Electronic Supplementary Material (ESI) for Journal of Materials Chemistry C.

Supporting Information

Title: Near-infrared Light-Emitting Devices from Individual Heavily Ga-Doped ZnO Microwires

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1. The Synthesis of Ga heavily doped ZnO Microwires

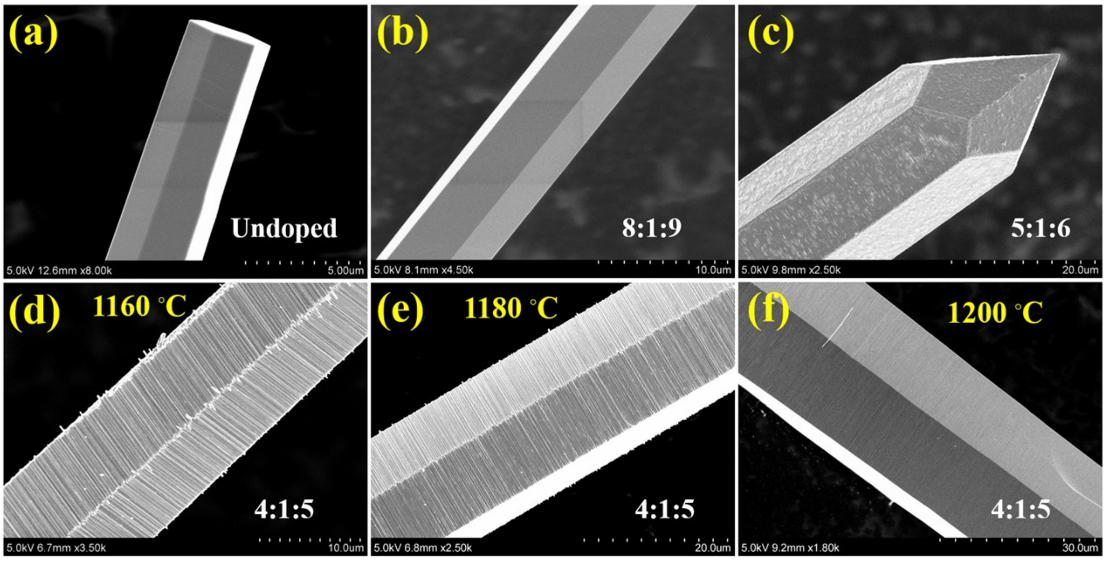

Figure S1: SEM image of undoped ZnO MWs and Ga-doped ZnO MWs with different Ga_2O_3 weight ratios in the source mixtures. Meanwhile, SEM images for heavily Ga-doped ZnO MWs under different reaction temperatures with weight ratio 4:1:5

Ga heavily doped ZnO microwires (GZO MWs) have been synthesized via a simple one-step chemical vapor deposition (CVD) method in a horizontal tube furnace. The mixture of ZnO, Ga_2O_3, and graphite powders with a weight ratio of 4:1:5 served as the reactant source materials, cleaned Si (100) substrates (without any catalyst coating) were placed on the ceramic boat to collect the products. During the synthesis process, a constant flow of argon (99.99%) (150 standard cubic centimeters per minute) was introduced into the tube furnace using as carrier gas. After being maintained at 1200 ℃ for 45 minutes, the furnace was cooled down to room temperature naturally. GZO MWs can be grown on a silicon substrate. In the synthesis process, cambered ceramic boat with the size of 100 mm × 35 mm × 25 mm (length, width, height) should be used, due to its high temperature resistance. In addition, the temperature of the furnace body reached its growth temperature should be as soon as possible to ensure the vapors mixture of Zn and Ga adequately. In order to obtain high-quality GZO MWs, reaction temperature and the growth time can be increased and extended accordingly. Higher reaction temperature can be used to increase the concentration of doping.

