TMA measurements of the viscous flow changes in glasses induced by illumination

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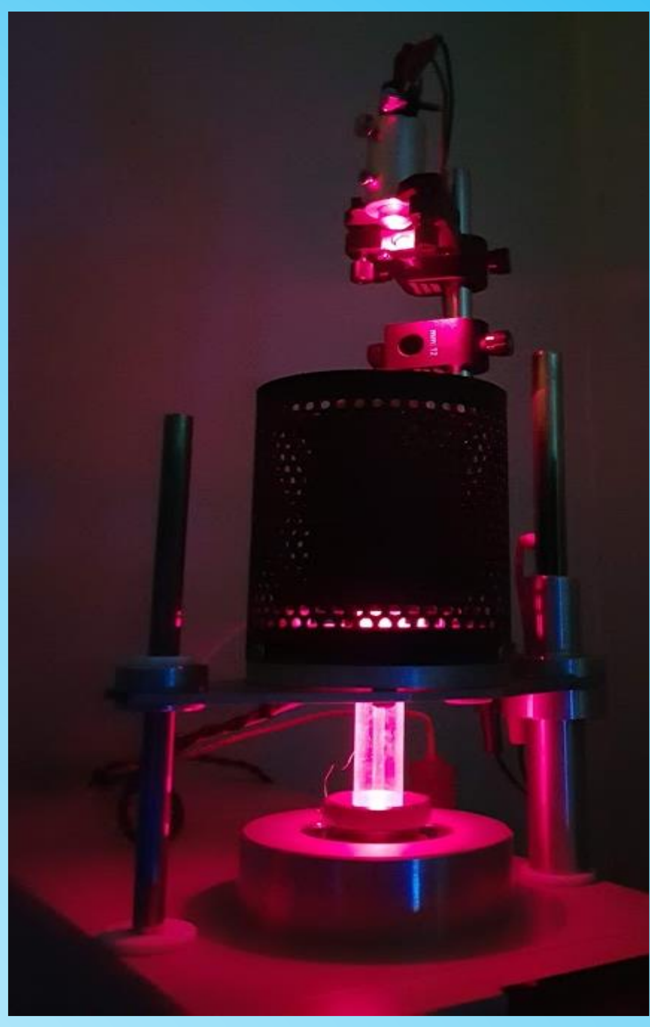


Introduction

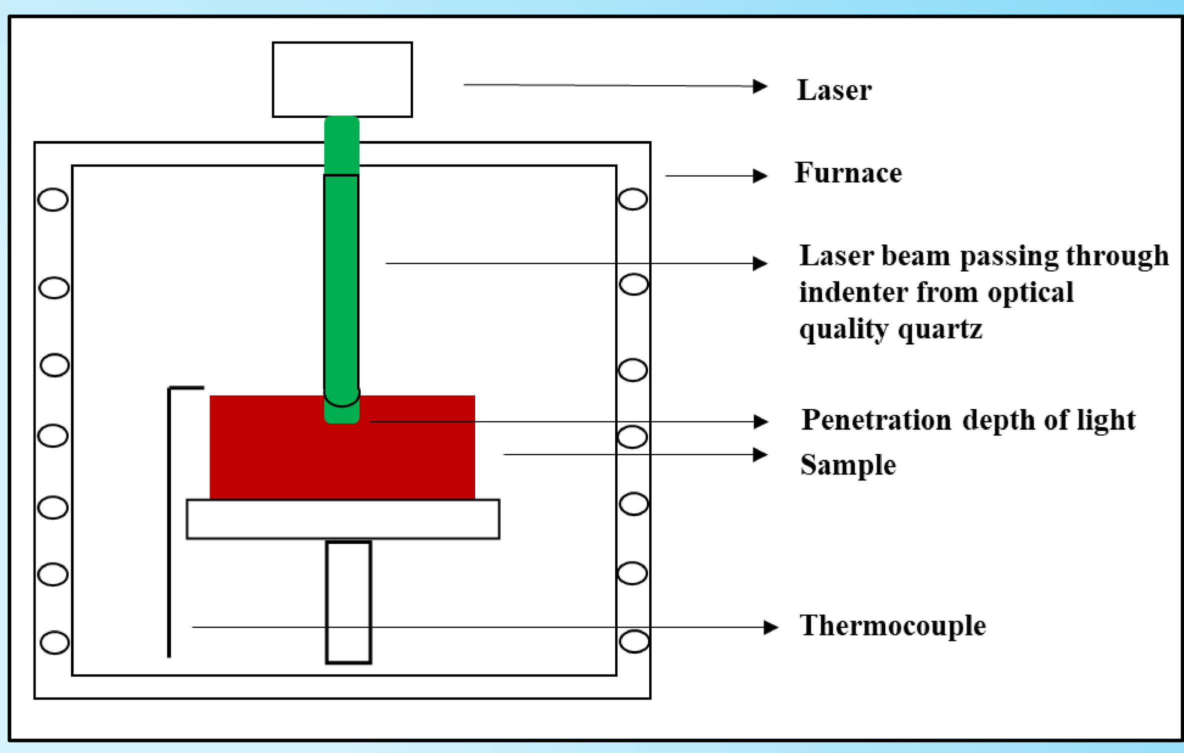
The viscous flow is important property of undercooled liquids and glassy materials that influences various processes and the possibility for the applications [1]. The viscous flow can be affected by photons with appropriate energy and intensity, see e.g. [2, 3], which could be interesting especially for applications in optics (e.g. modification of optical fibers or formation of micro-optical elements).

