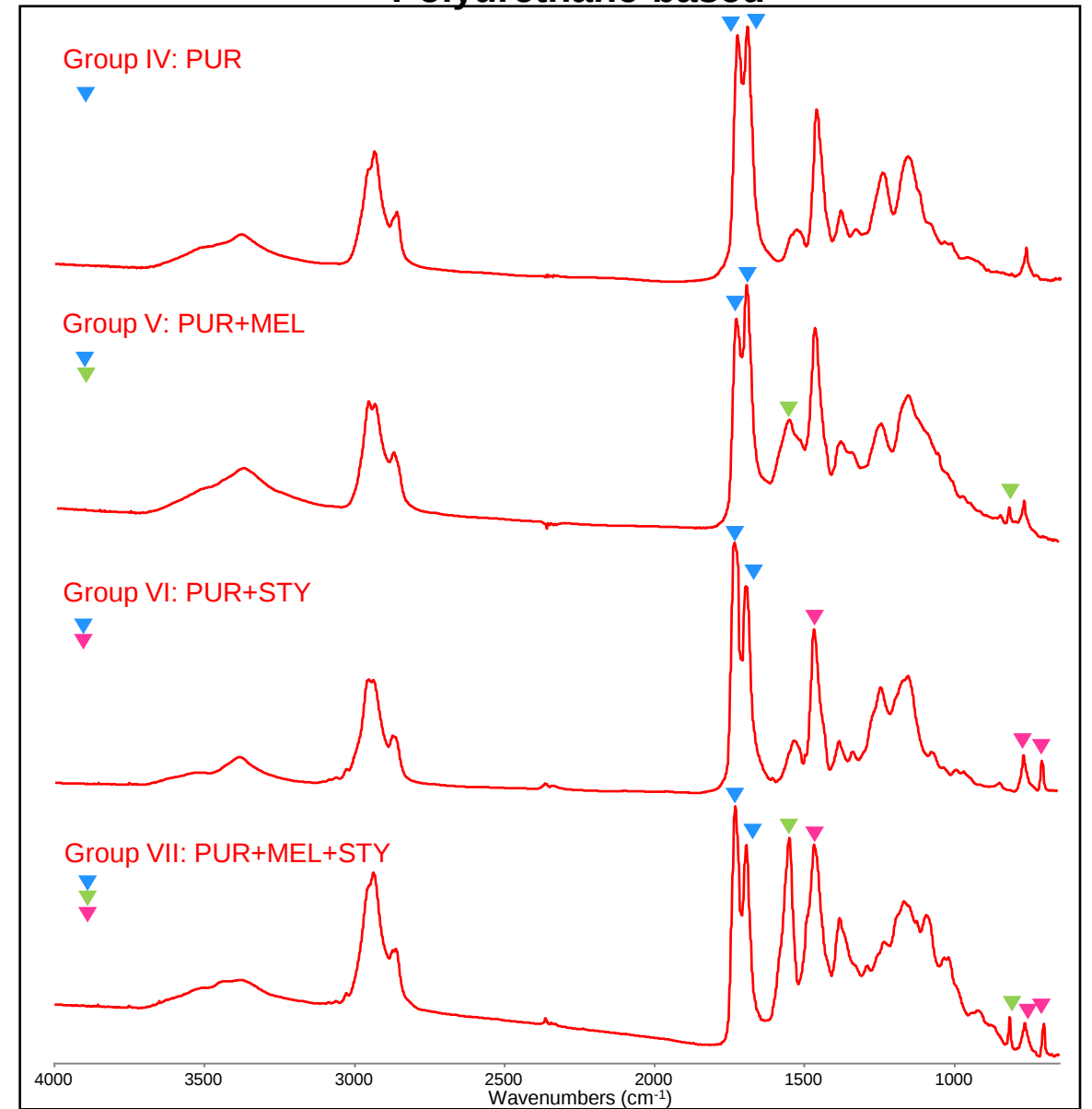


Results – FTIR spectroscopy

Acrylic-based



Polyurethane-based



Results – FTIR spectroscopy

Group I: ACRYL-MEL (n = 1)	Group II: ACRYL-STY (n = 3)	Group III: ACRYL-MEL-STY (n = 4)
2017 Blue Metallic Ford Fusion	1994 White Metallic Mazda Millenia (Refinish) 2007 Red Metallic Toyota Camry SE 2016 Black Metallic Toyota Camry	2017 Black Non Metallic Honda Civic 2015 Silver Metallic Honda Civic 2007 Red Metallic Jeep Compass 2013 Black Metallic Hyundai Sonata

