Modern power devices made of silicon are the mainstream but they are approaching fundamental performance limitations, making the commercial power systems bulky and inefficient. A new generation of power devices based on the wide-bandgap (WBG) semiconductor, gallium oxide (Ga_2O_3), is expected to revolutionize the power electronics industry. The monoclinic β-phase is thermally stable with reported bandgap values in the 4.6 - 4.9 eV range, depending on the specific crystal orientation and measurement method. It is promising material for extreme environment (high temperature, high voltage, and high radiation) electronics and has been experiencing a renewed interest due to its many attractive physical properties: (i) the theoretical breakdown electric field is 3.5 times larger than that of SiC or GaN, which enables β-Ga_2O_3-based devices to handle gigantic switching voltages; (ii) the conduction loss of β-Ga_2O_3 is reduced significantly as compared to SiC and GaN; (iii) the saturation electron velocity making it alluring for high-frequency operations. Another distinctive interest of β-Ga_2O_3 among WBG semiconductors is that high-quality single crystals can be synthesized cost-effectively using melt growth techniques. In addition, high-quality *n*-type epitaxial films can be realized via precise doping with Sn, Si, Ge, and Mg. Many promising β-Ga_2O_3-based devices have been reported, for instance, Schottky barrier diodes, MOSFETs, and various types of solar-blind photodetectors. Actually, the development of Ga_2O_3-based transistors has focused on a lateral geometry. However, lateral devices are not amenable to the high currents and high voltages required for many applications owing to large device areas and reliability issues arising from self-heating and surface instabilities. Opposite to that, the vertical geometry allows for higher current drives without having to enlarge the chip size, simplified thermal management, and far superior field termination. The properties of a vertical transistor switch are engineered by introducing two types of impurities (dopants) into the semiconductor - *n*-type doping, which provides mobile charge carriers (electrons) to carry electrical current when the switch is in the on-state; and *p*-type doping, which enables voltage blocking when the switch is in the off-state. Wong *et al.* proposed to use Si as *n*-type dopant in Ga_2O_3 devices, but the research community has long struggled to identify a suitable *p*-type dopant. As is well known, *p*-type doping in Ga_2O_3 is fundamentally difficult because of the very flat valence band maximum of O 2*p* in nature and self-compensation. However, the feasibility of N to serve as *p*-type dopant was investigated by Prof. Higashiwaki group of NIICT, Tokyo, Japan. According to their report, N is much more thermally stable compared to Mg (this dopant failed to deliver its expected performance since it diffuses significantly at high processing temperatures), thereby creating unique opportunities for designing and engineering a variety of high-voltage Ga_2O_3 devices. Latest accomplishment of Prof. Higashiwaki group involves integrating Si and N doping to engineer a Ga_2O_3 transistor for the first time, through a high energy dopant introduction process known as ion implantation. Ion implantation is a technique widely adopted in the mass production of commercial semiconductor devices such as Si and SiC MOSFETs. The demonstration of an all-ion-implanted vertical Ga_2O_3 transistor greatly enhances the prospects for Ga_2O_3-based power electronics. Thus, ion implantation can be used for channel/contact region doping and device isolation. Implant isolation is a method of using ion implantation of either electrically inactive or deep level impurities to produce electrically insulating regions that can be used for inter-device isolation. Knowledge about it is crucial in context of contacts performance improvements as well, because, one of the challenges for Ga_2O_3 application, for instance in MOSFET devices, is the difficulty in forming Ohmic contacts compared with NBG semiconductors. An excellent Ohmic contact between the semiconductor and the metal electrode is essential for high-performance semiconductor devices. Generally, in WBG semiconductors, Ohmic contacts are typically realized by metal-semiconductor structures in which the potential barrier is reduced by heavily doping the semiconductor under the metal, which enhances electron tunneling. For Ga_2O_3 implantation of Si, an increase of surface conductivity has been usually employed to achieve acceptable contact resistance.

Understanding the physical properties of defects and impurities in Ga_2O_3 and in turn controlling them are crucial for increasing device performance. They affect material properties critical to device operation (output power, breakdown voltage, carrier mobility by scattering and trapping effects, luminescence, and charge-trapping) and a mandatory for *p*-type doping. Under this Project doping Ga_2O_3 with both shallow donors (Si) and deep acceptors (N) by ion implantation is proposed with efficient dopant activation. In the as-implanted stage, most of the dopants are electrically inactive and therefore, the post-implantation annealing leading to the recovery of the crystal structure and so call dopant activation is necessary. In the case of Ga_2O_3 the mechanism of post implantation defect buildup is completely unknown. The processes of ion implantation and post-implantation annealing in Ga_2O_3:Si/N adds to the complexity of the problem allowing reorganization and/or creation of even further complexes around selected implanted ions during annealing. Thus, better understanding of dopants and defects, lattice location of dopants and insight the role of native defects and their role in residual conductivity relative to extrinsic impurities is desperately needed since all above impact on electrical conductivity, mobility, and optical properties. This understanding, in a further perspective, should allow device fabrication based on a manufacturable all-ion-implanted process resembling that for MOSFETs. In addition, the obtained knowledge might lead to more efficient electronic devices which could operate under harsh conditions.