Technical Update

May 2010

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DCG's nanoInstruments division – the only nanoprobing solution down to 32nm and beyond

In February 2010, DCG Systems experienced a significant expansion as the result of an acquisition. Zyvex Instruments, located in Richardson, Texas is now the DCG nanoInstruments Division. This issue of our DCG Technical Update discusses the technologies behind this exciting new line of products.

The History of Nanoprobing at DCG

The integration of mechanical probes with vacuum-based analytical tools is not new to DCG. Back in the 1990's, when at the Diagnostic Systems Group of Schlumberger ATE, many customers requested the integration of mechanical probes into the vacuum chambers of the IDS 5000 and IDS 10000 E-beam probers. This led to the development of the Mechanical Probe-in Chamber (MPC) option, thus allowing simultaneous E-beam and mechanical probing of the device under test. Since E-beam probers were optimized for acquiring waveforms at the expense of image quality, it was still not possible to perform high resolution SEM imaging while simultaneously probing the device.

As diagnostic technology progressed beyond E-beam probing, the MPC was left behind as well. By the time DCG Systems was formed, the MPC had become a part of DCG's history.

The State-of-the-art in Nanoprobing

Although DCG's predecessor had abandoned in-chamber mechanical probing, others in the industry were bringing the technology to the leading-edge. Zyvex Instruments developed a sophisticated portfolio of nanoprobing solutions for nanoscale research labs across the world. The systems were used to characterize structures as small as 2nm double-walled carbon nanotubes. Zyvex recognized the need for these systems in the semiconductor industry as the

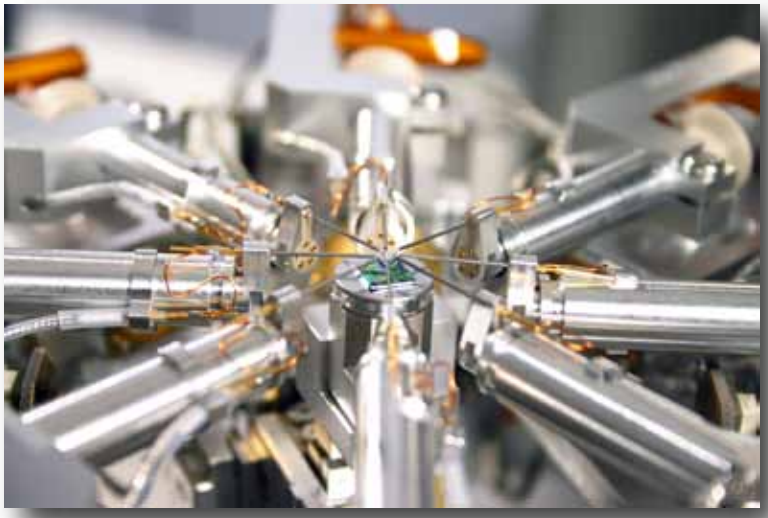
News and Events

Papers and Presentations

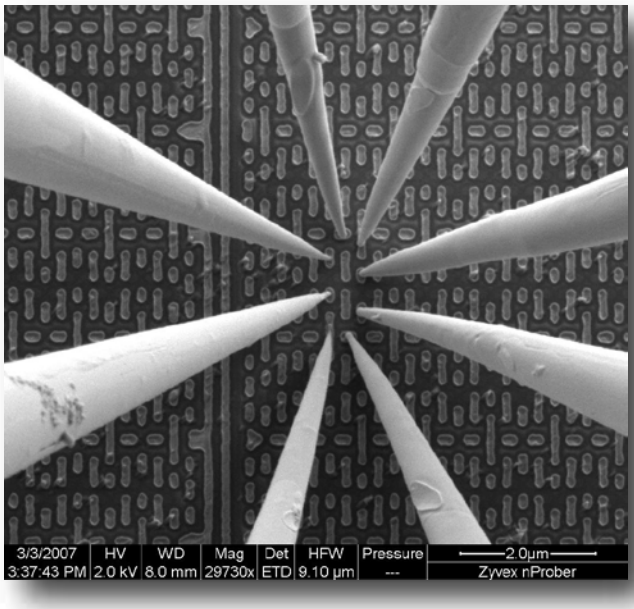
- **Selected as BEST PAPER at ISTFA 2009!** Rudolf Schlangen, et al., "Extended Circuit Edit, Analysis and Trimming Capabilities." Rudolf has been invited to present this paper at IPFA, 5-9 July 2010, Singapore
- Gupta, et al., "Physical Fault Isolation on Large Designs using a Hybrid Logical-to-Physical Cross Mapping Solution," (DCG and NVIDIA), SDD, 12 Mar. 2010, Dresden
- Scholz, et al., "Using focused ion beam for rapid solid immersion lens creation in backside silicon material," (DCG and Berlin University of Technology), FIB for Photonics, 6-7 Apr. 2010, United Kingdom
- Jain, et al., "Coaxial photon-ion column: applications and techniques," (DCG), FIB for Photonics, 6-7 Apr. 2010, United Kingdom
- Schlangen, "Lock-In Thermography for non-invasive failure analysis of a single die, packaged devices and complex 3D stacked die architectures," (DCG), EDFAS Golden Gate Chapter, 11 Mar. 2010, San Jose
- Scott, et al., "Novel Pulsed Spot Milling Technique to Extend Gallium Ion Beam Technology for Circuit Edit" (DCG and Intel), EIPBN, 1-4 Jun. 2010, Anchorage, Alaska
- Schmidt, et al., "Non-Destructive Defect Depth Determination at Fully Packaged and Stacked Die Devices Using Lock-in Thermography," (DCG and Fraunhofer Institute), IPFA, 5-9 Jun. 2010, Singapore

