Etch endpoint detection in a batch-mode RIE typically relies on changing fluorescence in the plasma as the elemental composition of the exposed surface changes. Unlike batch-mode systems where processes occur as a function of time, in roll-to-roll systems, processes occur as a function of position, so different monitoring methods are required. Since the photopolymer etch mask and circuit materials are semi-transparent and comparable in thickness to the wavelength of visible light, the varying color of these films as material is removed gives information about the progress of the etching process. An experienced operator can readily judge the state of an etch process by examining the colors of the various layers. Removing an entire roll of material for inspection under a microscope is cumbersome and time-consuming, especially given the necessity of venting and pumping down the etch chamber. Logic therefore compels the placement of a microscope into the etch system itself.

Figure 1 Inspection microscope inside the roll-to-roll RIE system

A photograph of the microscope placed into the LIFE roll-to-roll -RIE system is shown in the illustration. The microscope consists of a 1600x1200 pixel CCD camera (Allied Vision Technologies), USB-controllable zoom and focus motors (Navitar), a 10x objective lens (Nikon), a fiber-optic illuminator and Matlab control software (Mathworks). The camera is capable of transmitting up to 30 frames per second via a FireWire connection. The Matlab software includes an autofocus algorithm based on the standard deviation of pixel values for coarse focus and a gradient-squared algorithm for fine focus. The magnification range of the complete optical system is from 10-65x, large enough to span the range of feature sizes and fields of view important to the RIE operator. The range can be modified simply by replacing the objective lens with any other infinity-corrected optic. The total cost of the optical system was kept to less than

$10,000, meaning that it would be feasible to install similar inspection modules on other process tools like the new roll-to-roll wet etcher.

In order to protect the optical system from the plasma, the entire unit is sealed inside a stainless steel can which is connected to the laboratory atmosphere via a conduit. The microscope looks at the web through a quartz window which may need periodic replacement. If the lifetime of the quartz window is problematic, the system can use a less reactive sapphire window instead. The web is tensioned over a roller which is placed directly beneath the microscope objective. Image resolution is limited by motional blur for a translating web and by chromatic aberration in the optics for a static one. The colors of SAIL features are easily discernible, allowing the RIE operator to judge the state of the etch process without venting the chamber and removing the roll.

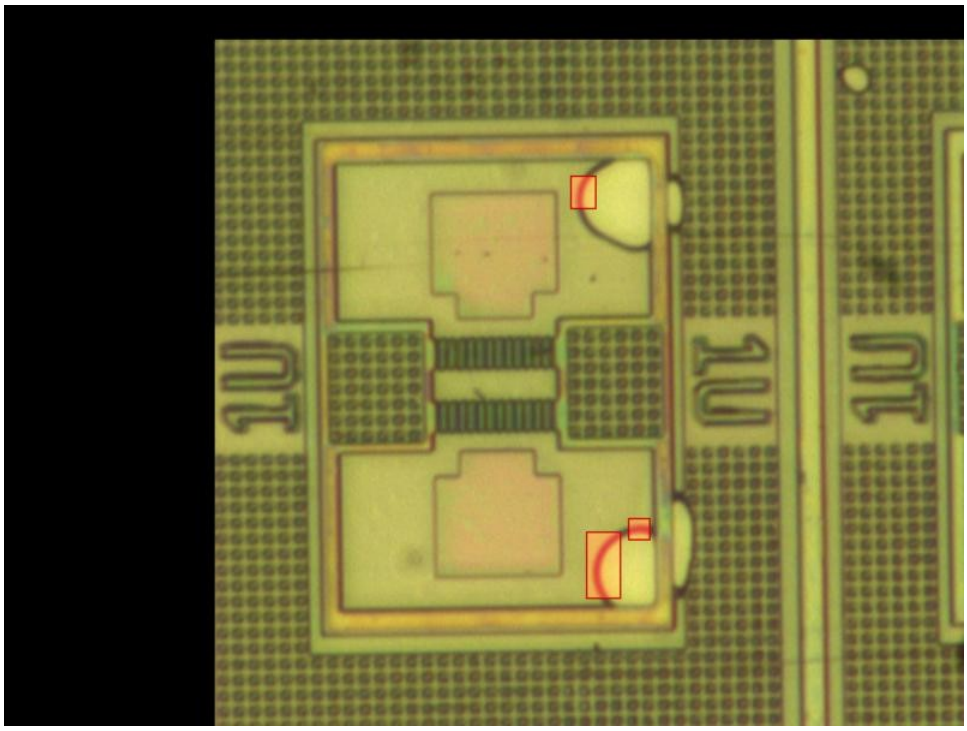

Figure 2 Image of bubbles in photopolymer imprint that have been flagged by defect identification software

For testing purposes, the microscope system was mounted on a small bench-top web-handling system and a series of images were acquired on an x-y grid using automated scanning software. A Matlab-based defect analysis software package created in-house was used to compare a template image of a transistor to the imprinted pattern. The figure shows some bubble defects in the imprint mask that were automatically flagged and counted by the software package.