PHYSICAL ELECTRONICS
A DIVISION OF ULVAC-PHI

Chemical State Imaging With The PHI *710* Scanning Auger NanoProbe

Overview: The use of a coaxial field emission electron column with a cylindrical mirror analyzer has led to the PHI Scanning Auger Nanoprobe instruments as the preferred surface analysis approach for ultra-high spatial resolution elemental analysis for samples of all sample geometries. The introduction of high energy resolution spectroscopy with the PHI *700Xi* Scanning Auger Nanoprobe has led to the inclusion of chemical state interpretation for point spectroscopy and depth profiling for many samples. The PHI *710* Scanning Auger Nanoprobe has now incorporated new electronics and data interpretation software to facilitate chemical state imaging based on images that contain a spectra at each pixel. In this application note, multiple chemical states of Si on a semiconductor sample have been characterized by high energy resolution Auger chemical state imaging.

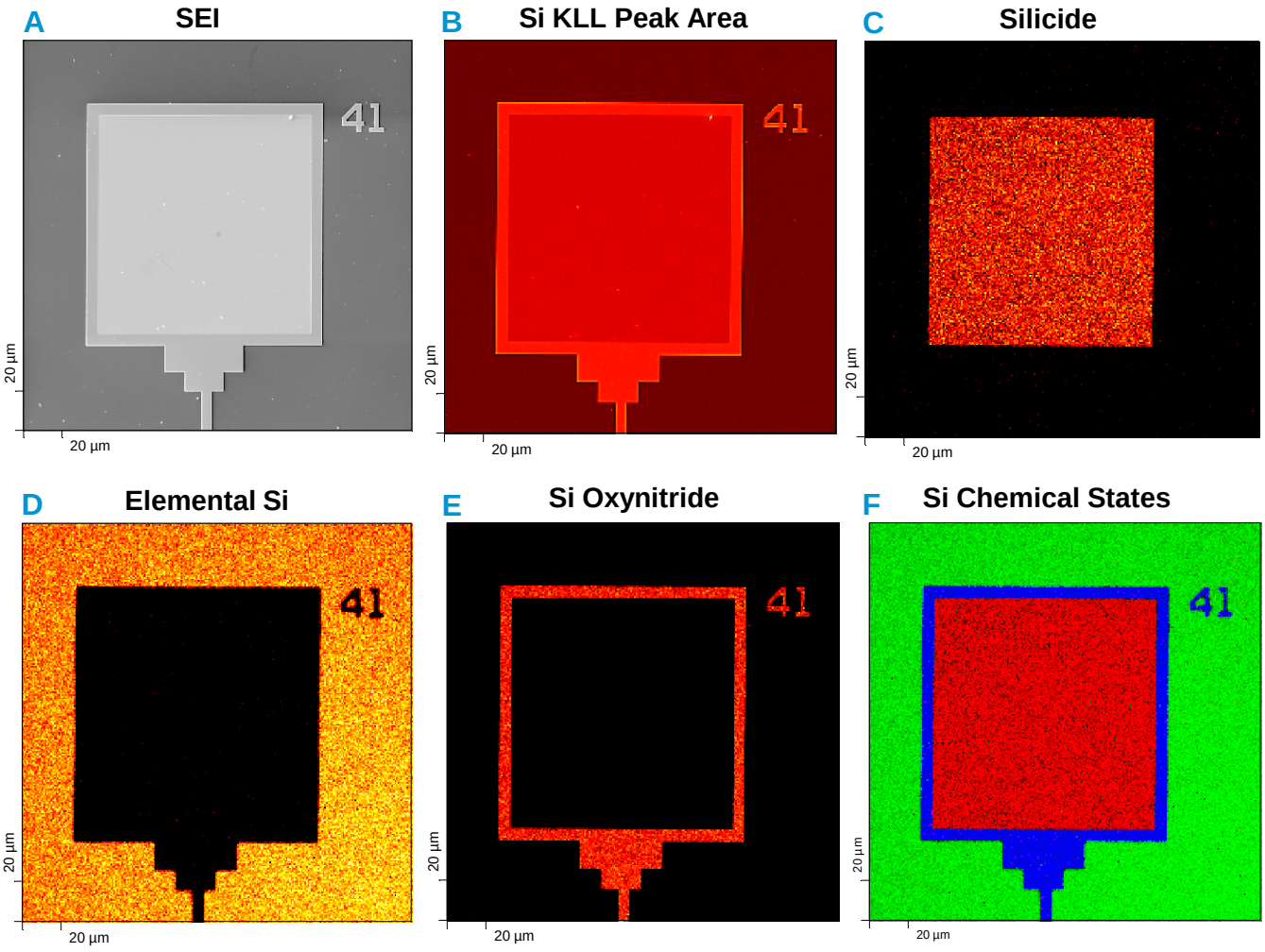

Figure 1. Panel A shows a 200 µm FOV SEI of a semiconductor bond pad. Panel B shows the Si KLL peak area image from the area of panel A. Panels C, D and E show the chemical state images of silicide, elemental Si and Si oxynitride respectively. Panel F shows a color overlay of elemental silicon, silicide and silicon oxynitride images.

Imaging Measurements: The semiconductor device bond pad structure was analyzed with a PHI *710* Scanning Auger Nanoprobe. Ar^+ ion sputtering with Zalar rotation was used to uniformly remove 20 nm of the surface contamination and surface oxidation before the Auger chemical state analysis. A 10 kV, 10 nA electron beam was rastered over a 200 µm field of view to acquire a 256 by 256 pixel Si KLL Auger image at 0.1% energy resolution. Each pixel of the image contained a 20 eV wide spectrum with 0.5 eV energy steps in the spectra. PHI MultiPak software was used to extract quantitative chemical state maps for three different Si chemical states from the Si KLL image.

