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Study on ZnO source using non-neutral plasma trap

非中性プラズマトラップを用いた酸素脱離のない ZnO 源の研究

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As one of applications of our Penning-type trap having both positive and negative electrostatic potential wells, we consider to use it to make the semiconductor ZnO, especially pure ZnO clusters or perhaps quantum dots for p-type conduction. Several numerical calculations are performed (Y. Nishioka, H. Himura *et al*., 24G15 in this conference.) Regarding the experimental machine, an equipment that introduces oxigen gas into the vacuum chamber is now ready. A source of zinc particles, on the other hand, is still under consideration. Principles and objectives of this proposed project are explained.

1. Next generation compound semiconductor

GaN and ZnO are compound materials that are categorized in wide band gap semiconductors. In the research field of GaN, plasma processing has already been recognized as one of key technologies.

As for ZnO, during the last several decades, optical properties and processes in zinc oxide (ZnO) as well as its refractive index have been extensively studied. Recently, the renewed interest in ZnO has been fuelled and fanned by prospects of its potential applications in optoelectronics owing to its direct wide band gap (E_g ~ 3.3 eV at 300 K), large excitation binding energy (~ 60 meV), and efficient radiation recombination.

For the purpose of developing new optical devices such as a blue light-emitting diode (LED) that is composed of ZnO-based structures with no use of rare metals, ZnO is required to grow into a uniform size of high-quality bulk ZnO cluster that has a unit of about $(ZnO)_{n=1000}$ structure with low impurity concentration.

2. Inherent problems of current processing

Although many reports dealing with deposition of ZnO have utilized industrial growth techniques such as magnetron sputtering with/without radio frequency (RF), chemical vapor deposition (CVD), they allow no control of ZnO particles over the deposition procedure, probably too insufficient to produce uniform and high-quality ZnO bulk clusters. Other methods of molecular beam epitaxy (MBE) and pulsed laser deposition (PLD) and so on are also extensively applied, depending on the chemistry used. However, any mechanical pieces provided for those facilities are hardly cheap, which is obviously unfavorable if we intend to apply those to industrials. Also, since in all methods working gases are directly introduced in vacuum reactors, we can never avoid difficulties due to residual background neutrals. A new method for the growth of ZnO clusters is thus called for.

3. The proposed experiment; Penning-type non-neutral plasma trap may work as a new plasma processing

In our laboratory, we have constructed a new Penning-type trap that contains a pair of positive and negative electrostatic potential wells in the vacuum chamber [1]. Also, the electric field along with the bias magnetic one (~ 1 kG) is completely static. Thus, any heating of charged particles due to AC electric field is never caused, which, in fact, may be a possible reason why larger Si clusters beyond n = 10 were never produced in a Paul trap [2].

The Penning-type trap may work as new plasma processing without impurity. If an ionized ZnO particle (ZnO^+) or just Zn^+ along with neutral ZnO particles can be externally injected into the static fields, the injected ZnO^+ or Zn^+ would be trapped in the bottom of positive potential well for a long time according to the conservation of angular momentum. On the other hand, in the bottom of negative electrostatic potential well, negative oxygen ions O- or O2- could be confined. Those charged particles attract each other, and moreover, the ion cluster does even neutral species of ZnO, too. Finally, those may grow into a $(ZnO)_n$ cluster via a condensation process.

In order to test the possibility of the Penning-type non-neutral plasma trap, we plan to perform several preliminary experiments. In this conference, we will discuss principles and objectives of those experiments.

References

[1] Y. Nishioka *et al*., 22C01 in this conference.
[2] H. Murakami and T. Kanayama, Appl. Phys. Lett. **67**, (1995) 2341.