In this work, the photo-viscous changes of bulk chalcogenide As_2S_3 and 55PbO-10ZnO-35P_2O_5 phosphate glass with addition of 3.55 mol% of CoO were examined by penetration method employing Thermomechanical analyzer (TMA). As_2S_3 glass was selected as the model system for the optimization of the measuring conditions and the phosphate glass was chosen as the promising material for applications in optics due to the high content of PbO leading to the interesting properties in comparison with conventional phosphate glasses and due to the intensive absorption in visible region by CoO.

Experimental

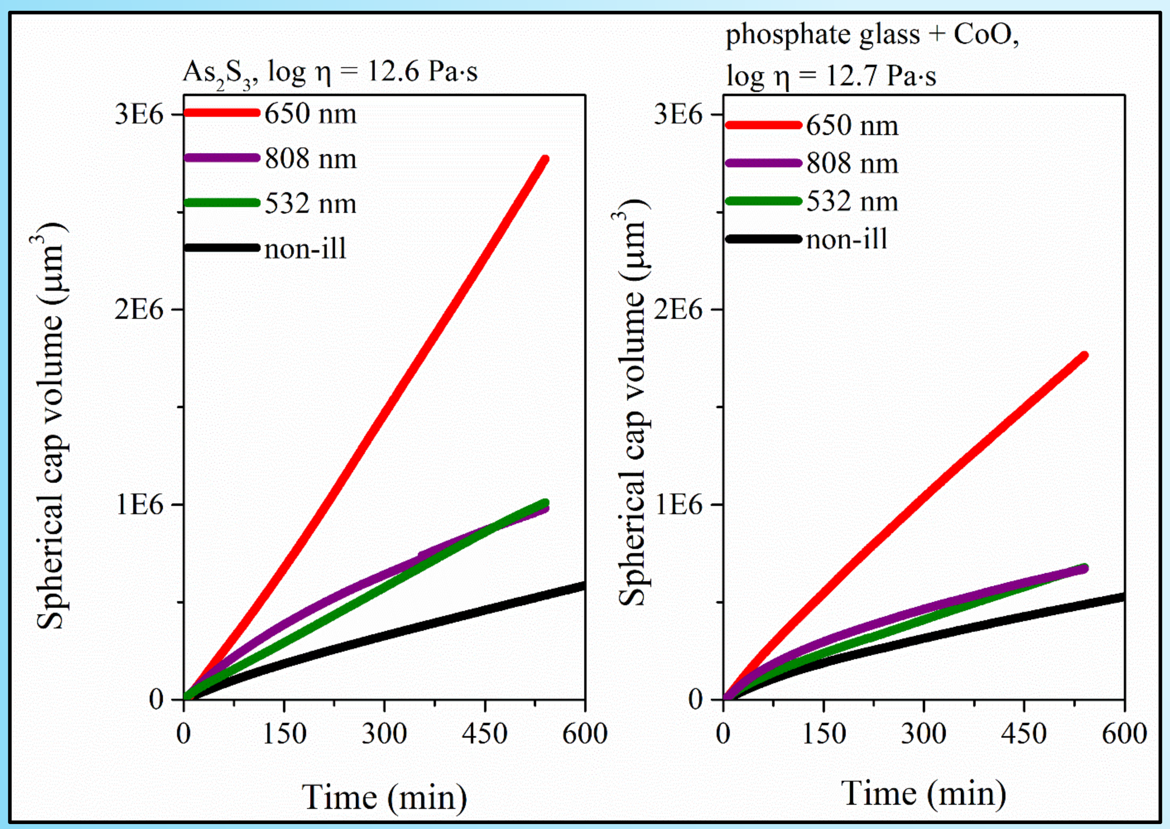
Bulk glassy samples were synthesized by classical melt-quenching technique (As_2S_3 in evacuated quartz ampoule and phosphate glass in corundum crucible, both cooled in the air). The as-prepared glasses were annealed at $T \approx T_g - 50$ °C to remove stress. Subsequently, plan-parallel samples (thickness typically 1 ± 0.1 mm) were prepared by grinding and polishing.

