











type of waveguide as shown in Fig. 2(a). Given most analyses will only use waveguides of a similar stress profile and geometry, this may be a practical model, however we do emphasize that it lumps all of the undying physics into a single non-generalizable parameter which cannot be fairly compared between a diverse set of literature as is apparent in the range of TiO<sub>2</sub> TOCs already reported.

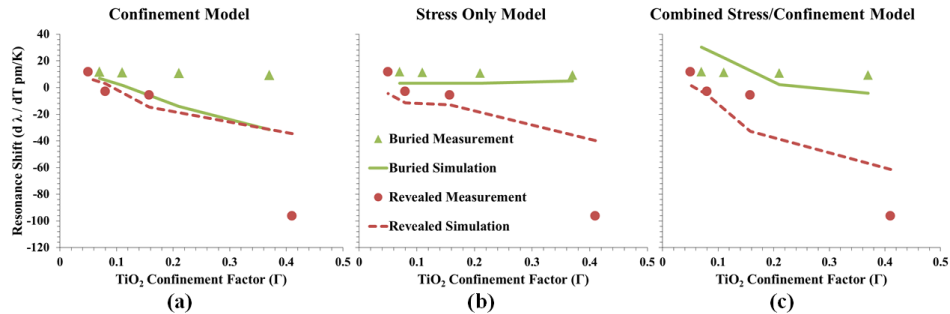


Fig. 3. Comparison of the (a) confinement, (b) stress, and (c) combined stress/confinement models.

Figure 4 plots the thermally induced stress profiles of characteristic revealed and buried waveguides showing the contrast of those stresses applied to the core and adjacent cladding. As is clear from the plots, these waveguides have complex and drastically different thermal stress profiles; which may cause the large difference in thermal drift uncorrelated to TiO<sub>2</sub> confinement.

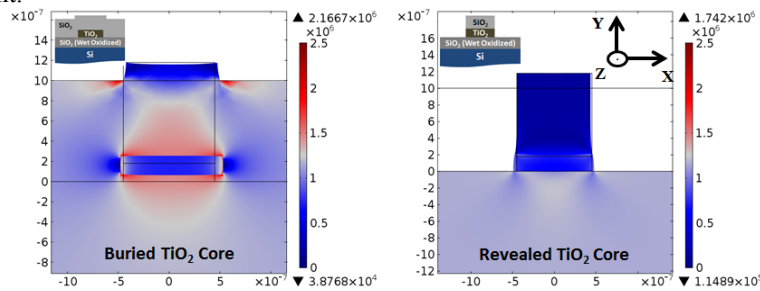


Fig. 4. Thermally induced stress profiles for Buried and revealed type waveguides. Figures are von Mises Stress profiles in Pa with a 10K temperature difference. A 10x displacement enhancement is applied for better visualization.

## 5. Conclusions

We have shown that TSO effects are important to performance of TiO<sub>2</sub> core waveguides most strongly indicated by reduction of the TOC by more than two orders of magnitude. Furthermore, we clarified the theoretical framework for this phenomenon with derivations of three models of ring resonator thermal drift. We believe that such buried channel waveguides show reduction in the thermal expansion of TiO<sub>2</sub> which is the likely cause of a stress induced suppression of the negative TOC in TiO<sub>2</sub>. Revealing the sidewalls to air appears to release that suppression. However, because of the complex nature of stress, each waveguide type requires numerical analysis to understand the role stress will play. Our model shows that in many cases this effect is at least as significant as non-stress related thermo-optic effects of the material and thus must be included to determine the correct TOC of TiO<sub>2</sub>. To generally solve the thermal drift problem without polymers or active feedback further stress research into TiO<sub>2</sub> is required to enable CMOS compatible athermal photonic integrated circuits.

## Acknowledgments

The authors acknowledge Sudharsanan Srinivasan and Martijn Heck for helpful discussions on theoretical details of this paper and support from Intel ARO program, and Semiconductor Research Corporation (SRC) for funding this research.