Publications

- Check the May 2010 issue of EDFA Magazine for articles on nanoprobing using DCG's nanoInstruments products.



A completely encoded, eight positioner nanoprober system (nProber).



Eight probe needles being use to characterize a 6T SRAM bitcell

technology shrank below the 130nm node. Nanoprobing became a must-have technology for FA labs dealing in these small geometries and Zyvex developed specific solutions to suit their needs. The first solutions were installable and removable platforms for users' existing E-beam systems. The product offering diversified to include complete door replacement platforms for higher throughput and ease-of-use. In 2006, Zyvex's experience culminated in the introduction of the *nProber*. The nProber is a semi-automated, complete nanoprobing system including the SEM and an unprecedented eight probes. Multiple systems are being used to characterize devices well below the 32nm node.

SEM-based nanoprobing returns to DCG

During the economic downturn, DCG took the opportunity to seek additional complementary technologies in order to grow our business. Zyvex Instruments turned out to be that perfect complement, with essentially the same customer base, but with no overlap with DCG's existing business.

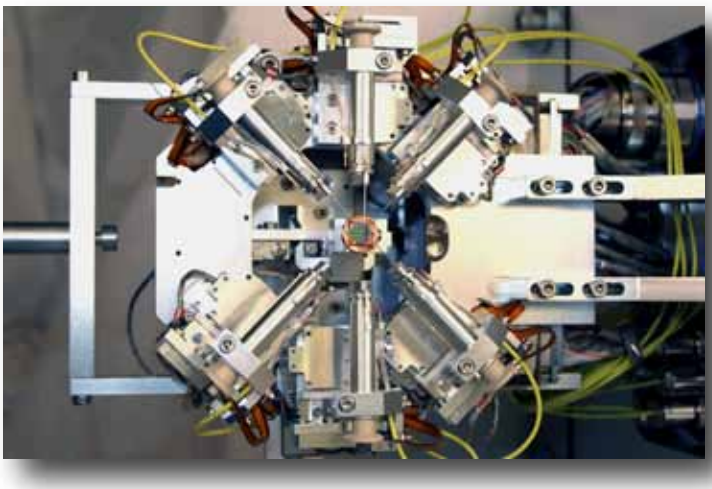
In identified failing bits, the SEM nanoprober is extremely valuable in determining the cause of non-visual failures. The SEM provides high resolution imaging, while the nanoprobes are used to individually characterize both passing and failing bits. In this type of analysis, the user probes six transistors in a reference bit and then six transistors in the failing bit.

The data is analyzed and a problem is found that points to a pair of contacts in a specific transistor. The transistor is cross sectioned and may then be moved to a Transmission Electron Microscope (TEM).

Keeping it clean

Experienced mechanical probe users know that there are factors that affect the accuracy of measurements. It is vital to make solid ohmic contact with the sample for accurate electrical characterization. The use of mechanical probes in a vacuum chamber eliminates many of the problems with oxidation that would occur in ambient. However, even in vacuum, there are still many factors which degrade measurement accuracy over time.

