

# **"NUMERICAL APERTURE INCREASING LENS MICROSCOPY FOR QUANTUM DOT AND INTEGRATED CIRCUIT IMAGING"**

M. Selim Ünlü, A. N. Vamivakas, S. B. Ippolito, B. B. Goldberg

*Department of Electrical and Computer Engineering, Boston University,  
Boston, MA 02215, USA.*

We recently developed a new technique involving a Numerical Aperture Increasing Lens (NAIL) for diffraction limited subsurface microscopy. The NAIL technique is demonstrated by near-IR inspection of Si integrated circuits yielding a 230 nm resolution at 1050 nm wavelength representing a factor of 4 improvement over the state-of-the-art. The results will be reviewed along with a theoretical analysis of resolution limitation. Currently, we are trying to demonstrate the ultimate limitations of NAIL microscopy on optimized samples. We have also demonstrated applications in semiconductor failure analysis modalities including thermal imaging, light induced and thermally induce voltage alteration (LIVA, TIVA) techniques.

We also applied NAIL microscopy to photoluminescence and PLE measurements of InGaAs/GaAs quantum dots and demonstrated high collection efficiency and spatial resolution of about 300 nm. In contrast to conventional Solid Immersion Lens (SIL) techniques, the NAIL configuration moves the interface between sample and SIL away from the focal plane of the confocal microscope thus minimizing interface imperfections on image quality.

Not only does the NAIL technique increase the optical resolution of confocal microscope, but, by altering the geometry of the sample-air interface, it is possible to collect photons into our system that would have otherwise been reflected by the planar interface. We have measured a six fold increase in collection efficiency for our system when employing a GaAs NAIL. We are now trying to take advantage of the increased collection efficiency in applications where high signal-to-noise ratio is beneficial. Specifically, we are building a Hanbury-Brown Twiss (HBT) interferometer to do both auto-correlation and cross-correlation measurements on lines in QD spectra.