

Low-Pressure HF Vapor MACE of Silicon Nanowires: Pt vs Pd Catalyst Effects on Morphology and Etch Rate

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Metal-assisted chemical etching (MACE) has emerged as a versatile route for fabricating low-dimensional, porous silicon nanostructures for photonics, optoelectronics, and sensing. It offers comparatively simple and cost-effective processing relative to anodic or stain etching but still relying predominantly on liquid-phase chemistries [1]. Previous studies have demonstrated that Pd-assisted chemical etching in aqueous HF/H₂O₂ can form well-aligned porous silicon nanowire arrays even on lightly doped p-type substrates, thereby overcoming doping constraints typical of Ag- and Au-based systems [2]. However, liquid-phase Pd-MACE still suffers from challenges such as mass-transport limitations, capillary-induced collapse, and limited control over pore morphology, which hinder scalability and precise shape engineering of nanowires.

In this work, a Pd-assisted MACE process in HF vapor phase is proposed for the first time, with the aim of achieving controlled growth of silicon nanowires (SiNWs) and enabling direct comparison with established vapor-phase Pt-MACE routes. Building on prior vapor-phase demonstrations where HF/H₂O vapor and ambient oxidizers drive localized, metal-catalyzed gas–solid etching to produce high-aspect-ratio nanowires [3], the present study replaces Pt with Pd as the catalyst to explore differences in etch rate, porosity, and nanowire morphology under otherwise comparable process conditions. Initial experiments use Pt-MACE-derived SiNWs as a reference and then systematically investigate Pd-MACE behavior in HF vapor, focusing on how the catalyst type, HF activity, and moisture content influence porosity formation as well as nanowire straightness and verticality.

The proposed study aims to map the process window in which Pd-MACE in vapor phase can generate vertically aligned, porous SiNWs with tunable diameter and porosity, while mitigating structural collapse and improving pattern transfer fidelity. By directly comparing Pt- and Pd-catalyzed HF vapor etching on similar defined patterns, the work seeks to reveal catalyst-dependent etching characteristics and identify regimes in which Pd offers advantages for porous Si nanowire engineering. The anticipated outcome is a novel, vapor-phase Pd-MACE platform that combines the materials flexibility of Pd-catalyzed wet MACE with the morphology-control and stiction-free advantages of gas-phase processing, opening pathways to scalable nanowire-based photonic, sensing, and energy devices.

References

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