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Transmission Electron Microscopy Studies of Pure Wurtzite Gallium Arsenide and Zinc Blende Gallium Arsenide Nanowires Using Recombination Process

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ABSTRACT

The transmission electron microscopy studies of pure Wurtzite Gallium Arsenide and Zinc blende Gallium Arsenide was made. The nanowires contain one Wurtzite segment and one Zinc blende segment and have sharp interfaces between the two segments. The nanowires are coupled to increase the luminescence yield. We have studied the nanowire using both photo-luminescence and transmission electron microscopy in order to correlate the structural and optical properties. A valence band offset of about 90-100 mev was found using the energy range over which peaks shifted. We have found that the band gap of Wurtzite Gallium Arsenide and Zinc Blende Gallium Arsenide were very close to each other both in Cathodo luminescence on the heterojunction samples and in photoluminescence on the control samples. Wurtzite Gallium Arsenide emitted much less than Zinc blende Gallium Arsenide, despite belonging to the same nanowire and having been grown under similar conditions. A low density of stacking defects in Wurtzite Gallium Arsenide did not affect the photoluminescence to any significant degree. The obtained results were found in good agreement with previously obtained results.

KEYWORDS

Transmission, Microscopy, Wurtzite, Zinc Blende, Nanowire, Interface, Coupling, Photoluminescence, Hetrojunction.

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INTRODUCTION

Caroff et al. [1] studied that nanowires be grown in either the Wurtzite or the Zinc blende crystal phase, despite the fact that only the zinc blende phase was found in bulk for non-nitride III-IV groups materials unless grown under non equilibrium conditions and high pressure [2]. This opened up even more possibilities for band structure and hetrojunction engineering. Band gap of the Wurtzite crystal phase of Gallium Arsenide was to be studied. The experimental determination of the Wurtzite Gallium Arsenide band gap ranges from 1.44 ev to 1.54 ev [3-7], whereas ab initio calculation resulted in band gaps between 1.38 ev and 1.81 ev [8-10]. Even less was known about the properties

of hetero junction between Wurtzite and Zinc blende III-IV material, where the valence band offset is the fundamental parameter. Kutanananda et al. [11] and Belabbes et al. [12] studied that the heterojunction between Wurtzite Gallium Arsenide and Zinc blende Gallium Arsenide was type II with the band edges of zinc blende Gallium Arsenide being about 100 mev lower in energy than the band edges of Wurtzite Gallium Arsenide. Hu et al[13] and Thewalt et al. [14] studied that the potential discontinuity in type II hetrojunctions caused a spatial separation of the charge carriers, where electrons were confined in one material and holes in the other. This gave rise to unusual photoluminescence behaviors, such as strong energy dependence of emission peaks as a function of excitation power density and long carrier life times even if the constituent materials have a direct band gap [15]. Duan et al. [16] studied semiconductor nanowires grown using III-IV groups materials having a potential to become building block elements for electronic and optoelectronic devices. One of them attractive properties was the possibility to combine highly lattice mismatched materials without structural defects[17], allowing feasible designed rules for band structure engineering. Lehmann etal[18] studied that nanowires were coupled by $Al_xGa_{1-x}\left(x \approx 0.2\right)$ in order to increase the luminescence yield. Burstein [19] and Moss [20] presented that the highest excitation power densities the band emission blue shifts were found due to state filling i.e. a Burstein Moss shift. Capiod et al. [21] presented that the Fermi level pinning to AlGaAs layer, density of states there was no quantitative model. Efroni et al. [22] studied the properties of carbon nanotube through phase transition using strain or a magnetic field. The soliton states carrying fractionalized charges, similar to domain wall in the Su-Schrieffer-Heeger model in a setup with a spatially inhomogeneous strain and an axial field. The fractionalized states were formed at the interface between regions with different strain, a spin charge separated states with integer charge and spin zero and a state with charge $\pm\frac{e}{2}$ and spin $\pm\frac{\hbar}{4}$. It was found that precise quantization of the fractionalized interface charged was a consequence of the symmetry of the carbon nanotube under a combination of spatial rotation by π and time reversal. Noury et al. [23] studied phase transition using helium recognized model system. It was found that measurements on super fluid helium films adsorbed on the surface of suspended carbon nanotube. It was measured the mechanical vibrations of the nanotube to probe the adsorbed helium film. It was found that helium multilayers adsorbed on a nanotube were of un-precedent quality compared to previous results. Nyeki et al. [24] studied when exposed graphite to a helium vapor at low temperature, a helium film formed on the graphite surface. It was found that there were successive layering transitions between layers *n* and (*n*+1). Menachekanian et al. [25] presented that despite of the modest quality of these surfaces growth layers were visible discontinuous. Chalin and Rocha [26] studied the shift of transition energies with respect to the values in pristine single walled nanotubes. It was found that the Rayleigh spectrum of the double walled carbon nanotube contained additional peaks. When tight binding approximation was used it was found that in specific double walled carbon nanotubes the interlayer coupling was slightly modified the band structure of pristine nanotubes in such that the unconventional intertube electronic transitions became possible and additional peaks in the double walled carbon nanotubes appeared. Rochal et al. [27] studied the incommensurate nature of double walled carbon nanotubes. The incommensurability together with the curved geometry and structural diversity of double walled carbon nanotubes resulted electronic properties for various applicatons [28-29]. Lu et al. [30] considered self consistently the coulomb renormalized Rabi coupling to light by using an induced optical depolarization field, corresponding to dynamical exchange interaction between two electrons within same quantum dot. Which gave rise to indirect transition of electrons for sum and difference transient optical response. This study is useful for controlling the phase entanglement of quantum dots and enhanced the electro-optical in transitions. Papari and Fomin [31] studied using Ginburg Landau theory used to model the parameter of a finite size mesoscopic ring to effects of the onset screening currents on the transport incoming ones. It was found that the magnetic flux broke the symmetry of currents between input

