PHOTON-TO-ELECTRON CONVERTER WITH 1 PPM QUANTUM DEFICIENCY

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1. ABSTRACT

An ordinary silicon photodiode is a photon-to-electron converter with a conversion efficiency of 99.8% in optimal conditions. The internal losses of 2000 ppm are mainly caused by recombination of electron-hole pairs close to impurity atoms in doped silicon. Doping is used to create the *p-n* junction of the photodiode. The challenge of designing a photon-to-electron converter with almost ideal efficiency is then to produce the *p-n* junction in highly pure silicon substrate without any intentional impurity doping.

The solution[1] to this problem is proposed as a thick silicon oxide layer grown on a high purity *p*-type silicon wafer with target impurity concentration as low as 10^{11} cm^{-3}. The oxide layer has a trapped surface charge of 10^{11} to 10^{12} e/cm^2 at the Si/SiO$_2$ interface producing an induced *n-p* junction.[2-4] The device is biased at about 10 V and operated in vacuum close to liquid nitrogen temperatures behind a Brewster-angled window. According to simulations, the internal quantum deficiency of 1 ppm should then be achieved, promising an improvement of three orders of magnitude over the photodiodes used earlier. Furthermore, we have designed detector structures[5,6] which can be used to eliminate photon losses due to reflection down to the ppm level.

This contribution reports on experimental results obtained with the new type of photodiodes produced within a joint European project.[7] Haze measurements of the processed wafers indicate that diffuse reflectance from the photodiodes is well below 1 ppm (see Fig. 1). The grown oxide layer and other wafer processing steps contribute only moderately to the scatter level of the photodiodes when operating in a high-quality clean room. Results on further test measurements will be presented in the conference.

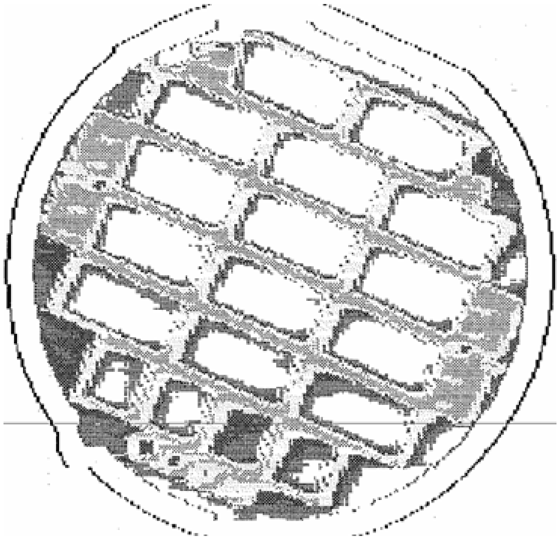

Figure 1. *Result of a scatter measurement of a processed silicon wafer. The grey area indicates high scatter from the implanted electrodes and white area low scatter from the surface of the photodiodes. The wafer is 100 mm in diameter and the photodiode dimensions are 11 x 22 mm2 and 11 x 11 mm2. In addition, there are test structures for surface charge and leakage current measurements. This important measurement result shows that the increase in haze from the surface of a large-area photodiode is within a factor of two as compared with an unprocessed reference wafer of the same type. The result allows use of a simple two-photodiode structure for further photon-to-electron-converter tests, as described in Ref. 6.*

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