with the sample grown on the Si substrate implanted with higher energy. This is in agreement with the TEM data that stronger interaction with misfit dislocations was observed for the sample implanted with lower energy, which facilitated He bubbles formation closer to the Si surface. This study showed that the substantial improvement in structural quality was obtained following the procedure described in this invention. Because the lattice mismatch and difference in thermal expansion coefficient between Si and GaN (and also AlN) is so large, a complete removal of threading dislocations is practically impossible, but the quality of the GaN layers obtained by application of this growth procedure is remarkably high and comparable to the structural perfection of GaN grown on Al_2O_3.

Summary

For the first time, it has been shown that misfit dislocations formed at the GaN/AlN/Si interface can interact with a strain field formed around He bubbles created in He implanted Si which allow redirecting of the misfit dislocations into the Si substrate instead of the epi-layer. It was found that an implantation fluence of (1×10^{16} cm^{-2}) at 15 keV, which forms He bubbles 120 nm from the interface, gave the best results. Too small or too large a distance of the bubbles from the interface does not lead to the desired interaction with misfit dislocations formed during the growth of AlN buffer layer. Placement of bubbles further from the interface at 240 nm (keeping the same implantation fluence) still works, but the density of redirected dislocations is smaller. This study also showed that in order to form He bubbles, a low growth temperature for the AlN layer is required. Pretreatment of the Si surface at high temperatures in order to get a 7×7 reconstruction (a proof of a clean surface) cannot be used because He bubbles diffuse to the interface and do not produces a strain field dislocation loops around them to attract interfacial dislocations.

This study also shows that in order to improve structural quality (in addition to redirecting the dislocations to the substrate) the proper cleaning procedure of the Si substrate and a well-defined growth temperature (a temperature at which He bubbles do not propagate to the substrate surface) needs to be applied. Our recent results show remarkable structural quality of GaN grown on He implanted Si in that are no cracks and grain diameter is comparable to that observed for samples grown on Al_2O_3, despite the large lattice mismatch and differences in thermal expansion coefficient.

REFERENCES

Reference to one or more of the following publications may provide context and/or assist in a better understanding of the invention described and claimed herein. Pertinent portions of the following references as cited herein are incorporated by reference:

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CONCLUSION

Misfit dislocations are redirected from the buffer/Si interface and propagated to the Si substrate due to the formation of bubbles in the substrate. The buffer layer growth process is generally a thermal process that also accomplishes annealing of the Si substrate so that bubbles of the implanted ion species are formed in the Si at an appropriate distance from the buffer/Si interface. In this way the bubbles will not migrate to the Si surface during annealing, but are close enough to the interface so that a strain field around the bubbles will be sensed by dislocations at the buffer/Si interface and dislocations are attracted by the strain field caused by the bubbles and move into the Si substrate instead of into the buffer epi-layer. Fabrication of improved integrated devices based on GaN (including GaN, InGaN or AlGaN) grown on Si, such as continuous wave (CW) lasers and light emitting diodes, at reduced cost is thereby enabled.

Although the foregoing invention has been described in some detail for purposes of clarity of understanding, certain changes and modifications will be apparent to those of skill in the art. It should be noted that there are many alternative ways of implementing both the process and compositions of the present invention. Accordingly, the present embodiments are to be considered as illustrative and not restrictive, and the invention is not to be limited to the details given herein.