Rapid and Contactless Implantation Damage Analysis by a Microwave Diagnostic

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Rapid thermal annealing (RTA) of lattice damage created by heavy ion implantation is required to maintain the integrity of semiconductor material used for submicron-integrated circuit devices. A quick but sensitive indicator of the implantation damage removal is highly desirable for the integrated-circuit production environment. A new recombination lifetime measurement technique has been recently applied to this problem; the technique is called resonance-coupled photoconductive decay (RCPCD) and uses a deeply penetrating, low-microwave frequency probe (0.5 to 1.0 GHz). The lifetime is extremely sensitive to recombination at damage sites. The procedure is an extremely sensitive, contactless, and quick (less than 1 second) technique, making it readily applicable to an on-line diagnostic. We have applied this technique to an evaluation of implantation damage in both boron and arsenic-implanted silicon wafers. Variable angle scanning ellipsometry indicated that the optical constants of the damage region are intermediate between those of amorphous silicon and crystalline silicon. The photoconductive signal occurs in the volume of the intersection of microwave and optical beams. Using a tunable optical excitation source, we have used short excitation wavelengths (~700 nm) to selectively excite the near-surface region (top 5 µm), which accentuates the influence of the damaged region. We have found a strong correlation between the inverse initial decay time and the leakage current of finished devices.

The figure shows the result of RCPCD measurements on p-type wafers. The p-type 150-mm <100> wafers and were prime semiconductor wafers. We grew a 100-Å thermal screen oxide, and implanted with arsenic using a 50-keV source and a wafer tilt of 0 degrees. The implantation dose was 2.4×10^{15} arsenic atoms/cm^2.

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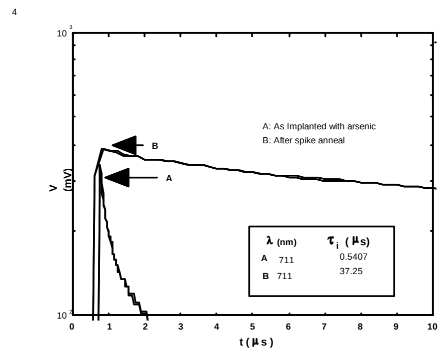

The data (Curve A) shows transient photoconductive decay with an initial (t=0) lifetime of about 0.54 µs for the as-implanted wafer. The photoresponse is dominated by the crystalline volume that is illuminated by the 711 nm radiation that penetrates the damage layer. As the carrier mobility is very low in the damage layer, we do not expect to see comparable photoconductive signals from that region. After a single "spike" anneal, the data in curve B show that the initial lifetime increased by a factor of 68 to 37µs. Measurements on finished devices show that the leakage current varies inversely with the initial 711 nm lifetime. A comprehensive analysis of the data gives a bulk lifetime of 127 µs and a damage layer lifetime of 10.8 ns. The latter increases to over 30 µs after the spike anneal. The conventional rapid thermal anneal produced similar results, in surface lifetime improvement.

Similar results were found for BF_2 implanted n-type wafers.

In summary, we have shown that the RCPCD method is very sensitive to the damage in the implanted region. As RCPCD measurement is contactless and the measurements are made in less than 1.0 seconds, it is a very attractive candidate for an on-line diagnostic.