Ion beam preparation of Au nanoparticles in crystalline GaN and ZnO semiconductors

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Wurtzite crystalline semiconductors, such as gallium nitride (GaN) and zinc oxide (ZnO), are widely used in electronics, energy storage devices, sensors, and as photocatalysts due to their attractive optoelectronic properties[1,2]. However, their wide bandgaps limit their functionality mainly to the UV region. Modification with metallic gold (Au) nanoparticles can enhance charge-carrier mobility and device performance[3]. Moreover, Au nanoparticles exhibit visible light absorption due to surface plasmon resonance (SPR), thereby extending the application range of these semiconductors[4]. Ion implantation is a promising direct method to synthesize metal nanoparticles within solids, offering high purity and stability[5]. However, this process may introduce structural damage and impact material properties, especially in crystals, necessitating a detailed investigation. In this work, Au nanoparticles were formed via 1.85 MeV and 1 MeV Au ion implantation in crystalline GaN and ZnO, respectively. Implantation in ZnO caused less lattice damage than in GaN, and the Au ions exhibited a Gaussian depth distribution as characterized by Rutherford Backscattering Spectroscopy in channeling mode (RBS-C). GaN showed a more complex damage profile, resulting in a multimodal Au depth distribution, also confirmed by RBS-C. Transmission electron microscopy revealed distinct stages of Au nanoparticle formation in GaN. These stages, along with crystal quality, significantly influenced the optical response, as characterized by absorption/reflection measurements and photoluminescence. In particular, implanted GaN exhibited new blue (2.8 eV) and red (2 eV) emission bands, attributed to the combined effects of SPR and implantation-induced defects.

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