In an electron-beam system, there is an additional contamination threat. The interaction of the electron beam with volatile hydrocarbons present in the vacuum chamber results in the deposition of contaminants on



A door mounted, six positioner nanoprobing system to replace the SEM door (*dProber*).

A custom load lock allows devices to be inserted quickly into the systems.

surfaces. The options to the analyst to deal with these issues are not attractive, since they would involve changing the probe tips and somehow manually removing contaminants from the surfaces inside the chamber.

DCG's nanoInstruments group elegantly solved this problem by developing a technique and associated hardware which rigorously and thoroughly cleans the SEM chamber on a regular basis, thus ensuring that the probes and surrounding surfaces remain in optimal condition. The technique injects free radical oxygen into the vacuum system. This free radical oxygen effectively scrubs the chamber of potentially contaminating hydrocarbons before they have a chance to interact with the electron beam. This capability was accurately given the name *Optimizer*®.

The Optimizer can be run every time the chamber is exposed to air, every time a sample is exchanged, once in the morning, again in the evening, and whenever contamination begins to build up after a long probing session.

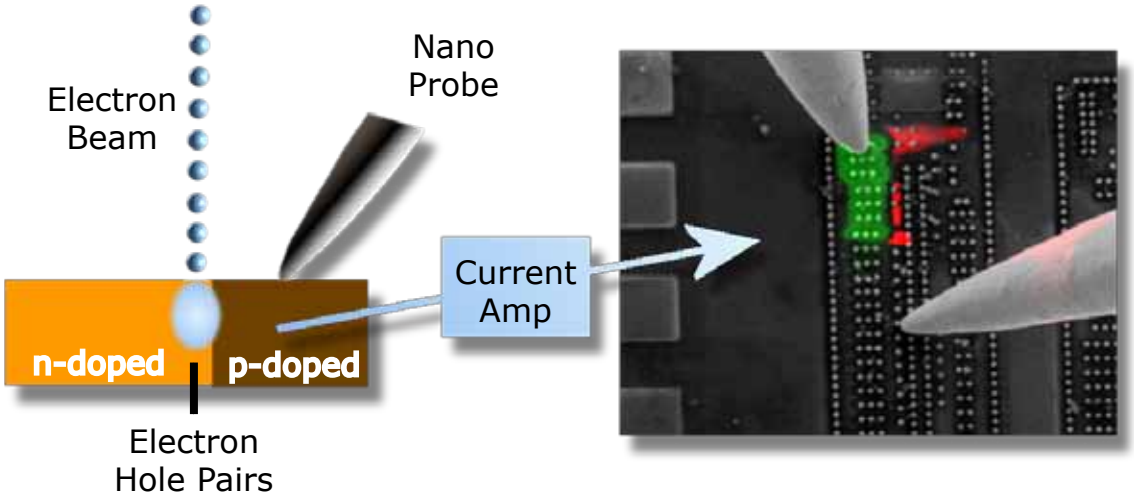
Electron Beam Induced Current

Nanoprobes may be used to perform Electron Beam Induced Current (EBIC) analysis. This technique is used to investigate the PN junctions and depletion regions in order to evaluate dopant levels and quality.