and output stubs on an induced spatial ordering upon diamagnetic and paramagnetic super currents circulating in the ring.

METHOD

For the study control sample of Wurtzite Gallium Arsenide nanowires were capped with Aluminium Gallium Arsenide compound. Another set of control samples consisted of a hetrojunction of Wurtzite Gallium Arsenide nanowire and Zinc blende Gallium Arsenide was not capped by Aluminium Gallium Arsenide. A photoluminescence peak below the band gap of both Wurtzite Gallium Arsenide and Zinc blende which gave blue shifts with in increasing excitation power density was consistently observed in the hetero-junction wires which was for recombination across a type II hetero-junction. This was confirmed by low temperature cathode-luminescence study. For study of optical properties of single nanowires we have used micro photoluminescence where the nanowires were deposited to the same nanowire for repeated operation on different days. All studied were made at low temperature in a continuous flow liquid helium cooled cold finger crystal. The luminescence from the nanowires was collected by microscope having a iox objective, dispersed by gating monochromateor and detected by a thermoelectrically cooled camera. For the lowest excitation power densities we have used about 1 h of integration time.

RESULTS AND DISCUSSION

Graph (1) shows the spectra of two nanowires, having a 30nm diameter, where multiple shifting peaks are more clearly seen than in the nanowires having 70 nm diameters. It is seen that there are several shifting peaks and that the transitions shifted from the deeper i.e., lower energy peaks to more shallow i.e., higher energy peaks with increasing excitation power density. This transition from deeper to shallower peaks with increasing excitation power density was observed in all nanowires where multiples peak were observed. The energy separation between the peaks is dependent on wire which is shown in graph (1). Multiple defects, where shifting peak transition is not band to band but band to defect. For increasing excitation power density the deeper defects saturated and then the transition moved to the shallower defect. Excited states of defects, where the shifting peak transition was band to defect. For increasing excitation power density saturated the ground state of the defects and transition moved to the first excited state and so on. Excited states in the triangular potential wells at the interface, also saturated the ground state of the potential wells and the transition moved to the first excited state with increasing excitation power density. Graph (2) shows cathode-luminescence spectra from the two segments as well as from the interface region. It was seen that the peak of the emission from Wurtzite segment is very close to the corresponding peak from the zinc blende segment. The Wurtzite emission is broader than the zinc blende emission. The interface region shows a broad, quite strong emission of 1.485 ev. Which attributed to the type II recombination. The beam current used was 10 pA correspondent to one electron every 10 ns. An alternate method scanned the electron beam along the Nanowire axis and spectra was found. Starting at the Wurtzite or Zinc blenene interface and moved upwards along the zinc blended top segment. A 50 nm step size was used and scan started at the heterojuntion moving towards the tip of the nanowire i.e., in the zinc blende segment. Graph (3) shows the result. The emission localized at the heterojunction became weaker and red shift was found. When moving the excitation being in the segment was not seen this effect, because the emission from the right segment is much broader than from the zinc blende segment making the shifting peak. The obtained results were compared to previous obtained results and were found in good agreement