Group IV: PUR (n = 4)	Group V: PUR-MEL (n = 1)	Group VI: PUR-STY (n = 5)	Group VII: PUR-MEL-STY (n = 4)
2004 Silver Metallic Chevrolet Silverado 2013 White Metallic Cadillac XTS 2007 Black Non Metallic GMC Sierra	2014 Black Non Metallic Chevrolet Silverado	2005 Black Non Metallic BMW 350i 2016 Red Metallic Toyota Corolla (Refinish) 2017 Blue Metallic Ford F150 2012 Silver Metallic BMW 528i (Refinish) 2017 Silver Metallic Nissan Altima (Refinish)	2014 Red Non Metallic Ford F250 2012 White Non Metallic Ford F250 2016 Black Non Metallic Ford Super Duty 2009 Black Non Metallic Ford F150

Results – FTIR spectroscopy

Group I: ACRYL-MEL (n = 1)	Group II: ACRYL-STY (n = 3)	Group III: ACRYL-MEL-STY (n = 4)
2017 Blue Metallic Ford Fusion	1994 White Metallic Mazda Millenia (Refinish) 2007 Red Metallic Toyota Camry SE 2016 Black Metallic Toyota Camry	2017 Black Non Metallic Honda Civic 2015 Silver Metallic Honda Civic 2007 Red Metallic Jeep Compass 2013 Black Metallic Hyundai Sonata

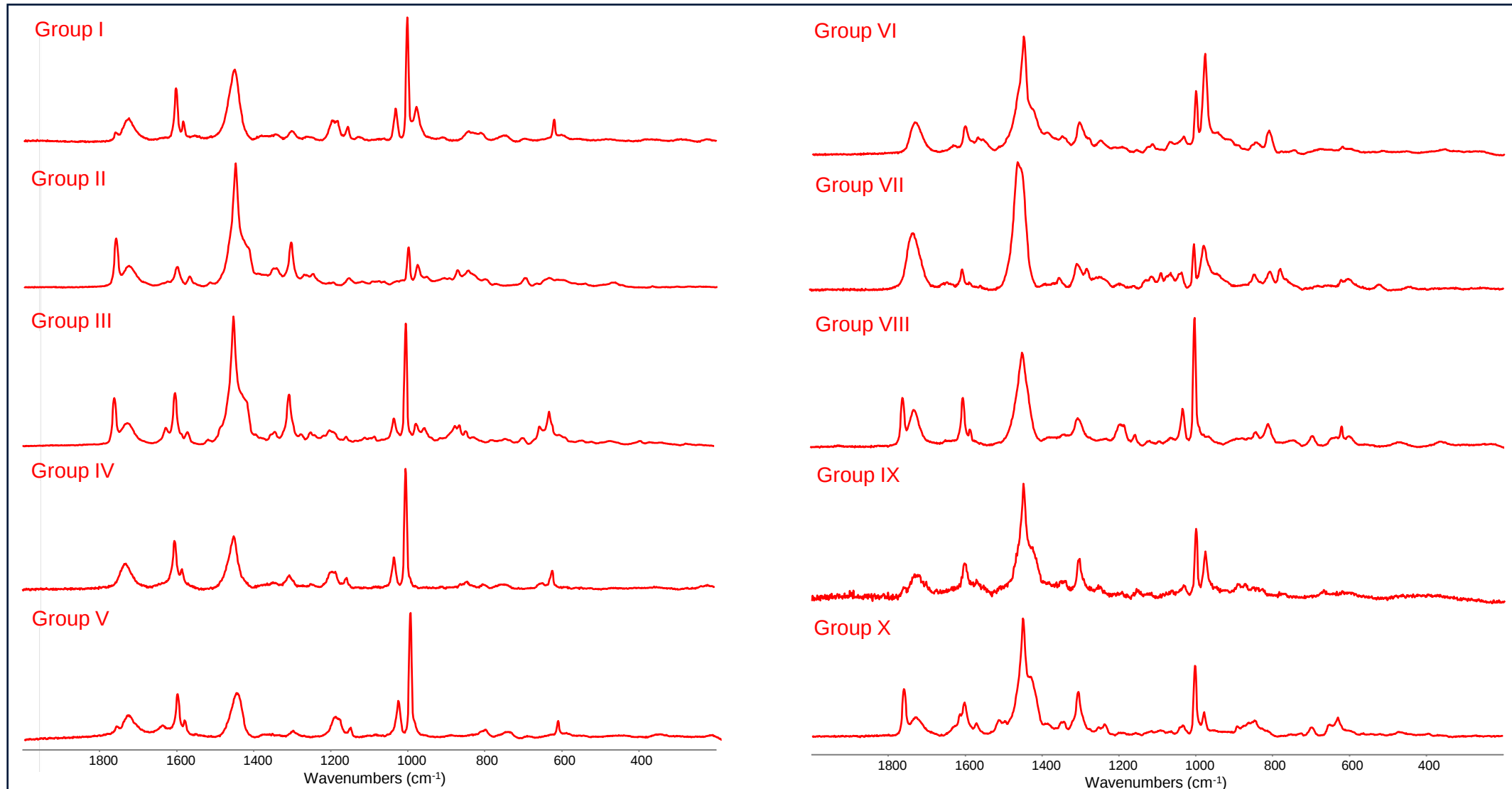
Group IV: PUR (n = 4)	Group V: PUR-MEL (n = 1)	Group VI: PUR-STY (n = 5)	Group VI: PUR-MEL-STY (n = 4)
2004 Silver Metallic Chevrolet Silverado 2013 White Metallic Cadillac XTS 2007 Black Non Metallic GMC Sierra	2014 Black Non Metallic Chevrolet Silverado	2005 Black Non Metallic BMW 350i 2016 Red Metallic Toyota Corolla (Refinish) 2017 Blue Metallic Ford F150* 2012 Silver Metallic BMW 528i (Refinish) 2017 Silver Metallic Nissan Altima (Refinish)	2014 Red Non Metallic Ford F250 2012 White Non Metallic Ford F250 2016 Black Non Metallic Ford Super Duty 2009 Black Non Metallic Ford F150