The photo-viscous changes measurements were performed by TMA (penetration method), see scheme. The classical indenter was replaced by the special indenter made from optical quality quartz for the simultaneous focusing of the laser beam passing through the indenter and penetration. The photo-viscous changes were evaluated as the penetration rate of the spherical cap indenter (dV/dt) in the time interval 200-480 min between the non-illuminated and illuminated sample (λ = 532, 650 and 808 nm with laser power density in the range 1.7-2.1 W/cm²). The spherical cap volume V was recalculated from experimental obtained indenter penetration depth h: $V = \frac{1}{6}\pi h(3r_1^2 + h^2)$ where r_1 was obtained using: $r_1 = \sqrt{h(2R-h)}$, R is radius of indenter.

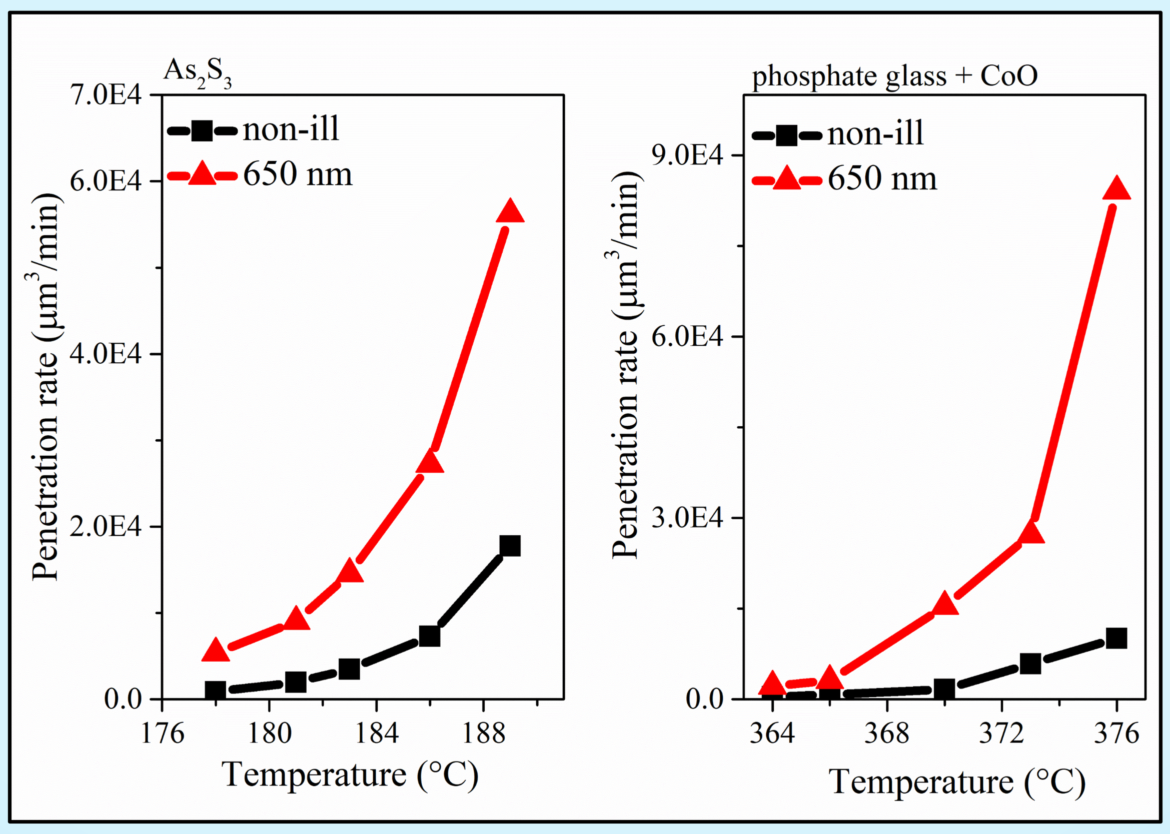


Obtained Results

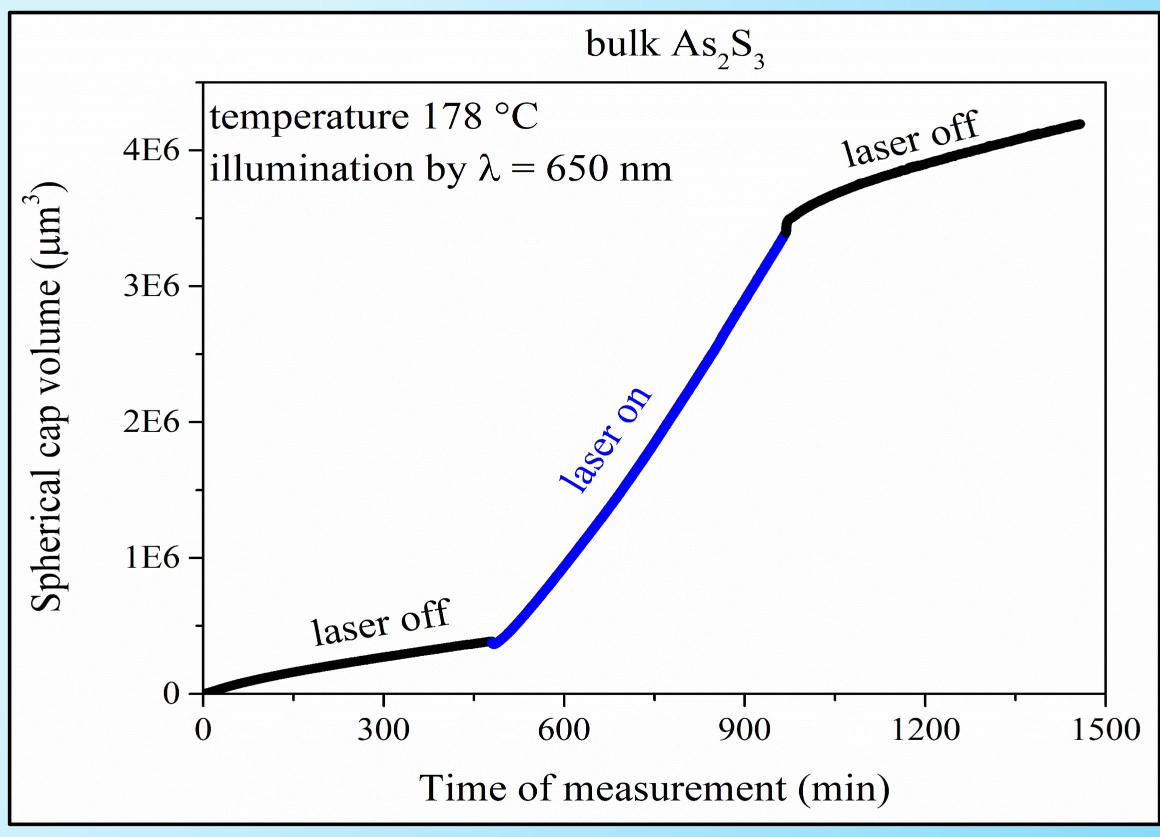
A. The influence of the wavelength



B. The influence of the temperature



C. Cyclic measurements



Conclusions

- The photo-viscous changes of bulk glasses As_2S_3 and 55PbO-10ZnO-35P_2O_5 with addition of 3.55CoO were examined. The role of wavelength, temperature on the photo-viscous changes and the nature of the photo-induced effect were investigated.
- **The influence of wavelength** on photo-viscous changes **(see figure A)** was studied using three different laser sources (λ = 532, 650 and 808 nm with F = 1.7-2.1 W/cm²). **For both glasses**, **the highest photo-viscous changes were observed using 650 nm exposition.**