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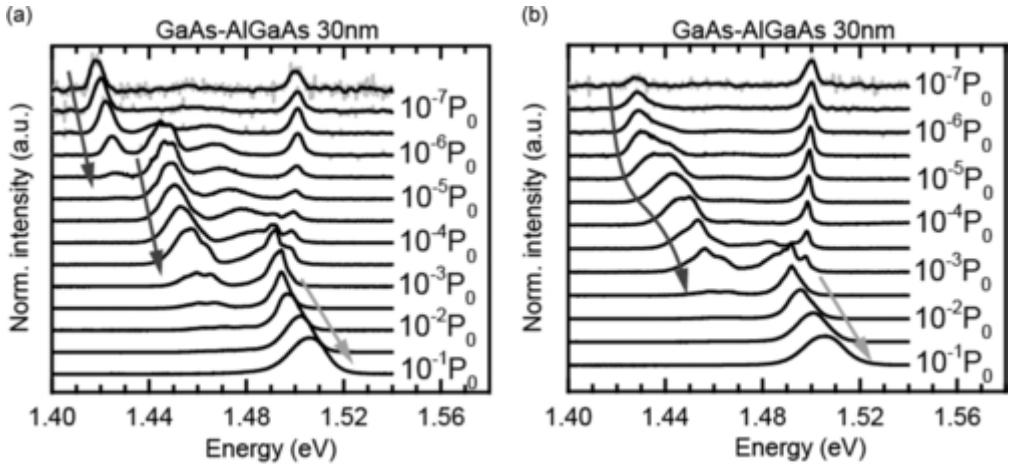
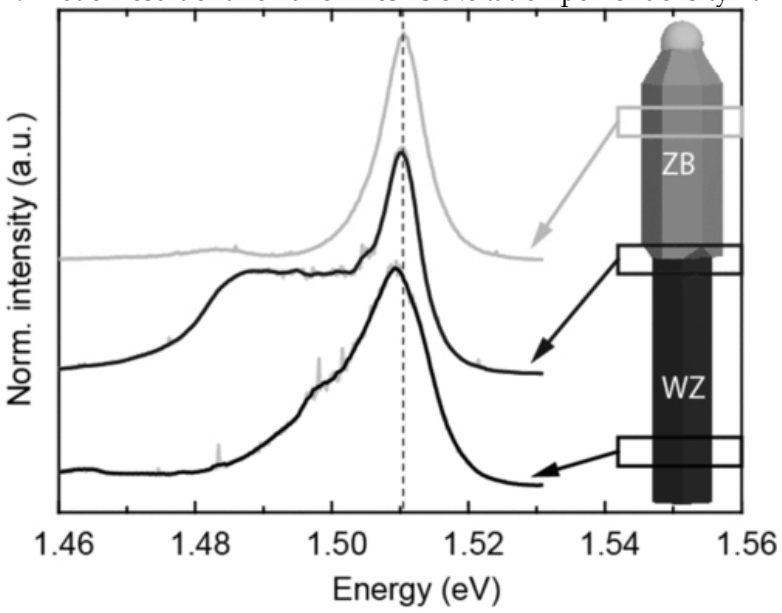
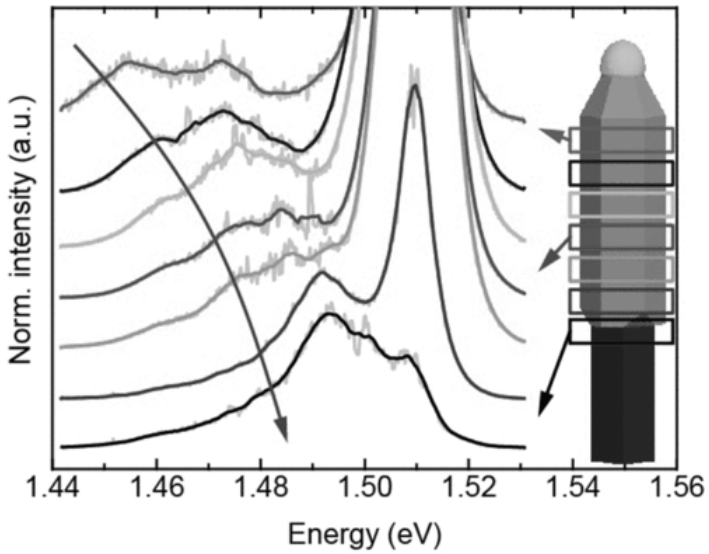


Graph 1: Plot of result of two nanowires vs excitation power density variations.



Graph: 2: Plot of mode spectra vs single nanowire in different positions.



Graph 3: Plot of excitation at hetrojunctions vs hetrojunction nanowire.

CONCLUSION

A large set of individual Wurtzite and Zinc blende Gallium Arsenide heterojunction nanowire were studied using transmission electron microscopy and photoluminescence. In this study cathod-luminescence was also used. It was found that band gap of Wurtzite Gallium Arsenide and Zinc blende Gallium were very close to each other both in Cathod-luminescence on the control sample. It was found that a strong blue shift was present due to deep emission. An increasing excitation power density was also found. The obtained data gave a valence band offset of about 100 mev. Wurtzite Gallium Arsenide emitted much less than Zinc blende Gallium Arsenide, despite belonging to the same nanowire and having been grown under similar conditions. A low density of stacking defects in Wurtzite Gallium Arsenide does not affected the photo luminescence to any significant degree. The emission was due to recombination across a heterojunction with type II band alignment. The results found were good agreement with previously obtained results of theoretical and experimental works.

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