Wet Etch, Dry Etch, and Now MacEtch

Xiuling Li

Department of Electrical and Computer Engineering, University of Texas at Austin, Austin, TX 78758

Xiuling.li@utexas.edu

In the fabrication of aggressively scaled optoelectronic and electronic devices, anisotropic etching is indispensable. Defying the isotropic nature of conventional wet etch, metal-assisted chemical etching (MacEtch or MACE) is a near-room temperature, plasma-free, yet highly anisotropic etching method. By leveraging the intricate interplay of local catalysis and electron transfer effects at the metal-semiconductor-solution interface, MacEtch transcends the definition of conventional chemical etching. We first reported MacEtch as a method to generate porous silicon using a discontinuous layer of noble metal catalyst metal film under open circuit in 2000 in a solution of hydrofluoric acid (HF) and peroxide.[1] Depending on the semiconductor doping type and level, metal catalyst-semiconductor barrier height, catalyst pattern, and etching solution composition and concentration, MacEtch can lead to different etching rates, topography, porosity, and morphology. This innovative etching method has profound impact on semiconductor fabrication, not only because of the readily achievable extraordinary aspect ratio (>>300:1), but also the inherent absence of ion-induced damage.[2] The simplicity, versatility, and scalability of MacEtch have catalyzed a myriad of applications in electronics, photonics, energy, quantum technologies, and bio-sensing. From Si nanowire-based lithium battery anodes, solar cells, high pixel density GaN microLEDs, hysteresis-free ultrawide bandgap Ga2O3 power finFETs, to through-substrate-via 3D integration, the role of MacEtch is unmistakably exemplified. Figure 1 shows a few examples of compound semiconductor structures, including III-N heterojunctions, fabricated by MacEtch and their relevant device performance.[3-5]

In this presentation, I will discuss the various forms of MacEtch (forward, inverse, self-anchored catalyst, magnetic field guided, and photo-enhanced MacEtch, as well as the vapor-phase MacEtch) and their applications in nanoelectronics and photonics.

Acknowledgement:
NSF ECCS #2200651, ARO MURI #W911NF2110337, NSF FuSe #2320107.

[1] X. Li and P.W. Bohn, "Metal-assisted chemical etching in HF/H2O2 produces porous silicon," ***Appl. Phys. Lett.***, 77, 2572 (2000).

[2] X. Li, "There is Plenty Room All-Around," ***IEEE Nanotechnology Magazine***, Feb. 9th, 2023. DOI: 10.1109/MNANO.2022.3228096

[3] Y. Song, P. K. Mohseni, S. H. Kim, J. C. Shin, T. Ishihara, I. Adesida, and X. Li, "Ultra-High Aspect Ratio InP Junctionless FinFETs by a Novel Wet Etching Method," ***IEEE Electron Dev. Lett.*** 37 (8), pp 970-973 (2016).

[4] H.-C. Huang, Z. Ren, A. U. Bhuiyan, Z. Feng, Z. Yang, X. Luo, A. Q. Huang, A. Green, K. Chabak, H. Zhao, and X. Li, "β-Ga_2O_3 FinFETs with ultra-low Hysteresis by Plasma-Free Metal-Assisted Chemical Etching," ***Appl. Phys. Lett.*** 121, 052102 (2022).

[5] C. Y. Chan, H. C. Roberts, Y. Xiao, P. J. Froeter, D. J. Siever, Z. Mi, and X. Li, "Plasma-Damage-Free Efficiency Scaling of Micro-LEDs by Metal-assisted Chemical Etching," *Appl. Opt. Mater.* accepted (2024).

