Polyoxovanadates as redox-active 2D materials for memristive applications

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Stoichiometric metal oxide nanoparticles, so called polyoxometalates, are a highly promising material class for the CMOS-compatible integration of molecular compounds into data memories, sensors, or intelligent medical devices.[1] Vanadium-based polyoxometalates (POVs) have shown outstanding properties as molecular multi-level switches at room temperature in memristive devices.[2] By chemical engineering the usually anionic particles can be immobilized on metallic and non-metallic substrates either in form of single molecules or expanded 2D layers. Depending on the specific molecular structure and the kind and number of containing metal atoms, the switching characteristics can be tuned in a wide range and, thus, be tailored for specific applications.

Depositing lanthanide-phthalocyanine-ligated {V12}-nuclearity POVs from organic solution results in the formation of multi-level switchable and completely closed molecular monolayers on non-metallic graphite substrates via intensive π-π bonding interactions, which can be structured on the nanometer scale by the electric field of a scanning tunneling microscope (STM) tip (Figure 1).[3]

First experiments on amorphous ALD-processed MoS_2 layers have shown the successful transfer of the molecular layer growth on technically important 2D-materials. Hereby, the switching characteristics differ slightly from the behavior on single-crystalline substrates, probably due to variations of the intermolecular interactions on the different surface morphologies.

Experimental data have already evidenced a tremendous effect of POV-surface interaction and hetero metals in POV structures on their electronic characteristics. Artificial intelligence-based algorithms might serve as an effective tool to predict such trends in bandgap tuning for the integration of molecular oxides in CMOS compatible devices as well as they may be used for micro-spectroscopy image recognition on the nanoscale.

References

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[3] M. Moors et al., Nanoscale Horiz., 9 (2024) 233–237.

Figures

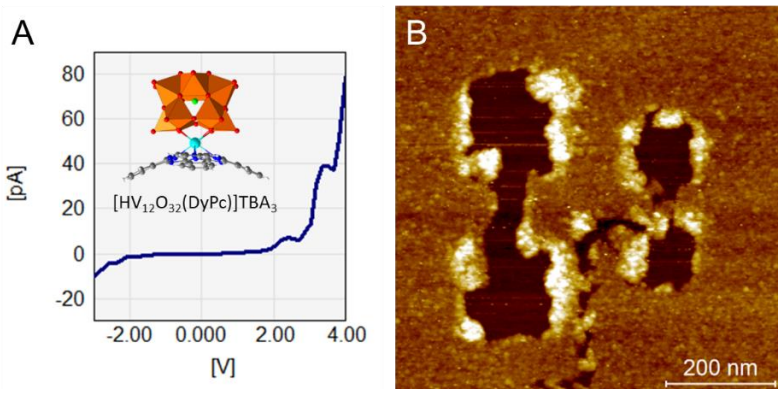

Figure 1. Switching characteristics of a dysposium-phthalocyanine-ligated {V12}-nuclearity POV monolayer deposited on graphite (A) and corresponding STM image with inscribed nanostructures (B).