Results – Raman spectroscopy

- 10 groups:
 - Spectral differences
- Discriminating power ~ 86%



Result – Raman spectroscopy



Results – Raman spectroscopy

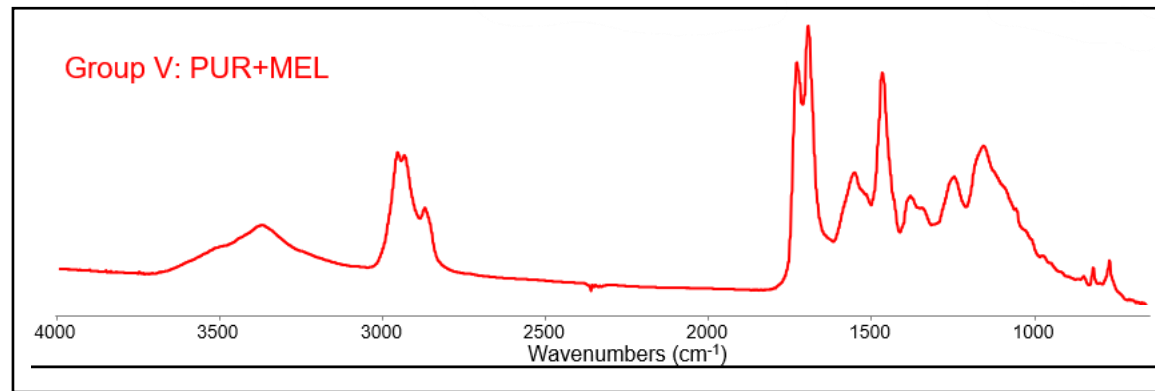
Group I (n = 7)	Group II (n = 4)	Group III (n = 3)	Group IV (n = 1)	Group V (n = 1)
2017 Black Non Metallic Honda Civic 2015 Silver Metallic Honda Civic 2013 Black Metallic Hyundai Sonata 2014 Red Non Metallic Ford F250 2012 White Non Metallic Ford F250 2016 Black Non Metallic Ford Super Duty 2009 Black Non Metallic Ford F150	2004 Silver Metallic Chevrolet Silverado 2013 White Metallic Cadillac XTS 2007 Black Non Metallic GMC Sierra 2014 Black Non Metallic Chevrolet Silverado	1994 White Metallic Mazda Millenia (Refinish) 2007 Red Metallic Toyota Camry SE 2016 Black Metallic Toyota Camry	2016 Red Metallic Toyota Corolla (Refinish)	2012 Silver Metallic BMW 528i (Refinish)
Group VI (n = 1)	Group VII (n = 1)	Group VIII (n = 1)	Group IX (n = 1)	Group X (n = 1)
2017 Blue Metallic Ford Fusion	2007 Red Metallic Jeep Compass	2017 Silver Metallic Nissan Altima (Refinish)	2017 Blue Metallic Ford F150	2005 Black Non Metallic BMW 350i