  - **As for As_2S_3 glass** the exposure by all laser sources led to the photo-viscous changes. It seems that the size of the observed photo-viscous changes in As_2S_3 could be connected especially with the penetration depth of the used light (the sub-band gap light (650 nm) is absorbed almost in the whole volume of the sample).

  - **In case of phosphate glass with CoO**, the other laser sources (532 and 808 nm) in contrast to 650 nm (**see above**) cause the minimal or no photo-viscous changes. **The real mechanism has not been quite clear yet.**

- **The role of temperature** was investigated as well **(see figure B)**. In case of non-illuminated samples, the penetration rate dV/dt (see Experimental) increases with the increasing temperature due to the increase of the viscous flow. Illumination (650 nm) accelerates the penetration rate for both samples (i.e. As_2S_3 and phosphate glass with CoO) at each measured temperature below T_g compared to non-illuminated samples - **the influence of light on photo-viscous changes is evident.**
- The cyclic **measurements: without – with (650 nm) – without illumination** were performed **(see figure C)**. **It is clearly seen that the illumination causes the significant increase of the penetration rate due to the increase of viscous flow.** When the laser is switched off, the penetration rate decreases again and approaches the penetration rate in the first step of cycle. **Based on the observed behaviour, the photo-viscous changes are only temporary effects.**

References

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Acknowledgements

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