Recrystallization of epitaxial MBE-grown MoS_2 monolayers induced by annealing in a CVD furnace

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A systematic study of MoS_2 grown by a combination of physical vapor deposition (PVD) and post-growth annealing treatment in a sulfur atmosphere has been conducted. Hereby, MoS_2 thin films with nominal thicknesses between 1-2 monolayers are first grown on sapphire by molecular beam epitaxy (MBE) at different growth temperatures and then transferred to S environment inside a chemical vapor deposition (CVD) furnace for a post-growth annealing. Depending on the growth temperature, the as-grown layers are either amorphous or form a crystalline structure composed of closely packed nm-size grains. The subsequent annealing leads to recrystallization of these layers significantly increasing the size of the MoS_2 crystalline domains to the range of 50 - 100 nm. While the originally amorphous layer displays randomly oriented domains after annealing, recrystallization of samples grown at high temperatures yields single crystalline layers. All samples show an increase of the crystallite dimension, which is accompanied by the disappearance of the defect-related peaks in the Raman spectra, sharpening of the excitonic signatures in absorption, and strong enhancement of the photoluminescence yield. The results represent a promising way to combine the tunability of PVD with post-growth CVD process towards fabrication of wafer-scale epitaxial transition metal dichalcogenide mono- and multilayer films on non-van der Waals substrates [1].

References

[1] R. Wang, N. Koch, J. Martin, and S. Sadofev, Phys. Status Solidi RRL, 2023, 2200476.

Figures

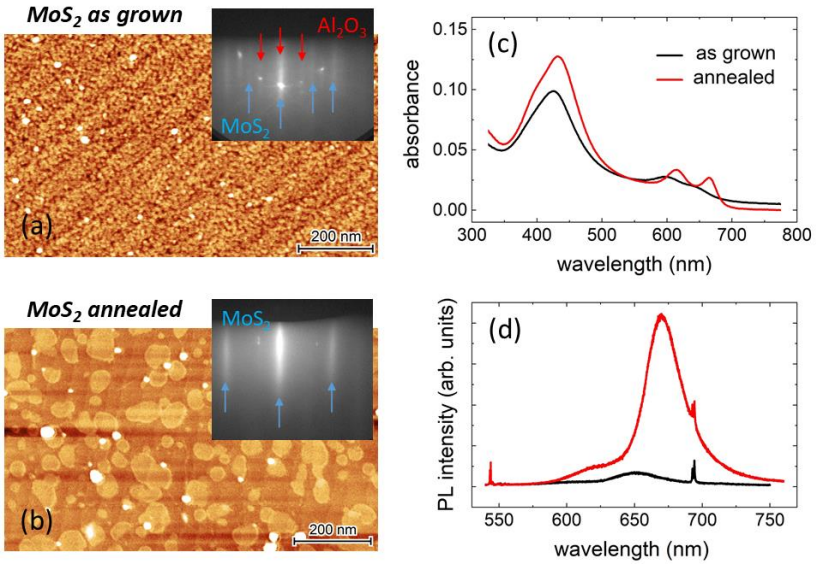

Figure 1: Exemplary properties of MBE-grown and annealed MoS_2 layers on sapphire. (a, b) AFM images. Inserts show reflection high energy diffraction (RHEED) patterns along <11-20> azimuth of the wafer. Reflections of sapphire and MoS_2 are marked by the red and blue arrows, correspondingly. (c, d) Absorption and PL spectra of the samples.