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Low Dimensional Growth: A Novel Method for Fabricating Nanostructures

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In this paper, a novel method for fabricating nanostructures called low-dimensional growth is presented. The technique relies on the ability to transfer the thickness control available in the vertical direction to the lateral direction by confining the growth of a film with a rigid upper film. Both selective chemical deposition and a selective etch are needed for this process to work. The method enables high throughput manufacturing of nanostructures since it is not limited by lithography. A simple example is the confined growth provided by a silicon nitride film situated on top of a polysilicon and oxide films (see Fig. 1). The polysilicon edge provides a seed for a selective growth for a variety of materials including tungsten, thus forming a quantum wire. The lateral growth can be continued with alternate materials to form arrays of quantum wires. A variation of this technique is the growth of quantum dots. To confine the growth to a single dimension, one quantum wire is selectively etched thus forming a one-dimensional tunnel. Selective growth done in this tunnel enables the formation of arrays of quantum dots suitable for single electron devices (see Fig. 2). The risks and advantages of this technique are discussed. The feasibility of growing arrays with a variety of selective growth techniques is discussed A variety of selective growth chemistries are available for low dimensional growth. Analysis of stress in this locally confined growth regime indicates that it is possible to grow highly mismatched materials without causing dislocations. The method is extendable to manufacturing a variety of electron and optical devices. Applications to biotechnology are also reviewed. Lastly, the technique is demonstrated in a metal stack by performing selective growth of Titanium oxide wire confined by a Titanium nitride upper layer (see Fig. 3).

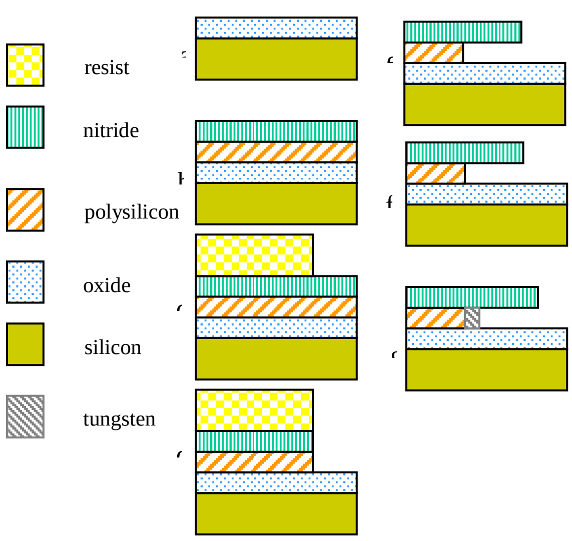

Fig. 1. Confined growth of a tungsten wire with a polysilicon seeding edge and a nitride top layer. Using standard lithography techniques, an edge is formed in a stack of oxide, polysilicon and nitride. The polysilicon is etched further to form a nitride overhang. The nitride confines the selective growth of tungsten. Mutiple wires can be formed by alternating the materials that are grown selectively.

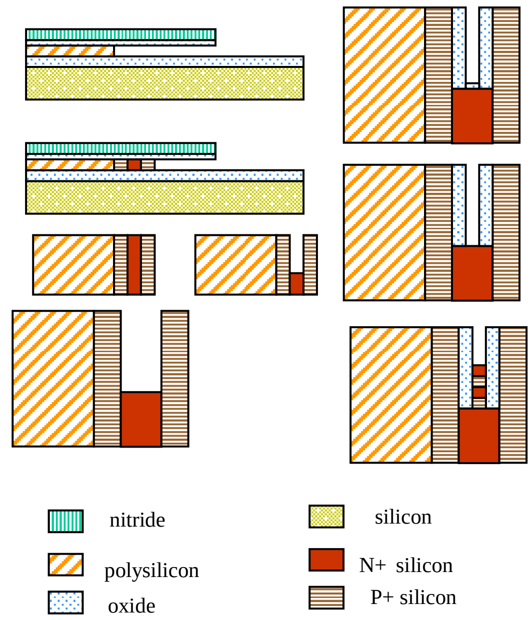

Fig.2. Example of one-dimensional growth: A seeding layer (single crystal or polycrystalline) of silicon is used to grow a sandwich of two p+ wires separated by a lightly doped n-type wire using low dimensional growth. Etching in Ethylene Diamine Pyrocathechol (EDP) is carried out until a desired length of the n-type wire is removed. Next, a short oxidation is performed to coat the sidewalls of the p+ wires. This step also covers the n-type wire with an oxide that is thinner than the one on the p+ wires. A limited etch in buffered HF removes the oxide on the n-type wire but keeps a thin layer of oxide on the p+ sidewalls. Afterwards, confined selective growth of alternating layers of p+ doped silicon and n+ doped silicon is carried out. This yields a series of quantum dots. Note that the growth is confined to 1-D by an upper capping layer and the oxide grown on the p+ regions.

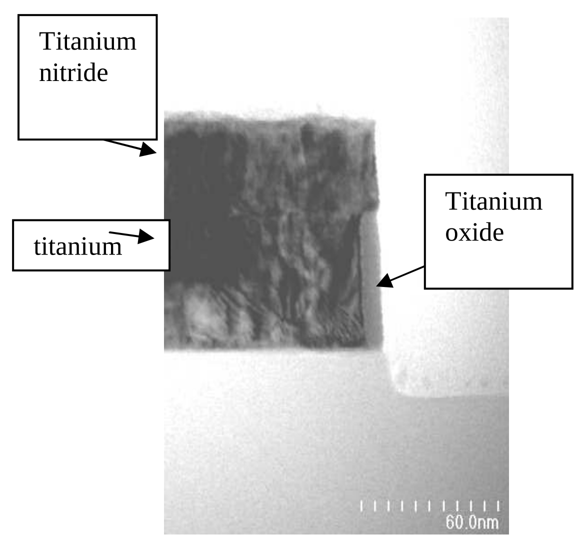

Fig. 3. Confined growth of a Titanium oxide wire on the edge of a titanium seed using a selective plasma process. The growth is confined by an upper layer of Titanium Nitride.