Results – Raman spectroscopy

Group I (n = 7)	Group II (n = 4)	Group III (n = 3)	Group IV (n = 1)	Group V (n = 1)
2017 Black Non Metallic Honda Civic 2015 Silver Metallic Honda Civic 2013 Black Metallic Hyundai Sonata 2014 Red Non Metallic Ford F250 2012 White Non Metallic Ford F250 2016 Black Non Metallic Ford Super Duty 2009 Black Non Metallic Ford F150	2004 Silver Metallic Chevrolet Silverado 2014 Black Non Metallic Chevrolet Silverado 2013 White Metallic Cadillac XTS 2007 Black Non Metallic GMC Sierra	1994 White Metallic Mazda Millenia (Refinish) 2007 Red Metallic Toyota Camry SE 2016 Black Metallic Toyota Camry	2016 Red Metallic Toyota Corolla (Refinish)	2012 Silver Metallic BMW 528i (Refinish)
Group VI (n = 1)	Group VII (n = 1)	Group VIII (n = 1)	Group IX (n = 1)	Group X (n = 1)
2017 Blue Metallic Ford Fusion	2007 Red Metallic Jeep Compass	2017 Silver Metallic Nissan Altima (Refinish)	2017 Blue Metallic Ford F150*	2005 Black Non Metallic BMW 350i

