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Application News

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Raman Spectroscopy

Deciphering Mobile Phone Touch Screens with Confocal Raman Microscopy

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■ Background

In modern Raman spectroscopy the sample is illuminated with laser light of a visible or NIR wavelength and the inelastically scattered Raman signal provides crucial information about vibrational modes of the sample. When combined with confocal microscopy, Raman spectroscopy routinely achieves lateral and depth resolutions from a few microns to sub-micron. For transparent composite samples, confocal Raman microscopy thus becomes the technology of choice for depth or 3D profiling without the need of physically sectioning the samples. Mobile phone touch screens represent tech niches of telecommunication corporations as they are composite modules that require superior transmittance, durability and compactness. In this application news, screens of two models of modern mobile phones were studied. We demonstrate that the Shimadzu AIRsight FTIR/Raman microscope proves to be an important tool for the investigation and reverse engineering of composite materials.

■ Instrumentation

The Shimadzu AIRsight combination microscope for FTIR and Raman is equipped with 532 nm and 785 nm laser sources for Raman microscopy. A standard 50x and an optional 100x objective can be installed separately to provide different levels of spatial resolution. AMsolution software is used for instrument control and data analysis. Optional mapping software is used to acquire depth (line) mapping data.

AIRsight Infrared/Raman Microscope

■ Sample Preparation

Screens of two models of mobile phones – Model 4 and Model 6 – made by a name brand consumer electronics company were investigated. Model 4 was initially released in 2010 and Model 6 was released in 2014. Phone screens were cleaned by isopropanol and the mobile phones were placed directly on the AIRsight stage for data acquisition.

■ Depth Profile of Model 4 Mobile Phone

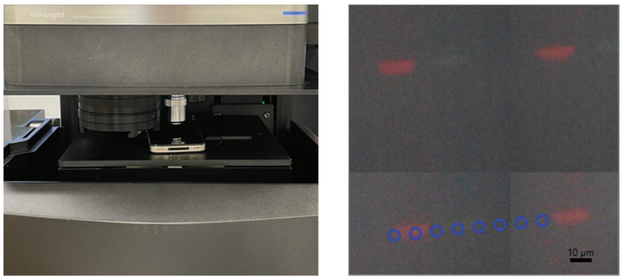
Wide-field and high-resolution tiling images were acquired for a small area on the screen. Depth mapping was carried out along a line passing through the red, green and blue colored LCD elements near the bottom of the screen with a spacing of 10 µm. The picture of the sample on the stage and the depth (line) setting are shown in Figure 1. Experimental parameters are listed in Table 1.

Raman spectra were acquired from the top of the screen to the bottom with a depth of approximately 1.4 mm and depth step of 20 µm. Each Raman spectrum was obtained from a 5 µm diameter laser illuminated area. Several layers were evident and consistent with the typical structure of touch screens in the early days of the mobile industry. The touch screen module starts with a glass layer about 700 µm thick followed by two ester layers with thickness of about 120 µm and 100 µm respectively. The two ester layers were separated by an intermedia layer about 200 µm thick. A PET film layer about 80 µm thick and an unidentified 120 µm thick layer followed the lower ester layer. Representative spectra of each layer are shown in Figure 2.

Using the Raman database in Wiley's KnowItAll™ software, the major components of each layer can be identified. The search results are summarized in Table 2. It is worthy of mention that due to the limitation of the Raman database and the complexity of the materials, identification of each layer may not be perfect, and sometimes not even possible. For example, the spectra of the two ester layers are almost identical but are identified as two different substances. The ester structures common to both compounds contribute to the main features of their Raman spectra. In the last layer, a few peaks below 400 cm^{-1} were observed in the Raman spectra. The current Raman database was not able to provide an acceptable match. The low peak frequencies suggested it might be contributed by some inorganic substance. In the PET film layer, the peaks below 400 cm^{-1} were not matched, suggesting multi components in this layer.

■ **Depth Profile of Model 4 Mobile Phone** *(Continued)*

Chemical images of the mapped area can easily be generated using the AMsolution software based on intensity, peak height, peak area or ratios of the aforementioned quantities. In Figure 3, peak height ratio and peak height maps were generated based on distinctive peaks in the Raman spectra of various layers. The boundary and thickness of the different layers can be clearly visualized.



a. b.

