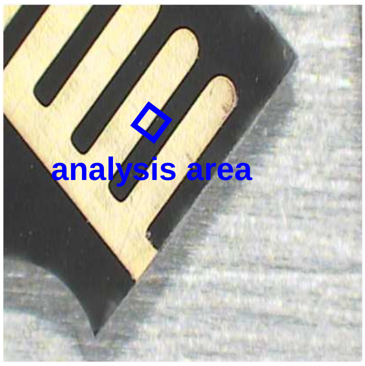
TOF-SIMS Chemical Imaging of Metal Interconnects on a Flexible Organic Substrate

Overview: The rapid spread of mobile devices has accelerated the manufacture of flexible electronic substrates for use in liquid crystal (LCD) and organic light emitting diode (OLED) display technologies. As devices are miniaturized, the flexible substrates are evolving toward small, high density features with requirements for high reliability. In following this trend, the metal interconnects have become smaller and the chemistry has become more complex. In this Note we use the PHI *nanoTOF* to visualize chemical inhomogeneities on a 40 µm thick metal interconnect on a flexible addressing substrate. A characteristic of time-of-flight secondary ion mass spectrometry (TOF-SIMS) is the ability to visualize chemical information in a spatially resolved manner, and at trace-level abundance sensitivity, which is a great advantage in both failure analysis and product development. The PHI *nanoTOF* is uniquely equipped for chemical imaging of topographically rough surfaces and step features, a distinguishing characteristic that is necessary for this chemical imaging application.



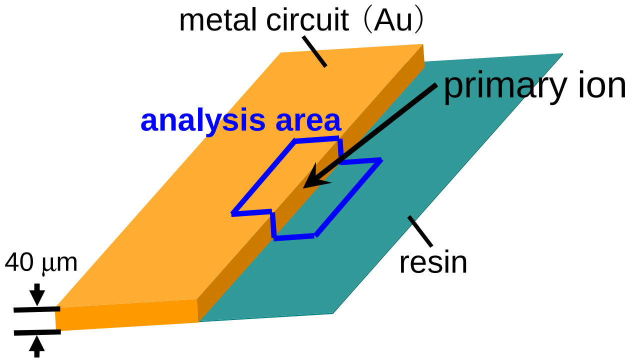


Figure 1. (LEFT) Optical microscope image of a metal interconnect structure on a flexible substrate that was obtained from a consumer product. An approximately 200 µm x 200 µm field-of-view is shown. (RIGHT) A schematic illustration of a gold interconnect on a flexible substrate where the approximated analysis area has been indicated.

Experimental: The flexible interconnect substrate was mounted in the as-received state for analysis. All TOF-SIMS measurements were made on a PHI TRIFT V *nanoTOF*. A 60 keV Bi_3^{++} primary ion beam, operating at a DC current of 100 pA, was used to acquire chemical images of the interconnect step edge in both the positive and the negative secondary ion polarities. The primary ion beam was digitally rastered at 256 pixels x 256 pixels over the 200 µm x 200 µm field-of-view, and the primary ion dose was maintained well within the static limit, i.e. $\leq 1.0\text{x}10^{13}$ Bi_3^{++}/cm^2, for each analysis. The sample stage was tilted 6º to optimize the observation of molecular and elemental species on the interconnect sidewall. Charge compensation was easily achieved with the PHI-patented dual-beam charge neutralization system. A raw data stream file was collected to allow full post-acquisition evaluation of the data.

Results: An optical microscope image of the flexible interconnect structure, and a schematic diagram showing the dimensions of the interconnect and the approximate analytical field-of-view, are shown in Figure 1. The topography of the device, which is illustrated in the schematic, requires that the mass spectrometer have a large angular acceptance and depth-of-field in order to achieve chemical imaging with high reliability in the observed chemical distributions. That is to say, the topography should produce no artifacts in the resulting chemical images. An added complexity is that the conducting metal wire on the insulating substrate produces a large kinetic energy spread of the secondary ions. In order to achieve optimum and reliable chemical imaging, the analyzer must be capable of focusing the large energy spread of the secondary ions while maintaining a large depth of field. The TRIFT analyzer of the *nanoTOF* leads the market in both angular acceptance and kinetic energy focusing to produce chemical images that are reliable and free of artifacts.