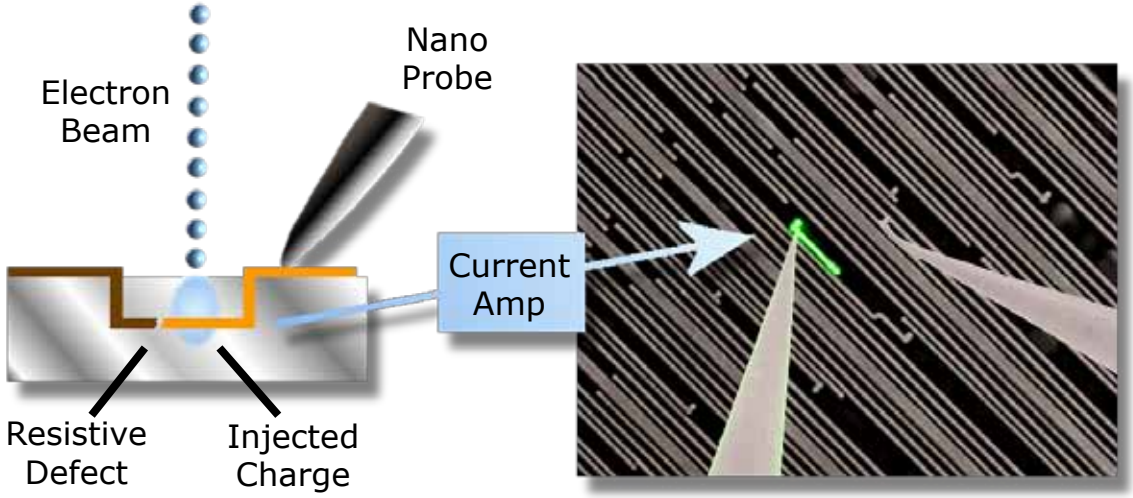
Electron Beam Absorbed Current

In-chamber nanoprobes used with an electron beam facilitate a number of useful analytical methodologies. One of these is Electron Beam Absorbed Current (EBAC), which helps locate breaks in metal lines that may be buried 3 or 4 layers deep. In EBAC, the nanoprobe is used as a current imaging device through a high gain amplifier. The end result is a form of active voltage contrast with femto-level sensitivity.

The finer points of probing

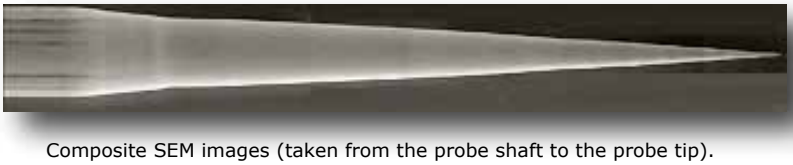


EBIC evaluates dopant levels at PN junctions and depletion regions.



EBAC characterization highlights opens in buried metal lines.

A nanomanipulator is only as good as the probe tip that it drives. It does no good to precisely position the probe, if the probe tip itself is not up to the task at hand.



Composite SEM images (taken from the probe shaft to the probe tip). The slender taper angle allows for probing small geometries.

There are two major challenges with probing at the nanoscale: probing small features (50 nm contact) and probing small geometries (four 50 nm contacts on a 50 nm pitch). The nanoInstruments division designed probes that overcome both challenges. With a probe tip radius of less than 50 nm, the probes also have a high length to diameter aspect ratio which allows up to 8 probe tips within a 500 nm workspace. These probes make nanoInstruments products the *only* nanoprobing solution for 32nm and beyond.

Spotlight on Japan Customer Service: Ichiro Kimura

Ichiro Kimura is DCG KK's Japan customer service manager. After his graduation from the Kanagawa Institute of Technology in 1990 with a Bachelor's degree in Electrical Engineering, Ichiro began his career with the Operation control division at Schlumberger's Fuchinobe office. As a customer service engineer, he supported the S700/S790 board testers until 1993. He then moved from board testers to providing support for IDS 3000 and IDS 5000 series E-beam probers.

The introduction of the IDS P2X Focused Ion-Beam system provided Ichiro with the opportunity to broaden his experience even further. With no prior FIB experience, Ichiro attended FIB training in San Jose and became determined to become an expert in FIB technology. With the help of Mark Antolik (who was featured in our Feb. Technical Update), Ichiro worked every night during the training period with the goal of becoming a FIB expert. Ichiro continued to gain experience on FIB equipment on the Simi Valley manufacturing floor as he assisted with the performance of FIB system acceptance.

Ichiro Kimura spends much of his time on the phone with customers and service engineers

Since moving to FIB customer support in 1995, Ichiro's passion for providing quality support has earned him a reputation among his customers as a "FIB guru." Sanyo sent a letter of appreciation to Ichiro praising his devoted support. Ichiro continued to support FIB products as the Diagnostic Systems Group moved from Schlumberger to NPTest, and then to Credence as the Diagnostic and Characterization Group. Ichiro worked with Credence's Japanese representative Noah for a period of time before rejoining DCG as part of the new DCG KK Japanese subsidiary. Throughout these transitions Ichiro continued to provide quality support for DCG products.

With the formation of DCG KK, Ichiro began serving as the customer service manager in Japan in order to share his experience with other service engineers. Despite his broadened responsibility, he still finds time to troubleshoot FIBs not only in Japan, but around the world as well. He is also a familiar face in some parts of the world outside of Japan, such as Korea, China and Taiwan. His efforts were significant in making DCG KK a profitable operation, with an extremely high level of customer satisfaction.

Ichiro and his wife Yuriko have two children and a dog. His day begins at 5:00 in the morning as he walks his dog "Koro." By 6:00AM he is on his two hour commute to reach the DCG KK office. Once there, he works from 8:00AM to 6:00PM before commuting back home, where he works another three hours every day.

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