Figure 1: a. Model 4 mobile phone placed on microscope stage ready for Raman depth profiling; **b.** depth (line) profiling set along a line passing through the colored LCD elements with a length of 70 µm and spacing of 10 µm

Item	Parameter
Instrument Type	AIRsight
Experiment Type	Raman Depth (line) Mapping
Laser Wavelength (nm)	532
Objective Lens	50x objective lens
Spectral Range (cm^{-1})	100-4000
Number of Scans	10
Exposure Time (s)	1
ND Filter	55%
Laser Diameter (µm)	5
Line Length (µm)	70
Step Width (µm)	10
Depth Width (µm)	1440
Depth Step Width (µm)	20

Table 1: Experimental Parameters for Model 4 touch screen

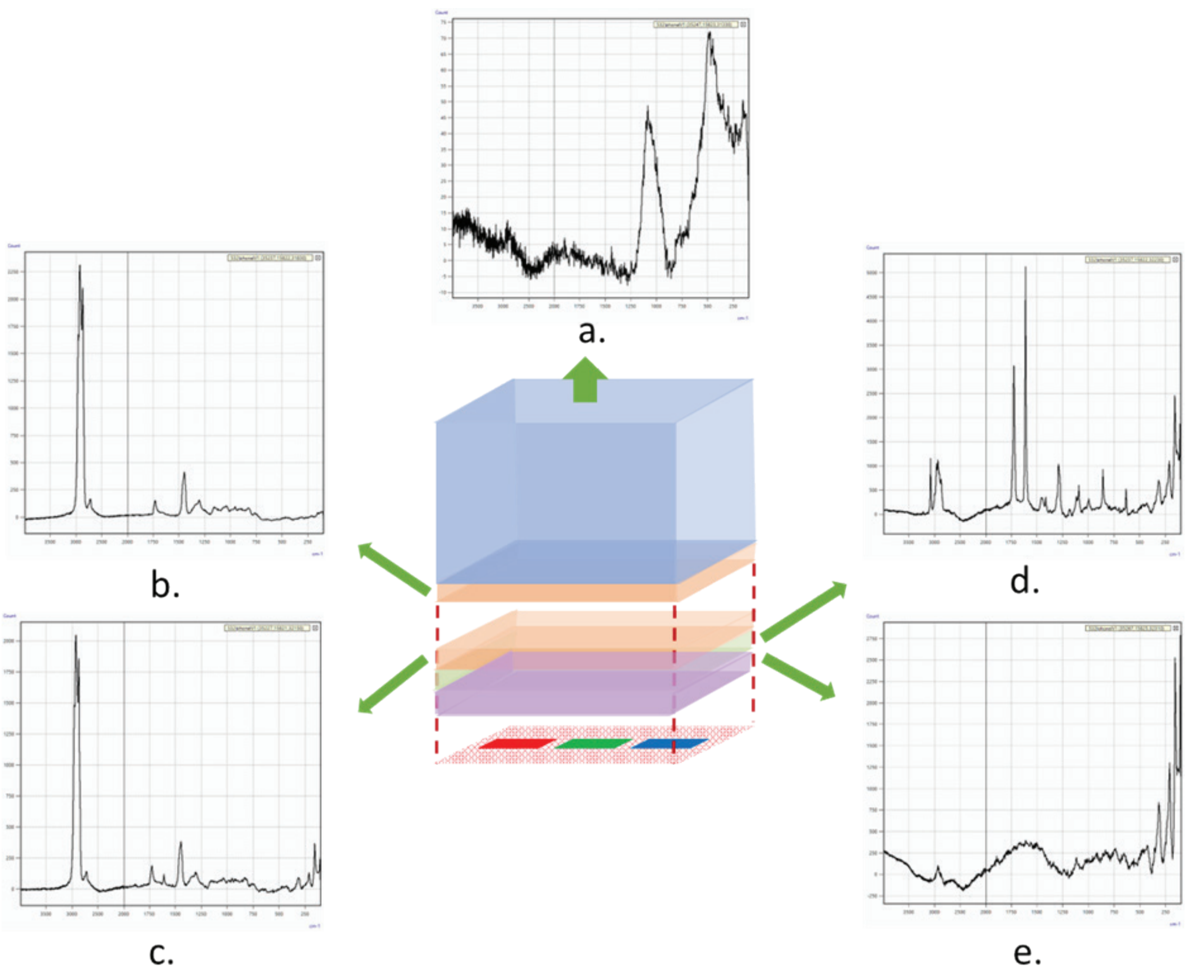


Figure 2: Diagram of the Model 4 touch screen structure based on Raman measurement and representative Raman spectra of layers. **a.** Raman spectrum of the glass layer; **b.** Raman spectrum of the upper ester layer; **c.** Raman spectrum of the lower ester layer; **d.** Raman spectrum of the PET film layer; **e.** Raman spectrum of the unidentified layer

Spectrum	Name	HQI
a	Sodium Trisilicate	73.7
b	Diisooctyl Adipate	93.6
c	Isobutyl Hexanoate	92.5
d	PET	76.0
e	Unidentified	NA

Table 2: Library search results of each representative Raman spectrum in Figure 2