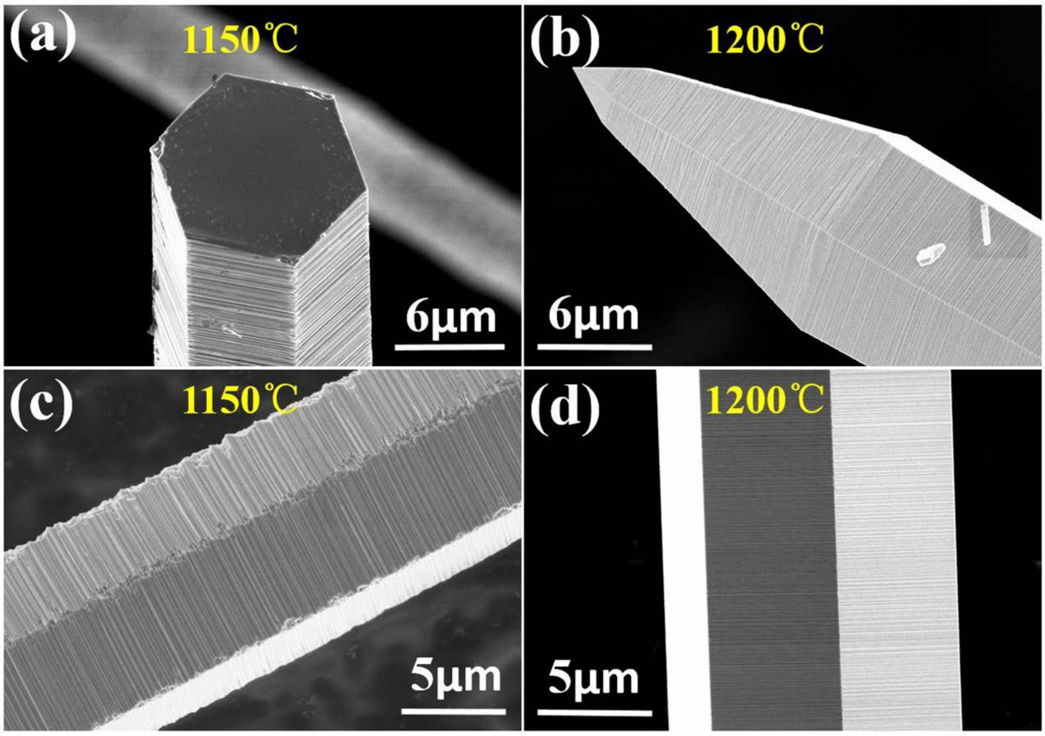

Figure S2: SEM images of Ga-doped ZnO microwire: (a) demonstrates the SEM images of hexagonal cross section of the wire under 1150℃; (b) demonstrates the a perfect hexagonal pencil-like structure of ZnO:Ga microwires corresponding reaction temperatures 1200℃; (c) shows hexagonal microstructures of Ga-doped ZnO microwire corresponding to hexagonal cross section demonstrated in (a); (d) shows hexagonal microstructures of Ga-doped ZnO microwire corresponding to hexagonal pencil-like structure demonstrated in (b).

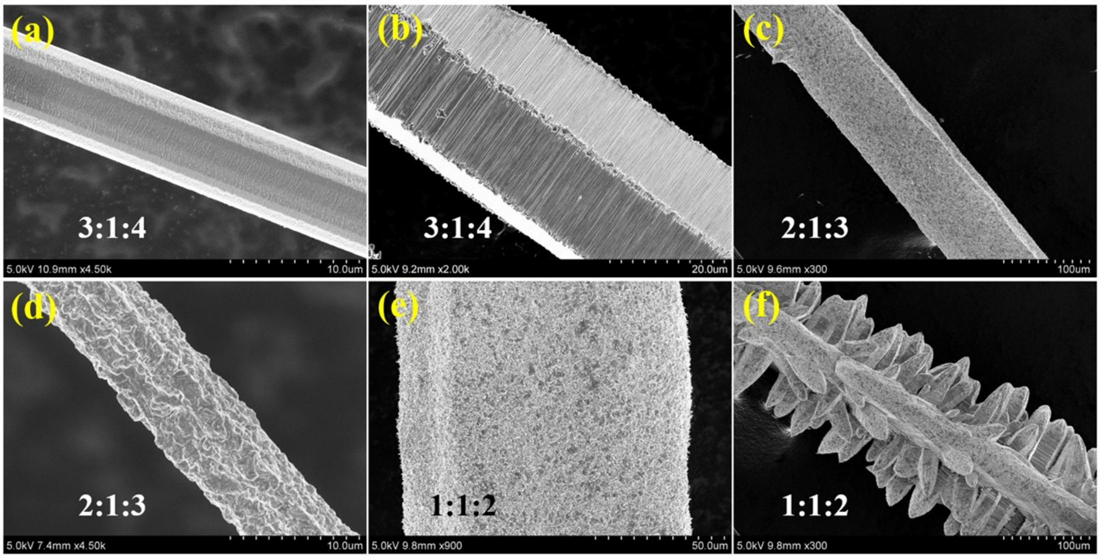

Figure S3: SEM images of heavily Ga-doped ZnO MWs with Ga_2O_3 weight ratios in the source mixtures higher that 8%, corresponding weight ratios marked in the images.

