Macroscopic and Microscopic Photoluminescence Mapping System Applicable to 300 mm Wafers

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We have developed a unique system for photoluminescence (PL) mapping on semiconductor wafers. The system was designed particularly for characterizing silicon-on-insulator (SOI) wafers up to 300 mm in diameter. The features of the system are (1) capability of ultraviolet (UV) to near infrared (NIR) laser excitation, (2) monochromatic detection of PL light in the wavelength region ranging from 400 to 1700 nm, and (3) macroscopic mapping of a full wafer up to 300 mm in diameter and microscopic mapping of a particular region of interest under a resolution as high as 1 μm.

PL occurs as a result of the radiative recombination of optically excited carriers. The excited area is determined by the beam size and the penetration depth of the light. The penetration depth of UV light in Si is 5 - 10 nm, which allows us to excite only the ultrathin top Si layer (100 - 200 nm). The excited carrier cannot diffuse into the substrate because of the presence of the buried oxide layer. This is the key advantage of the UV excitation in SOI wafer characterization. The intensity variation of the band-edge emission reflects the distribution of crystalline and interfacial defects [1].

The apparatus consists of a sample stage, lasers, a microscope, and light detection system; a schematic illustration is shown in Fig. 1. The stage was made of granite, and had an X-Y air-bearing-slide mechanism driven by linear motors. We were able to perform macroscopic mapping on a full wafer of 300 mm diameter as well as microscopic mapping on a particular area of interest with position-repeatability as high as ± 0.3 μm. We used a variety of lasers with wavelength ranging from deep UV to NIR (266 -1064 nm). The laser beam was focused on the sample surface through an objective of the microscope with a diameter of 1-10 μm for microscopic mapping. The beam was irradiated sideways with an incidence angle of 30° and with a diameter of 100-1000 μm for full wafer mapping. PL light was collected by the objective, and passed through the dichroic mirror to block the laser light, through the iris to improve the spatial resolution, and then through the bandpass filters to extract a specific spectral component. We prepared four objectives and four dichroic mirrors, according to the wavelength of the laser. The resultant light was detected by a cooled photomultiplier (Hamamatsu R5509-72). The wavelength region for the PL detection ranged from 400 to 1700 nm.

Preliminary data of wafer mappings on a commercial SOI wafer are shown in Fig. 2. The wafer was a 200 mm Unibond® wafer with a top Si layer thickness of 204 nm, and was thermally oxidized with an oxide layer thickness of 10 nm. The band-edge emission from the top Si layer and that from the substrate were obtained under the UV and visible laser excitation, respectively, as shown in (a) and (b). A clear oxygen striation pattern was observed in (b), which was the result of the nucleation and growth of the oxygen precipitation during thermal treatment of the Smart-Cut® process [1]. Although the striation pattern was not observed in the top Si layer, some irregularity was recognized. Microscopic mapping on a dark spot area in the upper middle part in Fig. 2(a) is shown in Fig. 3. We will report our detailed investigation on the nonuniformity of the state-of-the-art SOI wafers in a forthcoming paper. The present system is also very powerful for PL analysis of wide bandgap semiconductor materials.

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[1] M. Tajima and S. Ibuka: Semiconductor Silicon 2002, Vol. 2, p. 815 (Electrochem. Soc., Pennington, 2002).

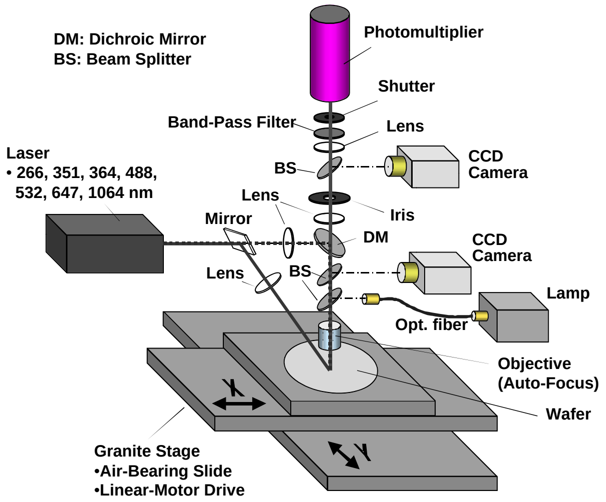

Fig. 1. Schematic illustration of PL mapping system.

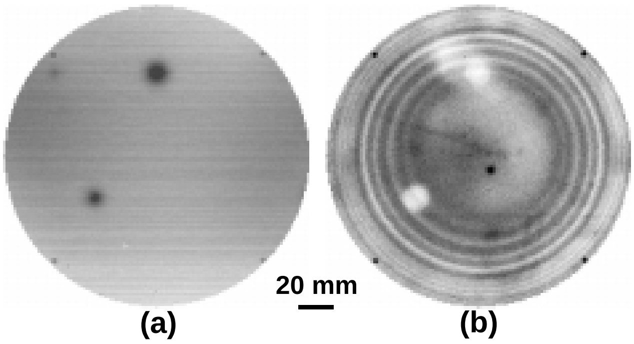

Fig. 2. PL mapping on 200 mm Unibond® wafer: (a) top Si layer and (b) substrate. Whiter regions indicate higher intensity.

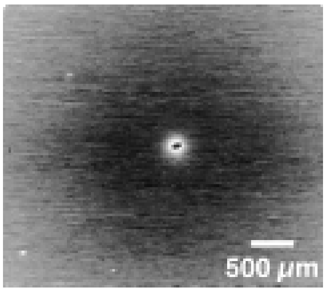

Fig. 3. Microscopic PL mapping on a dark spot area in the upper middle part in Fig. 2(a)