Wet Etch, Dry Etch, and Now MacEtch

Xiuling Li

Department of Electrical and Computer Engineering, University of Texas at Austin, Austin, TX 78758

Xiuling.li@utexas.edu

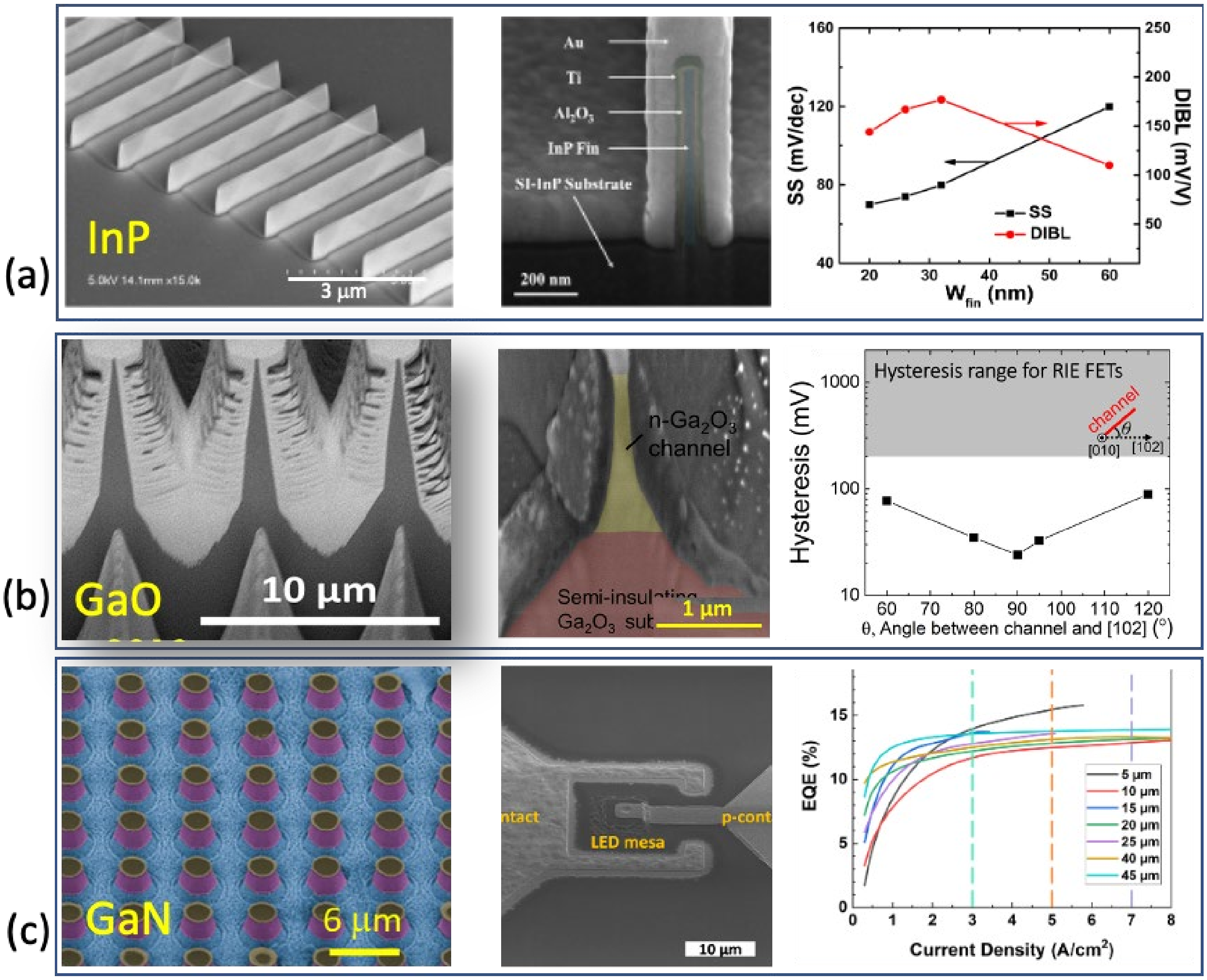

Fig. 1 Examples of MacEtch structure and device performance. (a) InP fin channels produced by MacEtch, cross-section of a single fully fabricated FinFET, and the plot of subthreshold (SS) and drain-induced barrier lowering (DIBL) as a function of fin width [3]; (b) Ga2O3 fin channels produced by hn-MacEtch, a single fin cross-section, and hysteresis vs the channel orientation, and benchmarking with that of RIE produced FinFETs [4]; and (c) GaN pillar array produced by hn-MacEtch, a fully fabricated 5 mm LED mesa, and the EQE of all sizes 5 – 45 mm [5], showing little size related degradation.