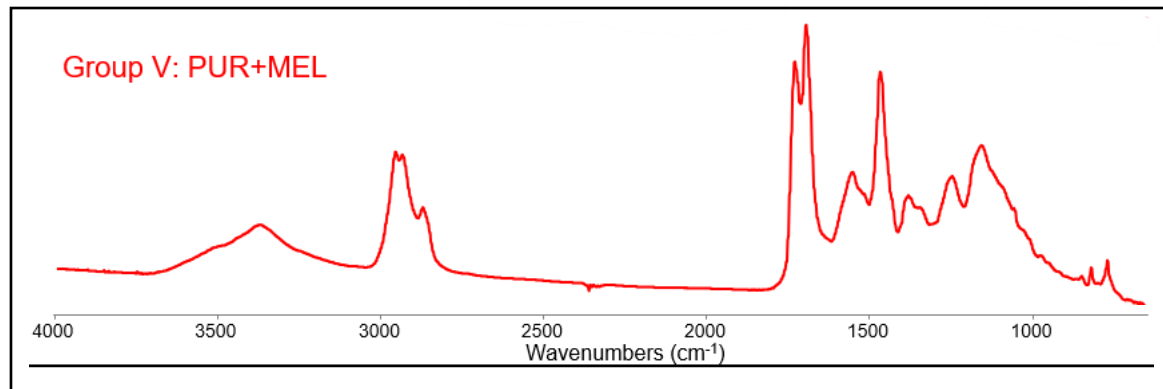
FTIR and Raman spectroscopy

FTIR

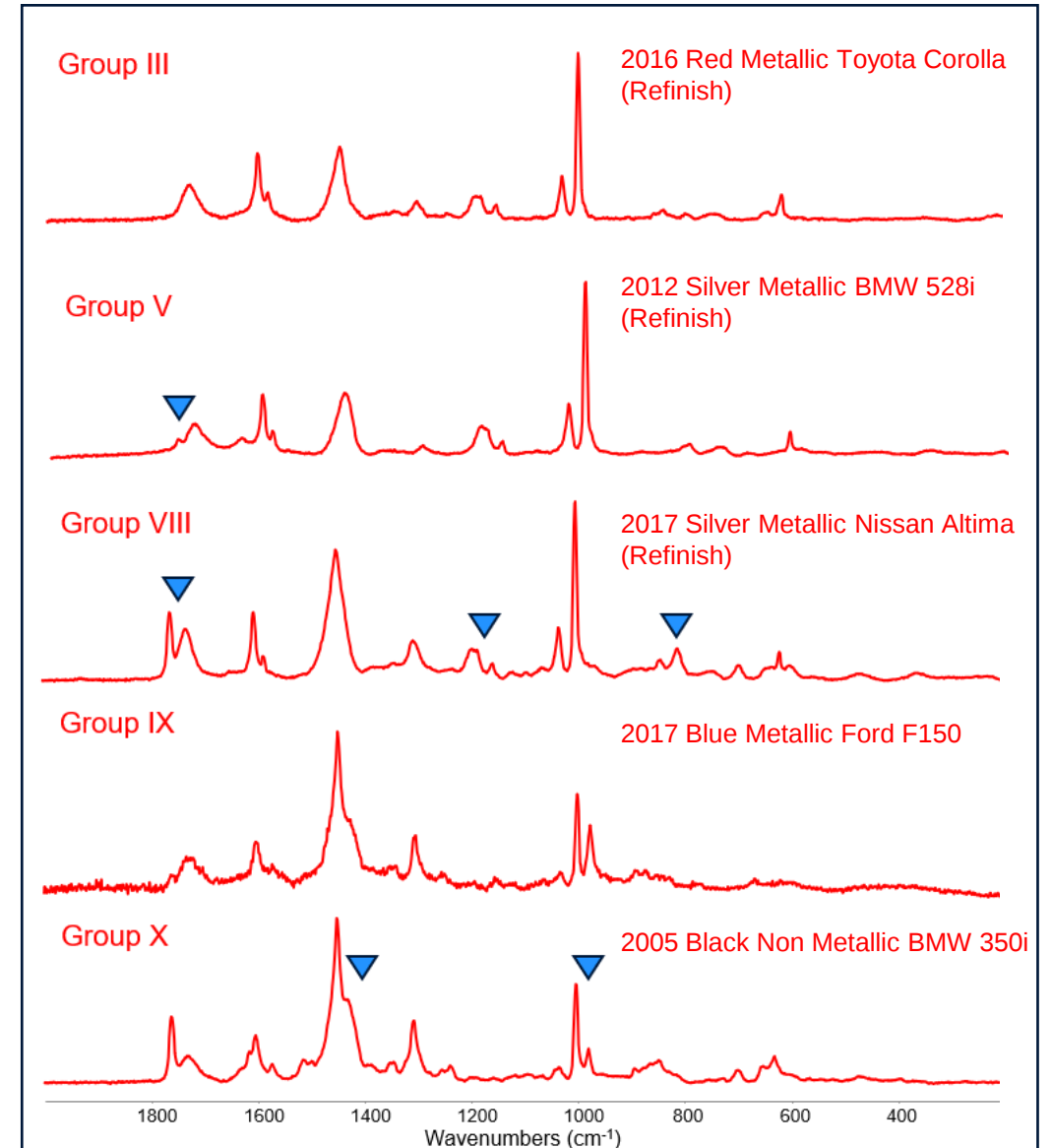


FTIR and Raman spectroscopy

FTIR

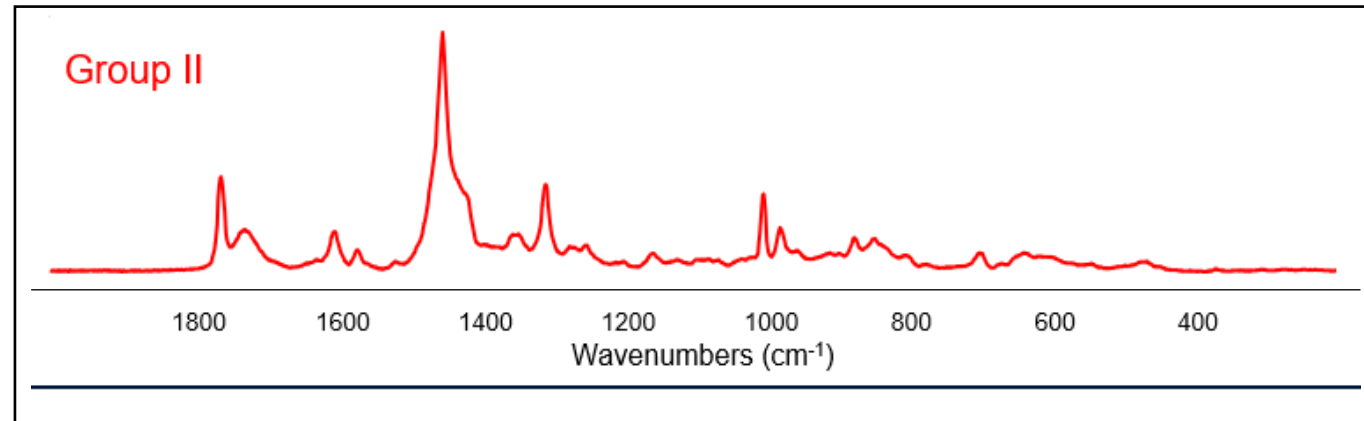


