Time Multiplexed Deep Reactive Ion Etching of Germanium and Silicon-A Comparison of Mechanisms and Application to X-ray Optics

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Although the plasma etching mechanisms of silicon in halogen based gases have been studied extensively, by comparison very little has been published on the mechanisms responsible for plasma etching of germanium despite its technological importance in many areas including electronics, photonics, and x-ray optics[1,2]. SiGe HBTs require making contact to the buried SiGe or Si layer in Si/SiGe/Si heterostructures, which necessitates the need for very selective etching[3,4]. A few fundamental studies of silicon and germanium etching in CF_4 [5,6] and SF_6[7,8] based RIE and ICP platforms have been conducted, and a recent study has demonstrated deep germanium etching using a modified Bosch process[9]. However, by directly comparing Si and Ge in a time multiplexed DRIE process, we highlight significant differences in etch mechanisms that are illuminated by RIE-LAG and sidewall characteristics, which ultimately affect relative performance in Collimating Channel Array (CCAs) x-ray optics.

In this work, we present the results of an orthogonal Taguchi L-9 design of experiment (DOE) where Si (100) and Ge (111) are etched under identical plasma conditions in a time multiplexed mode using SF_6/C_4F_8 based chemistry. Based on the results of the DOE which are derived from variations of the plasma parameters, we will propose mechanisms for the specific etch characteristics of Si and Ge in this cyclic deep etch process. In addition, we will compare the performance of CCAs that have been fabricated in Si and Ge with DRIE.

Specifically, we examine the etch behavior of Si and Ge DRIE while varying the ICP power in the respective steps of the cyclic process, i.e. deposition of polymer, etch A which is responsible for polymer removal, and etch B which is responsible for the isotropic substrate etch. Also, within etch A, the peak-to-peak bias voltage is varied. We will show how the Si and Ge etch rates respond as a function of these parameters and how the etch rates correlate with feature size and aspect ratio, (see Fig1,2.) The significant difference in the etched sidewall quality is illustrated in Fig.3. We propose that the different respective sidewall passivations on Si and Ge are largely responsible for the observed differences in etch characteristics and the resulting x-ray optic efficiency.

1. L.Alianelli, et.al., Journal of Physics: Conference Series **186** (2009) 012062.
2. David N. Agyeman-Budu, et. al. AIP Conference Proceedings **1764**, 020004 (2016).
3. G.S. Oerhlein, et.al., J. Vac. Sci. Technol.A **9**, 768 (1991).
4. G.S. Oerhlein, et. al, J. Electrochem. Soc. **138**, 1443 (1991).
5. A.Campo, et.al., Plasma Sources Sci. Technol. **4**, 398, (1995).
6. Kyu-Hwan Shim, et. al., Electronic Materials Letters, **8**, 423 (2012).
7. A.Campo, et. al, J. Vac. Sci. Technol. B, **13**, 235, (1995).
8. K-H. Shim, et.al., Materials Science in Semiconductor Processing, **15**, 364 (2012)
9. M.Darnon, et. al., J. Vac. Sci. Technol. B, **33**, 060605-1, (2015).

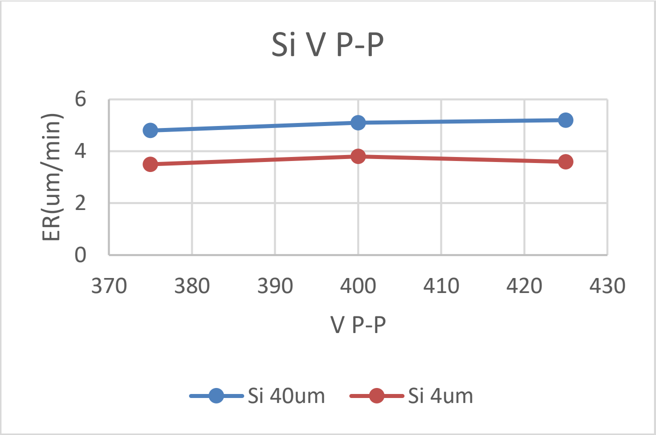

Figure 1: Effect of RIE-LAG on Si as a function of peak-to-peak voltage.

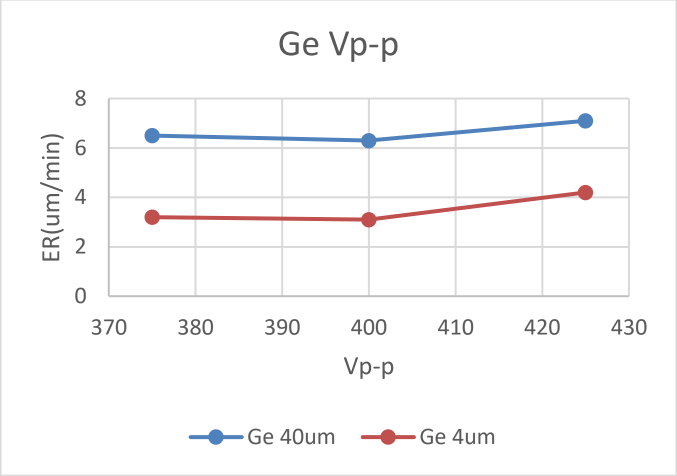

Figure 2: Effect of RIE-LAG on Ge as a function of peak-to-peak voltage.

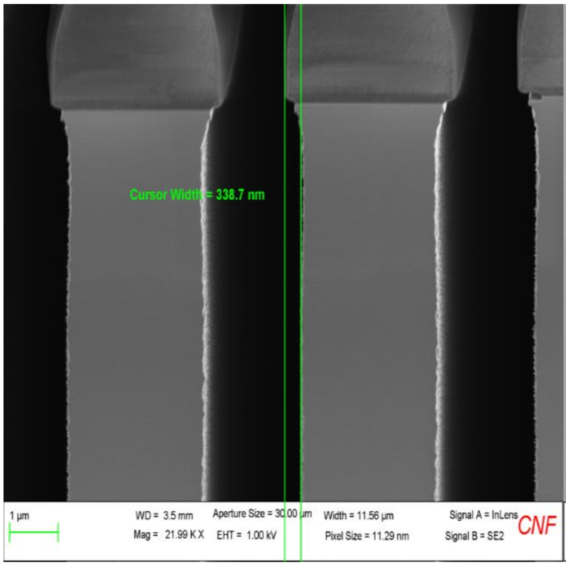

Figure 3A: Ge DRIE with photoresist mask

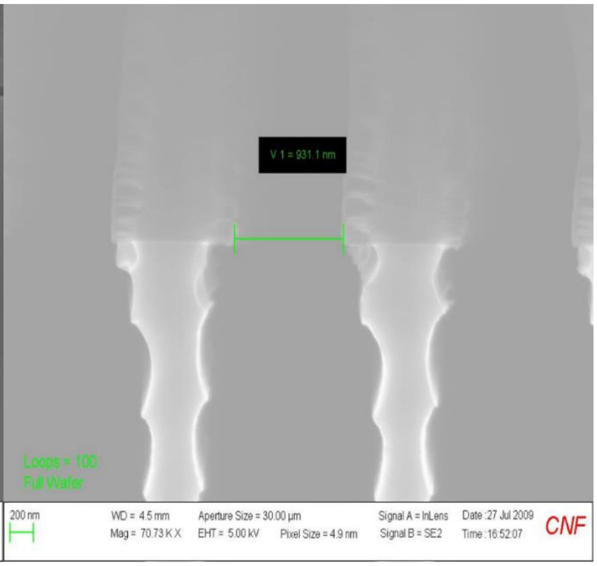

Figure 3B: Si DRIE with photoresist mask.