Aalto University

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Looking for missing and foreign atoms around the lattice in novel semiconductors

Title of the dissertation	Point defects in oxide and nitride compounds, alloys and heterostructures
Contents of the dissertation	What do all novel semiconductors have in common irrespective of level of their complexity or how promising they are for real-life applications? One certain answer to this question is point defects such as missing or foreign atoms within the lattice structure. With positrons it is possible to peek into crystalline matter without any special sample preparations and try to identify some of its point defects. There are no appealing high-resolution photos produced, but instead we may qualify and quantify those defects considering growth conditions and treatment methods of technologically important semiconductors. State-of-the-art theoretical calculations of positron-electron annihilation support this endeavour. This doctoral dissertation deals with point defects in oxide and nitride semiconductors. The observation of zinc vacancies and vacancy clusters in zinc oxide upon doping and post-growth treatment aids to select preferred parameters when preparing large-area substrates. Similarly, the ability of a beryllium dopant atom to move from a substitutional site to an interstitial leaving behind a gallium vacancy and back observed in gallium nitride is of practical importance for processing conditions in nitride-based electronics. The correlation between cation vacancy concentration, doping and indium to gallium ratio found in novel transparent semiconducting oxide $(In_xGa_{1-x})_2O_3$ paves the road for future investigations of material properties and applications. The practical risks for devices designed to operate at extreme conditions such as extraterrestrial radiation are investigated for another three-component system, this time the nitride semiconductor $In_xGa_{1-x}N$. Finally, positrons allowed to resolve a nearly ten-year quest of hole traps located at one of the interfaces in N-polar nitride heterostructures. It was possible to identify the reason limiting the performance of unoptimised devices – which turned out to be nitrogen vacancies. This is the first direct observation of anion vacancies in nitride systems of this kind. No photos were taken, but most of the missing atoms were identified and counted. No samples were destroyed.
Field of the dissertation	Engineering Physics
Doctoral candidate	Vera Prozheeva, M. Sc.
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Custos	Professor Filip Tuomisto, Aalto University School of Science, Department of Applied Physics
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Doctoral candidate's contact information	Vera Prozheeva, Department of Applied Physics, vera.prozheeva@aalto.fi