Supporting Information

Electrically Excited Hot-Electrons Dominated Fluorescent Emitters Using Individual Ga-doped ZnO Microwires via Metal Quasiparticle Films Decoration

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Figure S1. Schematic diagram of hybrid architectures comprising single Ga-doped ZnO microwires (ZnO:Ga MWs) via metal quasiparticle films decoration. By applying bias onto MWs, electroluminescence (EL) could be observed once the drain current reached a certain value.



Figure S2. Schematic illustration of EL emissions from individual ZnO:Ga MWs via metal quasiparticle films decoration, with the light-emitting regions located towards the center of MWs.



Figure S3. SEM images of surface morphologies of single ZnO:Ga MWs via Au quasiparticle films decoration: (a) Surface morphologies of Au nanostructures towards critical region between lighting or not, transferred from quasiparticle films into physically isolated nanoparticles (Sputtering time: 60 s). (b) SEM image of Au nanostructures located in the lighting region, Au quasiparticle films transferred into physically isolated nanoparticles completely (Sputtering time: 60 s). (c) SEM image of Au nanoparticles located in the center of lighting regions (Sputtering time: 60 s). (d) Magnifying SEM image of Au nanoparticles located in the center of lighting region, average diameter for isolated Au nanoparticles located towards the center of lighting region (Sputtering time: 30 s). (f) SEM image of Au nanoparticles towards the center of lighting region (Sputtering time: 30 s).



Figure S4. SEM images of surface morphologies of single ZnO:Ga MWs via Al quasiparticle films decoration: (a) SEM image of Al nanostructures distribution towards contact region between In electrode and ZnO:Ga MWs (Sputtering time: 60 s). (b) SEM image of Al nanostructures distribution, which evaporated on the surfaces of ZnO:Ga MWs in the non-lighting region (Sputtering time: 60 s). (c) SEM image of Al nanostructures distribution, which located in the lighting region, corresponding metal films transferred into isolated nanoparticles (Sputtering time: 60 s). (d) Magnifying SEM image of Al nanostructures distributed in the center of lighting regions (Sputtering time: 60 s). (e) SEM image of Al nanostructures distributed in the center of lighting region (Sputtering time: 30 s). (f) SEM image of Al nanostructures distributed towards the center of lighting region (Sputtering time: 80 s).



Figure S5. Instantaneous electrical breakdown measurement of single ZnO:Ga MWs via Ag quasiparticle films decoration: (a) SEM image of breakdown zone of Ag quasiparticle films decorated ZnO:Ga MW located in the lighting region. (b) SEM image of magnified breakdown region. (c) SEM image of Ag nanostructures in the emission regions, which near the broken region. (d) Magnified SEM image of surface morphologies of Ag nanostructures located in the lighting region, which near the broken region. (e) SEM image of surface morphologies located towards the breakdown region, microspheres and discrete nanoparticles can be found towards the center of the broken regions. (f) Magnified SEM images demonstrate the recrystallization process from single crystalline to polycrystalline pearl-like structures, which scattered around the broken area.



Figure S6. (a) SEM images of Ag nanoparticles with different sputtering times ranged from 30 s to 80 s. (b) Absorption spectra of Ag nanoparticles with different sputtering times ranged from 30 s to 80s.



Figure S7. (a) Extinction (scattering + absorption) spectra of single Ag nanoparticles with diameters ranged from 60 nm to 100 nm, corresponding effective dielectric constant of the environment defined as 2.5. (b) To demonstrate the effective dielectric constant of the environment influence on the surface plasmon resonances, normalized extinction spectra of single Ag nanoparticles with diameter d = 80 nm, corresponding dielectric constant of the environment ranged from 1.8 to 3.5 were carried out. (c) Spatial distribution of the electric field intensity, incident wavelength of 500 nm, d = 80 nm, corresponding cross section are perpendicular to the direction of incident light and parallel to the direction of incident light, respectively.



Figure S8. (a) Absorption spectra of Au nanoparticles with different sputtering times ranged from 30 s to 80s, corresponding resonance peaks redshift from 550 nm to 606 nm. (b) SEM images of Au nanoparticles with different sputtering times ranged from 30 s to 80 s.



Figure S9. SEM images of Al nanoparticles with different sputtering times (a) 30 s, (b) 40 s, (c) 60 s, and (d) 80 s.



Figure S10. Localized surface plasmon resonances of Al nanoparticles: (a) Extinction spectra of single Al nanoparticles with diameters ranged from 50 nm to 90 nm, corresponding effective dielectric constant of the environment defined as 2.5. (b) Extinction spectra of Al dimer with diameter d = 70 nm, the gap distances ranged from 5 nm to 30 nm.



Figure S11. Electrical field distribution (Incident wavelength $\lambda = 500$ nm): (a) are perpendicular to the direction of incident light; (b) are parallel to the direction of incident light. The diameter of Al nanoparticles $d \sim 40$ nm and the interspace gap of the dimer is $g \sim 15$ nm.



Figure S12. EL emissions from single ZnO:Ga MWs via metal quasiparticle films decoration, the emission wavelengths tuned in the visible regions can be labelled on the basis of the CIE 1931 standard.



Figure S13: Introducing metal quasiparticle films decoration, for example, Au and Al, EDX energy spectrum of single ZnO:Ga MW, ZnO:Ga MW via Au nanostructures decoration and ZnO:Ga MW via Al nanostructures decoration demonstrated that metal singles can be detected explicitly.



Figure S14: Optical microscope images of visible light emissions from single ZnO:Ga MWs via metal quasiparticle films decoration. The brightest emission region is always located towards the center of MWs. Increasing the drain currents can lead to the increase of the brightness and emission regions. The emitted visible light is so intense that it is visible even to the naked eye, without additional magnification (Scale bar: $150 \mu m$).



Figure S15: (a) EL emissions from single ZnO:Ga MWs, while the right half evaporated by Au quasiparticle films. The emission regions located towards the center of the section, which decorated by Ag quasiparticle films (Scale bar: 1mm). (b) Brightfiled and darkfield environment of EL emissions from single ZnO:Ga MWs, with the right half decorated by Ag quasiparticle films. (c) EL emissions from single ZnO:Ga MWs, while the right half evaporated by Au quasiparticle films. The emission regions located towards the center of the section, which decorated by Au quasiparticle films. The emission regions located towards the center of the section, which decorated by Au quasiparticle films (Scale bar: 1mm). (d) EL emissions from single ZnO:Ga MWs, while the right half evaporated by Al quasiparticle films. The emission regions located towards the center of the section single ZnO:Ga MWs, while the right half evaporated by Al quasiparticle films. The emission regions located towards the center of the section single ZnO:Ga MWs, while the right half evaporated by Al quasiparticle films. The emission regions located towards the center of the section single ZnO:Ga MWs, while the right half evaporated by Al quasiparticle films. The emission regions located towards the center of the section, which decorated by Al quasiparticle films. The emission regions located towards the center of the section, which decorated by Al quasiparticle films (Scale bar: 1mm).



Figure S16: Light-emitting devices comprising single ZnO:Ga MWs via Au quasiparticle films decoration were constructed. By applying bias onto MWs, once the drain currents exceeded a certain value, the MW began to emit visible light. Increasing the injection currents can lead to the enhancement of the brightness and emission regions, which located towards the center. Continue to increase the current, instantaneous electrical breakdown can happen, with the breakdown points on the MWs appeared near the middle.



Figure S17: I-V characteristics from single undoped ZnO MWs, bare ZnO:Ga MW, and ZnO:Ga MW via Au quasiparticle films decoration (Sputtering time: 60 s).