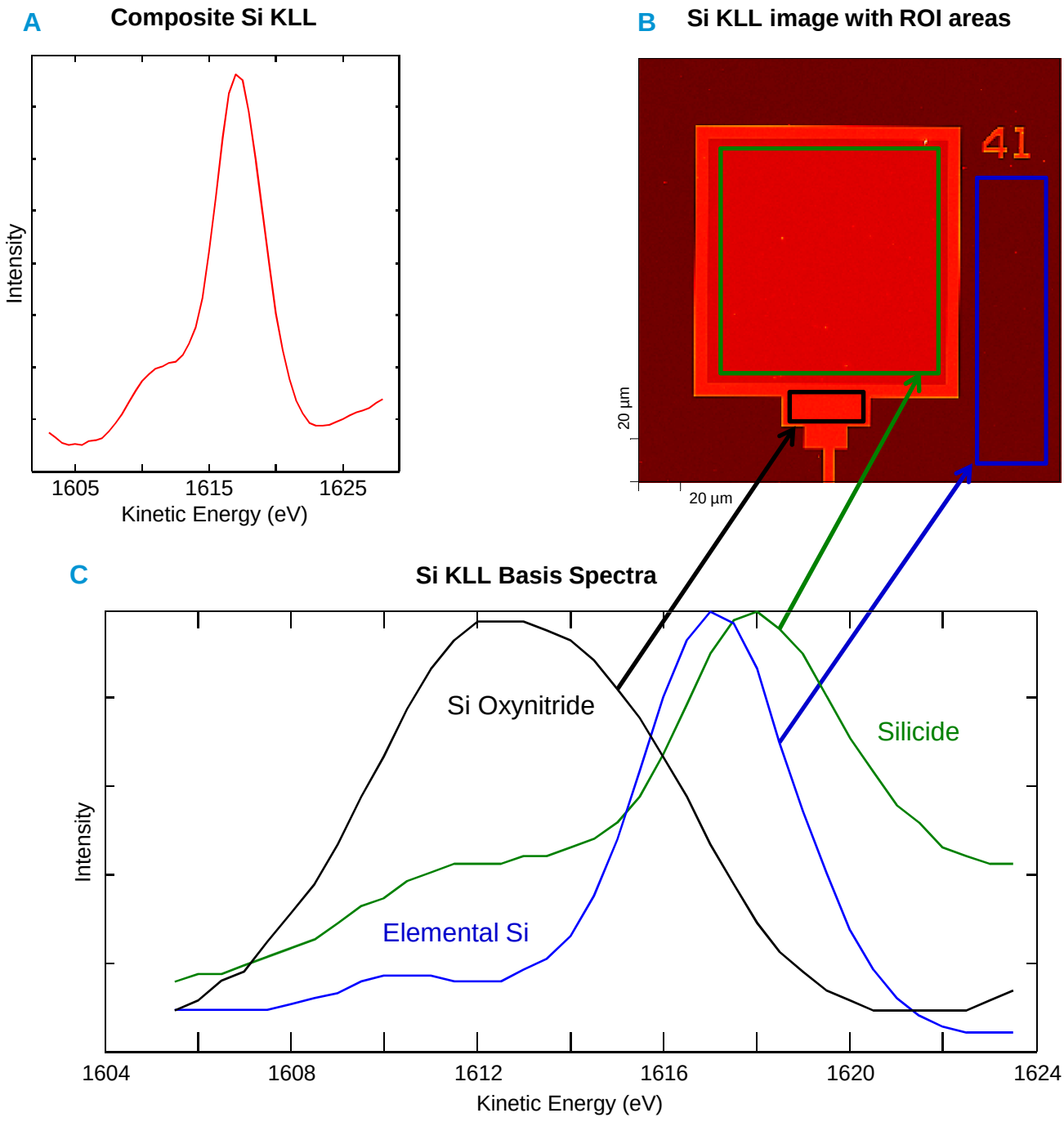

Figure 2. Panel A shows the Si KLL spectrum from the sum of all pixel spectra in the Si KLL Auger image shown in panel B. Panel B shows the three Regions Of Interest (ROI) selected for creation of the basis spectra for Linear Least Squares (LLS) fitting of the Si KLL image data set. Panel C shows the three basis spectra with their corresponding chemical state identifications.

Results: The Secondary Electron Image (SEI) and the Si KLL Auger image displayed in Figure 1 clearly show the locations of multiple regions of interest on the semiconductor device bond pad structure. After sputter ion cleaning of the structure, Auger survey spectra (not shown) in the center of the bond pad indicate W and Si, with Si, N and O forming a border around the bond pad, and elemental Si everywhere else. The 0.1% high energy resolution Si KLL Auger image with 20 eV wide spectra at each pixel should therefore confirm the chemical states of the silicon as suggested by the elements identified with the Auger survey spectra. The composite high energy resolution Si KLL spectrum summed from all of the pixels in the Auger image is shown in Figure 2A. This composite spectrum is suggestive of multiple chemical states in the image. Three regions, indicated on Figure 2B, where selected for extraction of basis spectra for Linear Least Squares (LLS) fitting with PHI MultiPak software. The resulting basis spectra from the three regions of interest (ROI) indicated on Figure 2B are shown in Figure 2C. From careful examination of the peak positions for the three basis spectra with previous standard high energy resolution spectra, the basis spectra can be identified as elemental silicon, silicide and silicon oxynitride. The LLS fitting results are shown in Figures 1C, 1D and 1E. An overlay image of the three silicon chemical state images is shown in Figure 1F.

Conclusion: Chemical state imaging based on spectra acquired at each image pixel with the PHI *710* Scanning Auger Nanoprobe were shown to be very useful in identifying multiple regions with different chemistries on the surface of the semiconductor device structure. The PHI MultiPak software with LLS fitting of the spectral window Auger images was shown to provide a powerful data interpretation tool for high energy resolution data acquired with the PHI *710*.

