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Atomic-Scale Investigations on the Wet Etching of Group IV Semiconductors in Acidic H_2O_2 Solution: The Case Ge Versus Si-Ge

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Abstract Text:

Over the decades, Si-based complementary metal–oxide semiconductor (CMOS) technology has challenged the semiconductor industry in improving device performance while maintaining the scaling requirements. However, the use of the group IV semiconductor as a channel material is reaching its ultimate limit due to physical complications, such as gate leakage, parasitic resistance/capacitance and size channel effects [1]. Some workaround solutions have implemented trigate structures, while novel gate-all-around (GAA) nanowire or nanosheet devices are also explored.[2] One of the core challenges for these devices is the highly selective removal of sacrificial SiGe epitaxial layers to release active parts of the device.[3] This aspect is further complicated by the introduction of Ge as an alternative channel material of higher mobility.[4]

Wet-chemical processing remains an essential step for new nanodevice fabrication. With channel widths of only a few tens of atomic layers, etching control up to the atomic-layer-scale is necessary. To achieve such a level of precision, basic insights in semiconductor/electrolyte interactions are indispensable. Unlike for Si, the surface chemistry of Ge in wet-chemical solutions has remained relatively unexplored. One of the factors impeding in-depth surface analysis is the high reactivity of Ge in air. For this reason, the use of an integrated surface preparation apparatus in a surface analytical tool is crucial to rule out controversial effects of atmospheric oxygen and water.

In this work we discuss the wet-chemical etching of Ge (100) in acidic H_2O_2 solutions. Kinetic studies were performed using inductively coupled plasma mass spectrometry (ICP-MS). Under reaction limited conditions, we showed that surface chloride chemistry has a profound impact on the dissolution kinetics and the anisotropy of wet etching, while proton effects were found to be less important. These results served as a starting point for the comparison of Ge versus SiGe. We provide an atomic scale investigation on the influence of the Si bulk concentration versus the kinetics of etching. The results are complimented by synchrotron X-ray photoemission spectroscopy (SXPS) measurements. We highlight the use of an integrated surface preparation chamber directly connected to SXPS apparatus to obtain fundamental insights into the surface chemistry of these technologically relevant group IV semiconductors. The results suggest that, while the release of Ge atoms from surface sites is favorable, the Si oxide chemistry determines the etching kinetics of SiGe. Basic etching schemes help to explain the formation of a (quasi) self-limiting oxide on SiGe. Energy dependent surface composition analysis provided insight into the nature of the oxide layer that showed depletion of Ge components at the outer surface due to pull out effects.[6]

In summary, this research provides a new outlook for various applications such as biomedicine [7], photodetectors [8] and for light absorbing and harvesting of solar energy [9]. In addition, it serves as an eye-opener for the potential of semiconductor surface chemical studies using an UHV-integrated chemical cell connected to XPS to study etching systems.

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This abstract was submitted in view of an invited talk. Invitation was send by Colm O'Dwyer.

Kind regards,

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