Raman



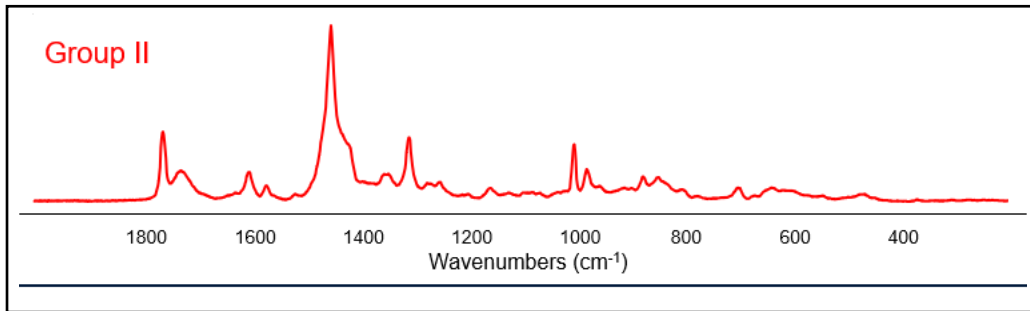
FTIR and Raman spectroscopy

Raman

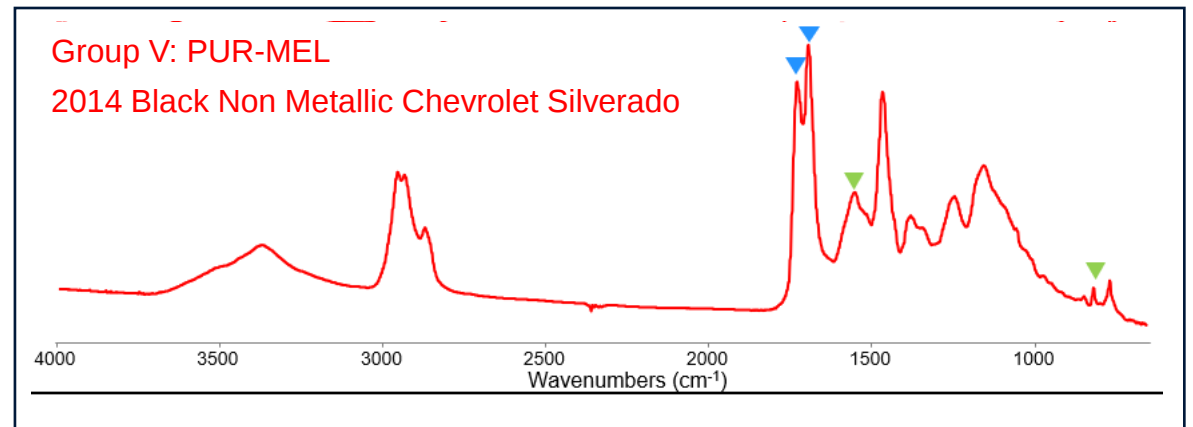
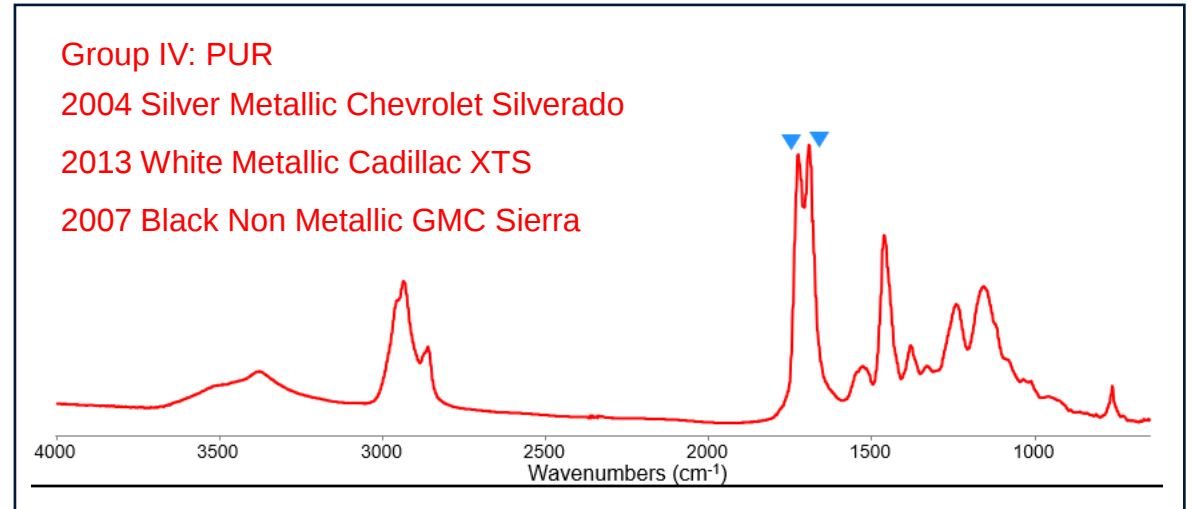


