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Rational Concept for Designing Vapor-Liquid-Solid Growth of Metal Oxide Nanowires

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Metal oxide nanowires hold great promise for various device applications due to their unique and robust physical properties in air and/or water and also due to their abundance on Earth. Vapor-liquid-solid (VLS) growth of metal oxide nanowires offers the high controllability of their diameters and spatial positions. In addition, VLS growth has applicability to axial and/or radial heterostructures, which are not attainable by other nanowire growth methods. However, material species available for the VLS growth of metal oxide nanowires are substantially limited even though the variation of material species, which have fascinating physical properties, is the most interesting feature of metal oxides. Here we demonstrate a rational design for the VLS growth of various metal oxide nanowires, based on the so-called "*material flux window*". This material flux window describes the concept of VLS nanowire growth only within a limited material flux range, where nucleation preferentially occurs only at a liquid-solid interface. Although the material flux was previously thought to affect primarily the growth rate, we experimentally and theoretically demonstrate that the material flux is the most important experimental variable for the VLS growth of metal oxides. Based on the material flux window concept, we discover novel metal oxide nanowires, including MnO, CaO, Sm_2O_3, NiO, and Eu_2O_3, which were previously impossible to form via the VLS route. The fabricated NiO nanowires exhibited stable memristive properties superior to conventional polycrystalline films due to the single crystallinity. Thus this new VLS design route offers a useful guideline for the design and discovery of novel nanowires that are composed of desirable functional oxide materials.