APPENDIX
WORKSHOP AND PANEL DISCUSSIONS

The material presented in this appendix has been written by W. Murray Bullis for Gettering and by Dave Rogers for Gallium Arsenide. It is based on their best recollections. The material did not go through the review process and is presented for information only.

1. WORKSHOP ON GETTERING TECHNIQUES AND CHARACTERIZATION


The workshop on Gettering Techniques and Characterization included the interactions between extrinsic and intrinsic gettering mechanisms, consistent and reliable methods of producing gettering, and characterization of gettering related parameters. Of particular interest was the issue of what, if any, of the characterization methods should be standardized.

Extrinsic gettering mechanisms include those based on mechanical damage (such as abrasion, ion implantation, laser-induced damage, and wet or dry bead impingement), metallurgical deformation (such as polysilicon back surface films, interfacial germanium-rich films, and back surface nitride films), or adjustment of the electrochemical by phosphorus diffusions or phosphorus-rich oxides. Intrinsic gettering is most commonly associated with the presence of oxide precipitates but recently papers have appeared which suggest that oxygen is not required for intrinsic gettering.

Characterization issues include determination of gettering efficiency (by methods such as measurement of generation lifetime by MOS C-t techniques, scratch and
etch techniques, observation of S-pits, direct observation of impurity trapping, and device yields), precipitate characteristics (such as precipitation rates by oxygen reduction measurement, precipitate density by sectioning and preferential etching, and precipitate morphology by direct observation by TEM), and denuded zone width (by methods such as sectioning and preferential etching, infrared tomography, spreading resistance profiling to establish thermal donor distribution, x-ray topography, surface photovoltage, and thermal wave analysis). In addition, the issue of how to relate the effects of bulk defects to surface properties must be considered.

Bob Swaroop (then at Fairchild Semiconductor) opened the discussion by introducing a problem encountered in bipolar processing. The substrate was a medium doped p-type wafer with (111)-orientation and oxygen concentration of either 28-29 ppma or 32-33 ppma (old ASTM specification). Back surface gettering techniques used included mechanical abrasion, wet honing (bead impingement), and polysilicon film. After high temperature processing he observed stacking fault defects in both the bulk and epi layer (if present) for the higher oxygen cases except with polysilicon back surface gettering; such defects were not observed after low temperature processing, or after high temperature processing in low oxygen wafers or in the wafers with polysilicon back surface gettering. Despite considerable discussion of the possibilities, a model to explain these results did not evolve.

Murray Bullis described some results on the influence of a polysilicon back surface film on oxygen precipitation. The key result was that the presence of the polysilicon film enhanced the oxygen precipitation more than a simple heat treatment at the same temperature and time. This suggests that the film properties themselves are influencing the process in addition to the formation of oxide precipitate nuclei which occurs during the deposition process. The increase in precipitation is thought to result because the polysilicon acts as a sink for silicon interstitials, reducing the interstitial concentration in the bulk and thus favoring the precipitation process in which excess
silicon interstitials are generated.

Shin Takasu (Toshiba Ceramics) described the use of infrared tomography to view the oxygen precipitates in silicon. The work was a collaborative effort with K. Kashima (Toshiba Ceramics) and K. Moriya (Mitsui Mining and Smelting). One motivation in developing this technique was the possibility of eliminating the need to use chrome-bearing defect etches to reveal the defects. In this technique, an infrared beam is directed on the polished surface of a wafer cleaved along a \{110\} plane and the scattered light is observed through the cleaved surface. In the equipment described, the light is obtained from a YAG laser with a collimating lens and the cleaved surface is viewed by an infrared sensitive TV camera through a microscope objective. The spot examined may be scanned in three mutually perpendicular directions. Precipitates larger than 40 nm, dislocations and stacking faults serve as scattering centers. In a series of measurements on seven wafers with oxide precipitates and well-formed denuded zone widths than were indicated by the preferential etching method. Estimates of precipitate size and density could also be made. The measurement is rapid compared with other means for observing oxide precipitates and denuded zones and is sensitive to smaller precipitates than can be observed by defect etching or by x-ray topography.

George Rozgonyi (North Carolina State University) presented a report of the work of a student, D. M. Lee, on the use of structures with misfit dislocations for studying extrinsic gettering phenomena in epi wafers. These structures provide an ideal vehicle for such studies since they allow for the controlled introduction of the contaminating impurity (gold, nickel, iron, and copper were studied), a defect-free controlled thickness region (the epi layer or the wafer bulk) for diffusion, and a sink with known properties in a known location (the line of misfit dislocations near the epi-substrate interface). Patterned regions on the front or back surface were used to control the areas where the impurities were introduced. All four impurities studied have very high diffusivity; the controlling parameter is the solubility of the impurity. Solubilities of these four
impurities vary over about three orders of magnitude, thus accounting for observed differences in their behavior. TEM examination of the cross section of the structure after various heat treatments clearly revealed trapping of the impurities along the line of misfit dislocations.

Although several interesting points were discussed and some novel approaches for characterizing precipitates and gettering mechanisms were described, no clear preference for one or another technique could be established and no mandate for standardization of methods for evaluating gettering efficiencies or gettering-related phenomena emerged. Perhaps it is too early for such concerns to be sufficiently widespread to support development of standard methods.

2. WORKSHOP ON GALLIUM ARSENIDE

Chairman: Dave Rogers, Cominco Ltd.

The discussions in this workshop addressed the connections between GaAs wafer properties, and the properties of the devices made on them. The panelists included Robert Adams, Epitronics, Jerry Galt, Harris Microwave Semiconductor, Paul Golden, Monsanto Electronic Materials, W.N. "Bud" Jones, AT&T Bell Laboratories and Les Palkuti, ARACOR.

Paul Golden and Bud Jones both addressed the challenge of qualifying, and improving, the ion implant performance of GaAs wafers. Paul pointed out that these days wafer vendors are giving their boules a long anneal cycle. This smooths out the electrical inhomogeneities that occur during boule growth, thus removing the main cause of ion implant variation across each wafer and from the seed end to the tail end of the boule. He showed the data which indicated that the largest remaining source of ion implant variation is residual trace impurities in the boule. Removing these impurities is the major challenge for wafer producers today. Bud Jones supported these comments, and described the standard ion implant test which SEMI is designing for GaAs
Jerry Galt reviewed the work on rapid versus slow cooling of GaAs wafers to control their resistivity. Wafers cooled from 850°C to room temperature in less than an hour remain semi-insulating, while those cooled over several hours become conductive. Both phenomena are reversible.

Les Palkuti reported on newer methods for characterizing GaAs wafer surfaces: photon backscatter, damage delineation etch, sensitive stylus profiling, and scanning tunneling microscopy. Today's state-of-the-art GaAs wafers have a surface microroughness with a typical peak-to-valley height of 10 angstroms height over a wavelength of ~1 micrometer, plus a longer wavelength texture of 20 angstroms height over wavelengths of 40-100 micrometers. With the polishing technique during the past few months, there is no longer any sub-surface lattice damage on commercial wafers.

Bob Adams presented many examples to underscore the immediate need for standards in GaAs materials and device technology.