FTIR and Raman spectroscopy

Raman



FTIR



Results – Discriminating power

Single use	Discriminating power
UV-Vis MSP	86%
FTIR spectroscopy	87%
Raman spectroscopy	86%

Joint use	Discriminating power
FTIR spectroscopy + UV-Vis MSP	98%
Raman spectroscopy + UV-Vis MSP	97%
FTIR spectroscopy + Raman spectroscopy	93%
FTIR spectroscopy + Raman spectroscopy + UV-Vis MSP	99%

Results – Discriminating power

The indistinguishable “1%”

MSP group	FTIR group	Raman group	Samples
I	ACRYL+MEL+STY	I	2017 Black Non Metallic Honda Civic 2015 Silver Metallic Honda Civic
I	PUR+MEL+STY	I	2014 Red Non Metallic Ford F250 2012 White Non Metallic Ford F250

Main takeaways

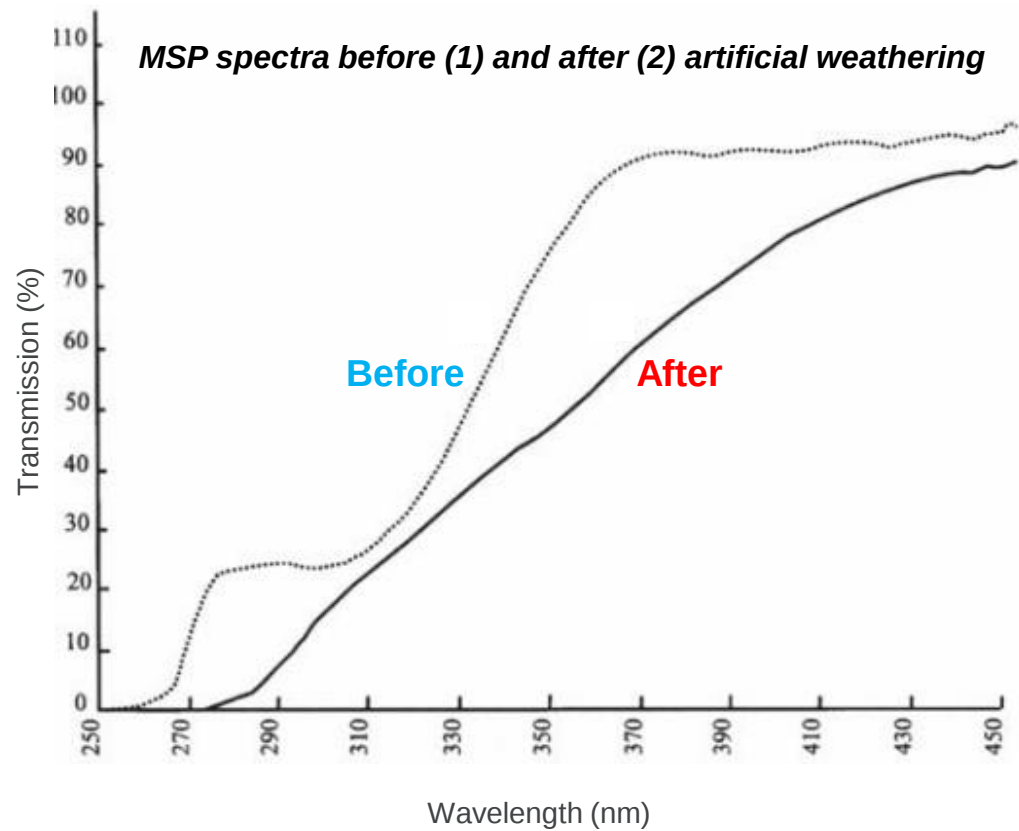
1. UV-Vis MSP: Additional discriminating information
2. Potential for investigative leads