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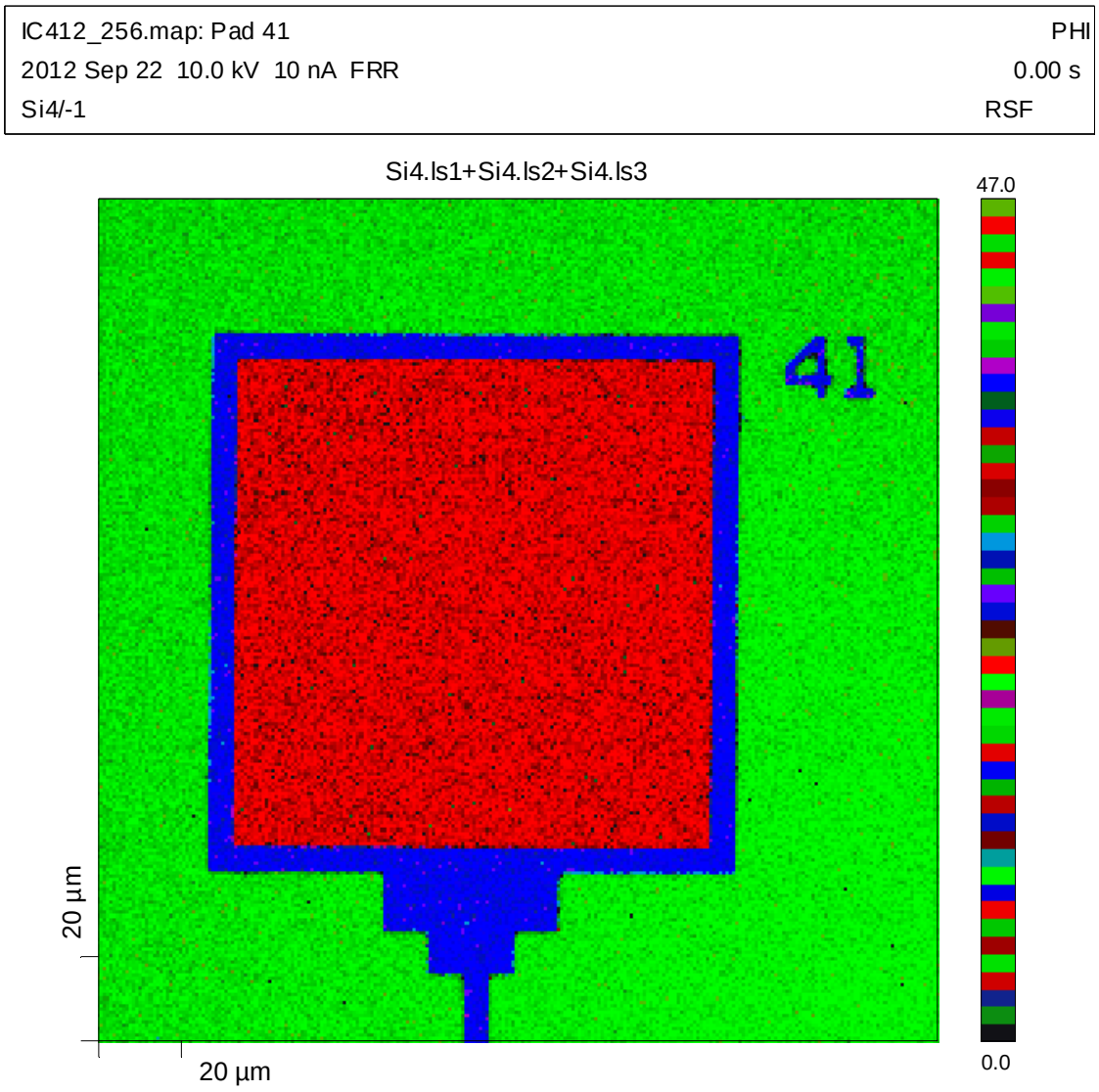
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PHI
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0.00 s
Si4/-1
RSF
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47.0
41
20 µm
20 µm
0.0