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Microspheres give improved resolution in nondestructive examination of semiconductor devices

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Abstract
The minimum spatial resolution of typical optical inspection systems used in the microelectronics industry is generally governed by the classical relations of Ernst Abbe. Kwon et al. show in a new Light: Science and Applications article that using an additional glass microsphere in the optical path can improve the resolution signi cantly.

The rst comprehensive theory of image formation in microscopes was formulated by Ernst Abbe in the 1870s and 1880s[1]. The basic principle conceived by Abbe was that a regular pattern of parallel lines used as a test object can be imaged and resolved as a pattern distinct from an unpatterned object if the rst-order diffracted beams from the object are collected by the imaging objective lens. Abbe introduced the concept of "Numerical Aperture" (NA) to specify how far the objective lens was able to collect that diffraction pattern. The NA is the refractive index of the imaging medium (usually air, having refractive index close to unity) multiplied by the sine of the largest angle of light that can enter the objective lens; the simplest expression of the most important of Abbe's results is that the smallest possible resolution is given by the optical wavelength divided by the NA. For well over a century this principle has formed the basis of the design of all microscopes and inspection and metrology equipment used in microelectronics and other elds.

Optical objectives having NAs on the order of unity are widely available from the major precision microscope manufacturers, but values larger than that are rare without using special immersion oil having a refractive index higher than

The nanojet has width significantly smaller than would be expected using Abbe's classical theory, enabling sub-Abbe resolution (or "super-resolution") to be obtained. The exact mechanism of sub-Abbe resolution remains unknown, but super-resolution techniques using microsphere-assistance can be applied to diverse optical metrology systems such as interferometry and confocal microscopy[5,6].

The new paper by Kwon et al.[7] shows how these researchers were able to harness the super-resolution properties of a microsphere in a spectroscopic reflectometry system for microelectronics applications. Their paper is highly significant because previously such systems were limited by the Abbe criterion to examining features having minimum size roughly the same as the wavelength of the illuminating light, and in practice rather larger than that. A typical optical system uses white-light illumination at optical wavelengths of around 430–700 nm, and smaller features could traditionally not be examined. The authors used commercially available polystyrene or soda lime glass spheres to improve the resolution of their spectroscopic reflectometry equipment. They mounted a conventional objective lens (up to 100× magnification) on a piezoelectric actuator so that its position could be controlled automatically for the best results. Introducing the microsphere mounted on a micromanipulator so that