2. Temperature-dependent PL spectra for Ga heavily doped ZnO microwires

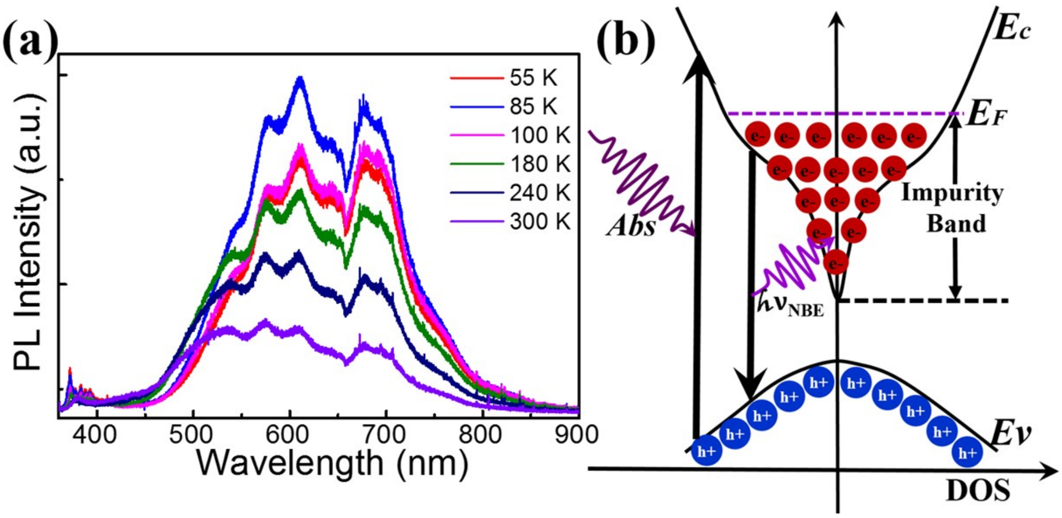

Figure S4: Temperature-dependent PL spectra for undoped and Ga-doped ZnO microwires: (a) PL spectra for the Ga-doped ZnO microwires with temperature dependent ranged from 55 K to 300 K indicated a broadening mechanism governed by the impurity band; (b) Schematic diagram of Ga heavily doping induced electrons occupied in the impurity bands, which can be derived from the donor impurity level evolving from the discrete level to impurity band and eventually to band tail with conduction band.

3. Electrical breakdown measurement of Ga heavily doped ZnO microwires

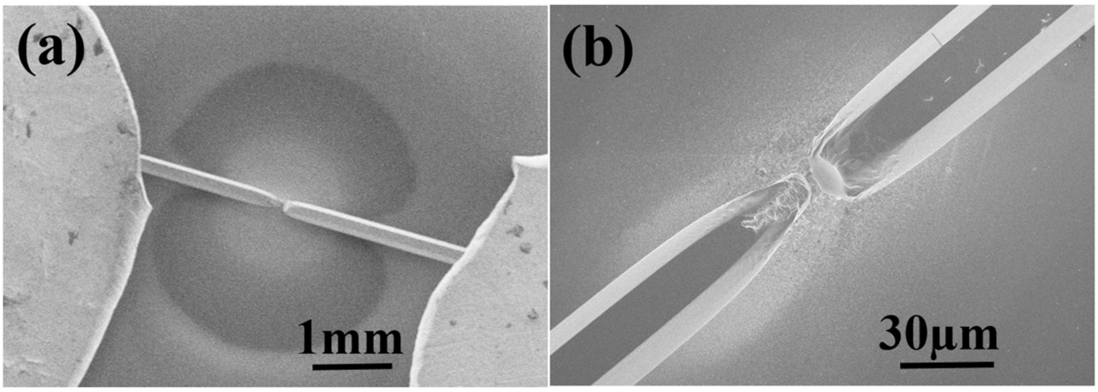

Figure S5: Electrical breakdown measurement of individual Ga heavily doped ZnO microwires: (a) SEM image of light-emitting device structure after injected current, the indium electrodes have been fixed on both ends of the microwire, respectively; meanwhile, corresponding emission region of distinctive ellipse spot shape, along with the length direction of microwire, is clearly visible in this picture. Once the biased voltage exteeded a certain value, electrical breakdown can be happened towards the center of the wire; (b) demonstrate the fracture of the high magnification images.