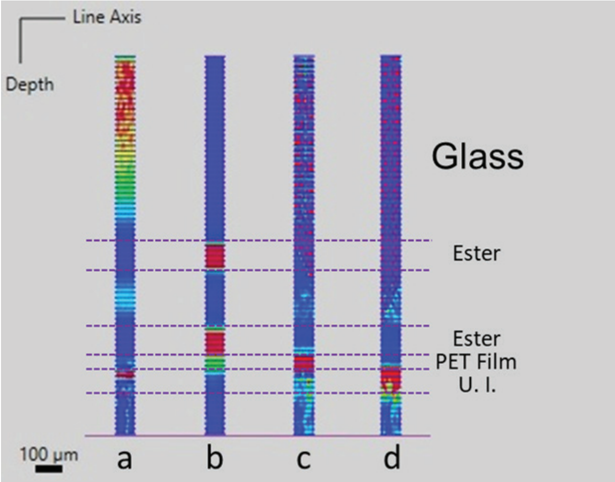


Figure 3: Chemical images help visualize various layers in the mapped area. **a.** based on peak height ratio of the peaks (847-1241 cm^{-1}) vs. (2789-3056 cm^{-1}); **b.** based on peak height of the peak (2790-3050 cm^{-1}); **c.** based on peak height ratio of the peaks (1577-1646 cm^{-1}) vs. (1388-1502 cm^{-1}); **d.** based on peak height ratio of the peaks (180-275 cm^{-1}) vs. (1219-1370 cm^{-1})

■ Depth Profile of Model 6 Mobile Phone

The Model 6 mobile phone was released about 4 years later than Model 4. Much innovation took place in the industry on the materials and structure of touch screens. This can be witnessed by the Raman depth profile study. A Model 6 mobile phone was placed on the translation stage of the microscope. The 50x objective lens and the 532 nm laser were used for Raman spectroscopy. Experimental parameters are listed in Table 3. The experimental setup and depth (line) setting are shown in Figure 4.

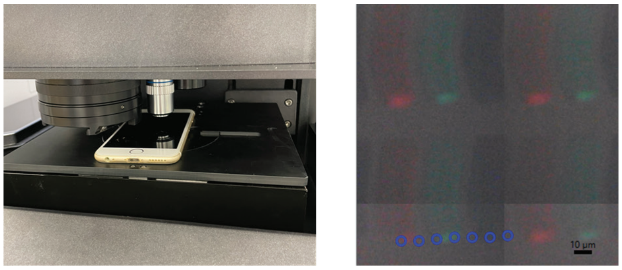
The touch screen thickness decreased from ~1.3 mm in Model 4 to ~0.7 mm in Model 6. The number of layers also decreased. From the Raman spectra, three layers were discernable above the LCD colored elements (Figure 5.) The top "glass" layer occupies a thickness of approximately 500 μm, more than 2/3 of the total thickness. The Raman spectra of the "glass" layer featured a broad envelope containing broad peaks in the high wavenumber region and a narrower peak centered around 490 cm^{-1}. The spectra in this layer looked different from the glass layer in Model 4, suggesting very different chemical make-ups.

Item	Parameter
Instrument Type	AIRsight
Experiment Type	Raman Depth (line) Mapping
Laser Wavelength (nm)	532
Objective Lens	50x objective lens
Spectral Range (cm^{-1})	100-4000
Number of Scans	10
Exposure Time (s)	1
ND Filter	55%
Laser Diameter (μm)	5
Line Length (μm)	60
Step Width (μm)	10
Depth Width (μm)	775
Depth Step Width (μm)	15

Table 3: Experimental Parameters for Model 6 touch screen

The top layer was followed by a 100 μm thick Layer 2 and a 50 μm thick Layer 3. Unlike the spectra in Model 4, where each layer often displayed as discrete layers with distinctive Raman peaks, the spectra of the layers in Model 6 seemed to share more common features. For example, all spectra appeared to have a broad envelope centered around 1750 cm^{-1}. Layers 2 and 3 both showed intense $-CH^2$ asymmetric and symmetric stretching peaks at about 2930 and 2860 cm^{-1}. These indicated the layers in Model 6 were more integrated, likely, various components disseminated in a common matrix.

The exact identification of the layers in the touch screen Model 6 was difficult due to the limitation of the current Raman database and the complicated nature of the materials used. Chemical images of the mapped area are shown in Figure 6, facilitating visualization of layered structure of the touch screen.



a. b.