Sample history

Stoecklein and Fujiwara (1999)

- Photochemical stability
- Effect of weathering

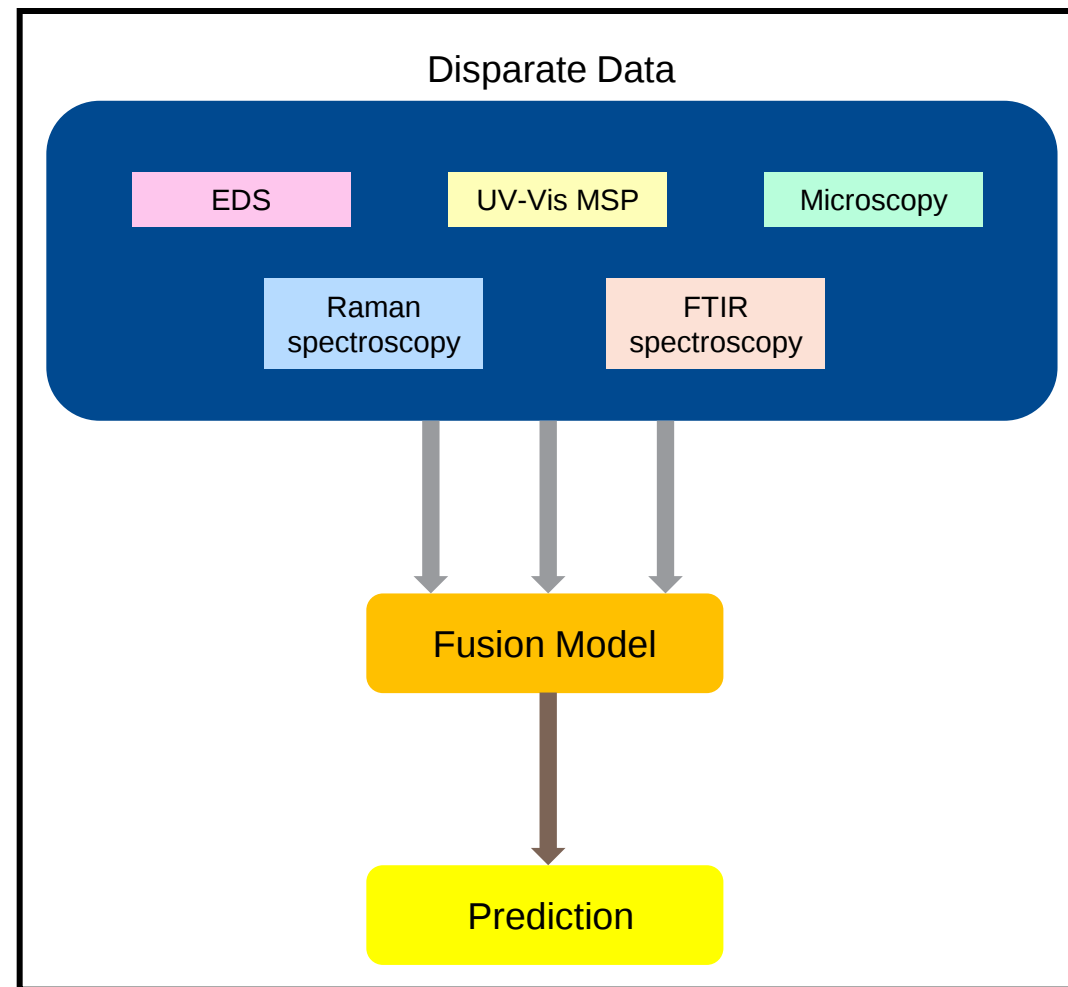


Future directions

Characterize known classes of UV absorbers

Paint Data Fusion Project

- Most informative chemical features from different analytical methods





Questions?

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