4. Temperature-dependent EL spectra for Ga-doped ZnO microwires

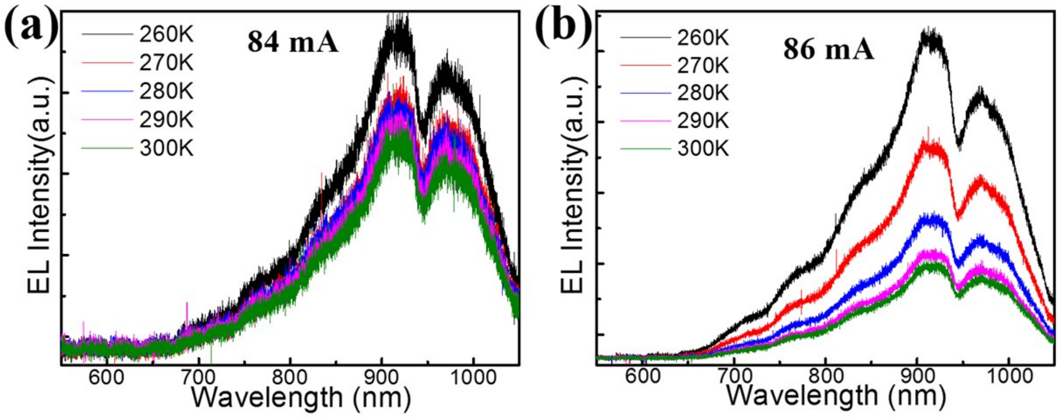

Figure S6: Temperature-dependent EL spectra for Ga-doped ZnO microwires collected at different temperatures, corresponding injected current (a) 84 mA, and (b) 86 mA.

5. Theoretical analysis and numerical simulation of three-dimentional microwire on the light field confinement and propagating with the aid of waveguide modes

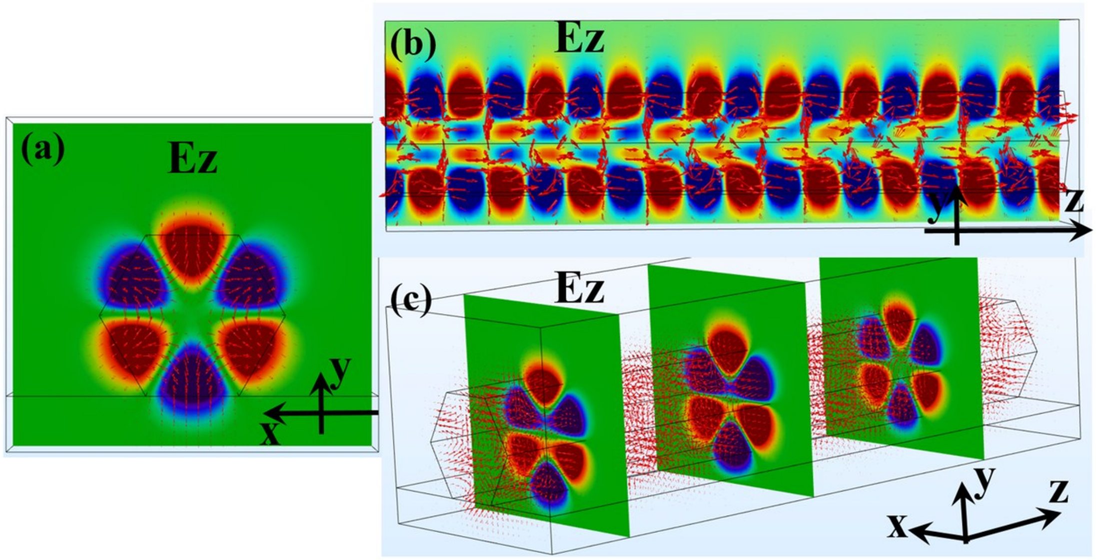

Figure S7: Theoretical analysis and numerical simulation of three-dimentional microwire on the light field confinement and propagating with the aid of waveguide modes: (a) Electrical field confined within hexagonal cross section of the wire; (b) Photons confined in the light-emitting region can propagate along the length diretion of wire, in which the red arrow demonstrated are distributed mainly in the surface segregation layers of Ga-doped ZnO microwires; (c) Waveguide propagating mode of electrical field distribution E_z with three slices of the bare microwire along the length direction of the wire.

Movie clip S8:

1) Near-infrared light emitting from individual Ga-doped ZnO microwire by the digital camera;
2) Alternating current (ac) drive near-infrared light-emitting