# ETCH RATE CHARACTERIZATION OF OXIDE ALD FILMS

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For designing any kind of nanofabrication process, knowing the etch rates of available thin films, as well as their compatibility with commonly used processing chemicals is crucially important. Previous work by Williams et al. [1][2] tabulating rates for large numbers of film-etchant combinations has gained great popularity in the nanofabrication community, but does not include any ALD films. While there have been examinations [3] for select ALD processes and etchants since, the etch rates of ALD films have not yet been studied in comprehensive fashion.

We report on the characterization of the etch rates of 9 oxide ALD films in 20 different wet and vapor etchants, which include many commonly used silicon etchants, oxide etchants and metal etchants, as well as solvents, cleaning solutions and photoresist strippers. Each of the 180 etch rates is based on data from a minimum of 4 separate etches, with a total of over 1500 thickness measurements performed by ellipsometry. To allow efficient coverage of such a large scope, a high-throughput sample fabrication and measurement workflow was developed and successfully employed. Extension of the work to nitride ALD films is currently underway.

All oxide films were deposited at 200°C in Veeco / Cambridge Nanotech Fiji F202 ALD reactors, employing both thermal and plasma-enhanced ALD (PEALD), when available. To achieve representative results, standard deposition recipes were used, which are not optimized for low etch rates or any other specific metric, but have been developed for general purpose use. Chemicals were freshly poured for all wet etching. Film compositions as deposited were characterized using X-ray photoelectron spectroscopy (XPS).

References

[1] K. Williams, and R. Muller, Etch Rates for Micromachining Processing, *JMEMS* 5 (**1996**) 256.
[2] K. Williams, K. Gupta, and M. Wasilik, Etch Rates for Micromachining Processing - Part II, JMEMS 12 (**2003**), 761.
[3] J Provine, P. Schindler, Y. Kim, S. Walch, H.J. Kim, K.H. Kim, and F. Prinz, Correlation of film density and wet etch rate in hydrofluoric acid of plasma enhanced atomic layer deposited silicon nitride, *AIP Advances* 6 (**2016**).

| Rates in nm/min | $Al_2O_3$ – p | $Al_2O_3$ – t | $HfO_2$ – p | $HfO_2$ – t | $TiO_2$ – p | $TiO_2$ – t | $ZrO_2$ – p | $ZrO_2$ – t | $SiO_2$ – p |
|---|---|---|---|---|---|---|---|---|---|
| 50:1 HF | 43.3 | 43.2 | 5.88 | 2.18 | *0.101 | 0 | 2.07 | *0.128 | 47.4 |
| 20:1 BOE | 26.6 | 26.6 | 0.921 | 0.585 | 0 | 0 | *13.6 | 0.347 | 149 |
| Pad Etch | 40.7 | 40.6 | 4.9 | 1.11 | 0.639 | 0.019 | 0.736 | 0.802 | >44 |
| HF vapor (SPTS uetch) | 0.003 | 0.003 | 0 | 0 | *0.037 | *0.033 | 0 | *0.019 | >23 |
| KOH @ 80°C | 182 | >204 | 0.166 | 0.139 | 0.249 | *1.77 | 0.053 | *0.278 | 56.2 |
| TMAH @ 80°C | 130 | 66.4 | 0.003 | 0.001 | 0.045 | 0 | 0.004 | 0.003 | 0.125 |
| $XeF_2$ (xactix e1) | 0.002 | 0.003 | 0.002 | 0.001 | 6.45 | 5.95 | 0.001 | 0.001 | 6.75 |

**Table 1:** Etch rates of oxide ALD films in oxide and silicon etchants (7 of the 20 etchants characterized in total). Colors are intended to represent the film's ability to withstand the etchant, with red corresponding to high and green to low or zero rates. *p* and *t* indicate plasma-enhanced and thermal ALD, respectively. * denotes data with large fit uncertainties requiring further experimental confirmation.