Figure 4: a. Model 6 mobile phone placed on microscope stage ready for Raman depth profiling; **b.** depth (line) profiling set along a line passing through the colored LCD elements with a length of 60 μm and spacing of 10 μm

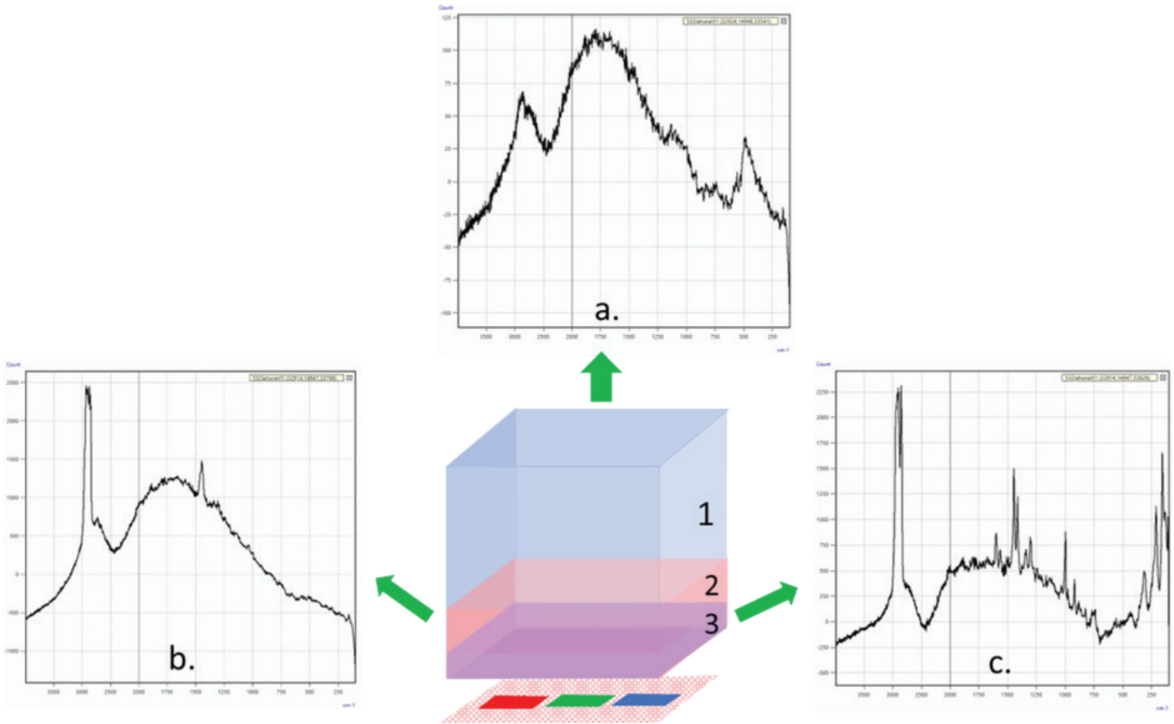


Figure 5: Diagram of Model 6 touch screen structure and representative Raman spectra of layers. **a.** Raman spectrum of the glass layer; **b.** Raman spectrum of layer 2; **c.** Raman spectrum of layer 3.

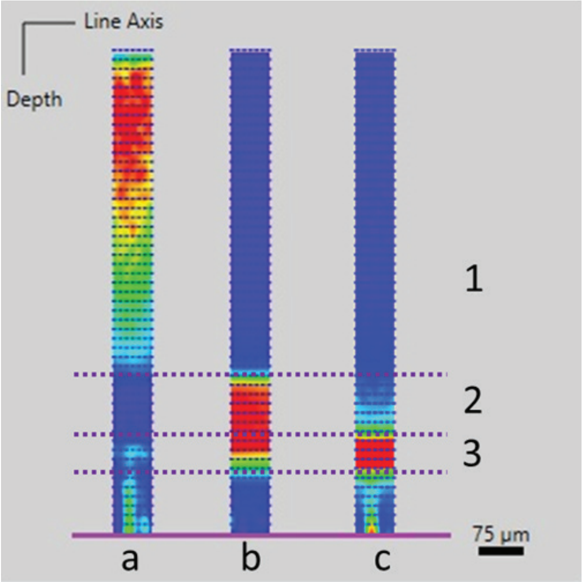


Figure 6: Chemical images of the mapped area. **a.** based on intensity ratio of 485 cm^{-1} vs. 1847 cm^{-1}; **b.** based on peak height of the peak (2786-3037 cm-1); **c.** based on peak height of the peak (120-180 cm^{-1})

■ Conclusion

Confocal Raman microscopy provides a unique opportunity for non-invasive investigation of transparent composite materials. The confocal microscopic capability of Shimadzu's AIRsight makes depth profiling of mobile phone touch screens possible. Depth resolution of 15 microns can be achieved with the standard 50x objective lens. Layered structures of two models of mobile phone touch screens illustrate technology advances in the mobile phone industry.

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