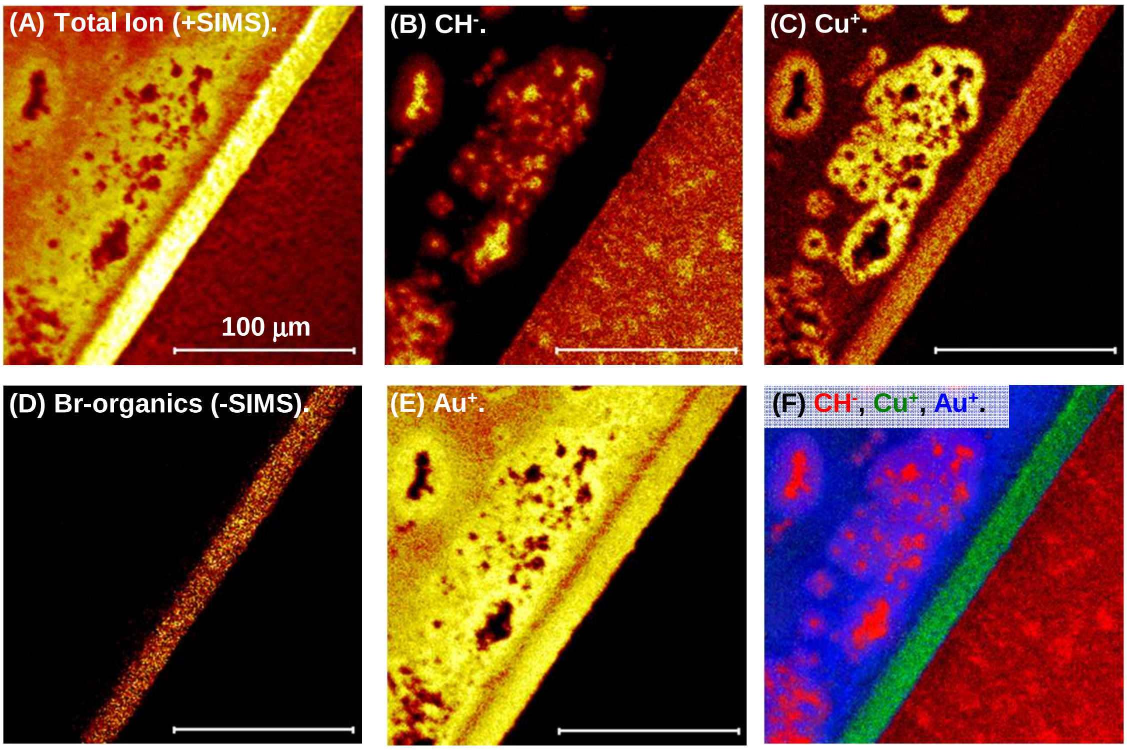


Figure 2. TOF-SIMS chemical images of the flexible interconnect device. Each image shows specific elemental or chemical distributions across the surface of the metal, the interconnect step edge, and the polymer film observed within a 200 µm x 200 µm field-of-view (the marker is 100 µm). The brominated organic fragments shown in panel (D) arise only at the step edge of the metal interconnect. Organic contamination is also observed on the surface of the metal interconnect. A false color overlay image of CH^- (red), Cu^+ (green) and Au^+ (blue) is given in panel (F). Note that the overlay image is composed of ion images from each secondary ion polarity which are in perfect registry.

Several elemental and organic ion images of the flexible interconnect device are presented in Figure 2 as well as a false color overlay image. The overlay image reveals the relative correlation of the organic and inorganic chemistries. Note that the overlay images are composed of ion images from each secondary ion polarity and are in perfect registry. It may be deduced from the ion images that the interconnect is composed of gold-coated copper. An organic component arising both from the polymer substrate and from surface contamination on the metal is overlaid in panel F along with the copper and gold components of the interconnect. The appearance of the organic signals on the surface of the interconnect, together with the higher elemental copper signal at the boundary of the organic contamination spots, is indicative of corrosion pits. The brominated organic species do not appear to play a role in the corrosion produced on the surface of the interconnect.

Conclusion: TOF-SIMS chemical imaging was performed using the PHI TRIFT V *nanoTOF* to evaluate corrosion on a flexible interconnect device. The large angular acceptance and kinetic energy focusing of the *nanoTOF*'s TRIFT analyzer is designed for efficient and uniform collection of secondary ion signals from all parts of rough and high aspect ratio samples in order to achieve reliable chemical imaging.

Physical Electronics USA, 18725 Lake Drive East, Chanhassen, MN 55317
Telephone: 952-828-6200, Website: www.phi.com

ULVAC-PHI, 370 Enzo, Chigasaki City, Kanagawa 253-8522, Japan
Telephone 81-467-85-4220, Website: www.ulvac-phi.co.jp