Light Emission of Ti Superlattice Doped 2D γ-alumina grown by Graphene Assisted Atomic Layer Deposition

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Overview

Atomically thin and layered 2D materials possess drastically superior optoelectronic characteristics in comparison to their bulk counterparts with many applications in semiconductor and metal oxide industry such as photovoltaic, light emitting devices and sensors. In this study we present the synthesis and characterization of free-standing 2D γ-Al₂O₃, a non van der Waals material grown by graphene assisted atomic layer deposition (ALD) and Ti super lattice doped 2D γ-Al₂O₃. As grown 2D γ-alumina annealed for 4 hours at 800 °C is luminescent at UV and visible range and by incorporating super-cycle ALD sequences in the synthesis, superlattice doping of 2D γ-alumina was achieved resulting in photoluminescence (PL) emission at near/infrared (NIR) as well as the UV/blue emission.

Fabrication

Photoluminescence (PL)

Fig 1. Fabrication schematic of (left) the two-step fabrication process for 2D γ-alumina, (right) two-step fabrication process involving ALD super cycle for 2D Ti/γ-alumina. On top a) SEM image of the graphene foam showing the interlaced graphene sheets network. b) SEM image of the amorphous alumina deposited on the graphene foam by ALD and c) SEM image of free-standing quasi-2D γ-alumina flakes after thermal annealing and graphene removal. d) SEM image of quasi 2D Ti/γ-alumina after thermal annealing and removal of graphene. On bottom d) EDX spectra of a) Graphene foam, b) 2D γ-alumina, and c) 2D Ti/γ-alumina. e) EDX mapping of 2D Ti/γ-alumina to Ti and O.

Photoluminescence Excitation (PLE)

Fig 2. Photoluminescence spectra of 2D γ-alumina and 2D Ti/γ-alumina, using excitation wavelength of 365 nm (3.43 eV), showing the evolution of the PL in a) UV/Visible range and b) NIR emission range below (31) and after UV illumination (2D and 4+). PL excitation 320 nm. Table 1. Photoluminescence emission peaks after Gaussian deconvolution for 2D γ-alumina and 2D Ti/γ-alumina showing the evolution of UV, visible and Near IR emission after UV illumination.

Fig 3. Photoluminescence Excitation (PLE) Spectra of 2D γ-alumina and 2D Ti/γ-alumina used to identify the defects and color centers (F-centers) contributing to the emission of PL emission peaks detected (Fig 2, Table 1). a) Excitation bands of interstitial aluminum ions (Al⁺) and oxygen vacancy complexes (F₁, F₂, etc.) contribute to the UV emission at 387-393 nm. b) Excitation bands of Al⁺, F₁, F₂, etc. and oxygen vacancy complexes (F₁, F₂, etc.) also contribute to the ultraviolet emission at 420-437 nm range and c) Al⁺, F₁, F₂, etc. and Titan-Aluminum vacancy-Titanium-Aluminum vacancy-Titanium (Ti-V-Ti) and new vacancy/Ti complexes contribute to the emission in the near IR for 2D Ti/γ-alumina for 4+ days after exposure to UV illumination at 320 nm.

Conclusion

In this study we have successfully fabricated 2D γ-alumina and 2D Ti/γ-alumina using a two-step graphene assisted Atomic Layer Deposition. According to the spectroscopy and microscopy results:

• As grown crystalline 2D γ-alumina and 2D Ti/γ-alumina are luminescent with a medium strength defect assisted light emission at UV/visible (389, 420, 464 nm) and UV/Visible/NIR (387, 416, 476, 757, 787 nm) respectively with the red/NIR emission is activated by UV illumination.

• The first three peaks in UV and visible are attributed to radiative recombination involving intrinsic oxygen vacancies (F-centers) and interstitial aluminum ion defects while the emission in near IR is attributed to interstitial oxygen vacancy clusters (F₂, F₂⁺, F₂⁺, etc.), interstitial aluminum ion defects (Al⁺), Ti ions (Ti⁺) and Titanium-Aluminum vacancy-Titanium (Ti-V-Ti) clusters.

• This study has the potential to lead to the development of future radiation hard thermally stable light emitters, high energy pulsed lasers, scintillation detectors for dark matter research, radiation dosimeters, catalyst supports, energy harvesting and environmental remediation.

References