Pressure induced changes to titanium phosphate glass

Lönnroth, Nadja Teresia; Youngman, Randall E.; Svenson, Mouritz Nolsøe; Aitken, Bruce; Smedskjær, Morten Mattrup

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Titanium phosphate (TiO$_2$-P$_2$O$_5$) glasses are interesting materials due to their unusual glass forming range with high (65-75%) TiO$_2$ content, making them fascinating subjects to study from a structural point of view. The as-made glasses are dark due to the presence of a small amount of Ti$^{3+}$. They can be bleached to colorless glass when held in air for extended time at a temperature around $T_g$, resulting in pure Ti$^{4+}$-glasses as confirmed by EPR. We have subjected an Al-doped (5 Al$_2$O$_3$:67.5TiO$_2$:27.5P$_2$O$_5$) glass sample at $T_g$ to a moderate pressure of 1GPa. Physical properties, including density, hardness and crack probability have been measured on both non-pressurized and pressurized samples. In addition, structural information has been obtained from Raman and MAS NMR spectroscopy. After pressurization a density increase of 6% is observed as well as an increase in hardness and crack probability. $^{31}$P MAS NMR indicates that the uncompressed glass consists mainly of Q$^1$ and Q$^0$ phosphate groups. The glass appears to become more depolymerized after the pressure treatment. A corresponding increase in both the proportion of 6-fold coordinated Ti and the fraction of higher coordinated Al species is also observed. These structural modifications can be correlated with the measured changes in physical properties.