# *DSCM O5* LOADING RATE DEPENDENT RELAXATION UNDER INDENTATION OF BOROPHOSPHATE GLASS

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The plasticity of glasses under compressive and shear stresses is governed by 2 main mechanisms: densification and shear flow. The relative contribution of each of these mechanisms depends on the glass structure and its atomic packing density. It was shown that the decrease of loading and hence strain rate contribute to the intensification of both shear flow and densification processes under indentation of phosphate glass [1]. In the present work we have investigated the influence of the loading rate on the relaxation processes during holding under the load and during unloading period.

The borophosphate glass of a complex composition $B_2O_3$–$P_2O_5$–$Li_2O$–$Al_2O_3$–ZnO–$Dy_2O_3$–$Tb_2O_3$ was subjected to depth-sensing nanoindentation using high (50 mN/s) and low (1 mN/s) loading rate ($v$) in combination with short (5 s) and long (300 s) holding time ($t_h$) under the load (Fig. 1a).

It was found that the creep of material (continuous deformation during holding under the load) is influenced by the loading rate. The higher loading rate contributes to larger deformation during creep ($\Delta h_2$), as opposed to deformation during loading ($\Delta h_1$), which is smaller for higher loading rate (Fig. 1 b, c). The decrease of $\Delta h_1$ with the increase of loading rate was explained by lower malleability of the glass network in the conditions when the deformation occurs very quickly. This leads to the increase of the accumulated internal stresses, giving rise to their enhanced relaxation during holding and causing a larger deformation during creep ($\Delta h_2$). These processes affect also the elastic-plastic recovery (relaxation) under unloading ($\Delta h_3$), which is smaller in case of higher loading rate, since a part of stresses relax during holding through the creep of material.

The processes of relaxation obviously influence the values of hardness ($H$), which change depending on loading conditions. Higher loading rate leads to the increase of $H$ in case of short holding time [1], but in case of long holding time vice versa - the values of $H$ decreases with the increase of loading rate. This was explained by larger deformation during creep for higher loading rate that compensates the reduced deformation during loading.

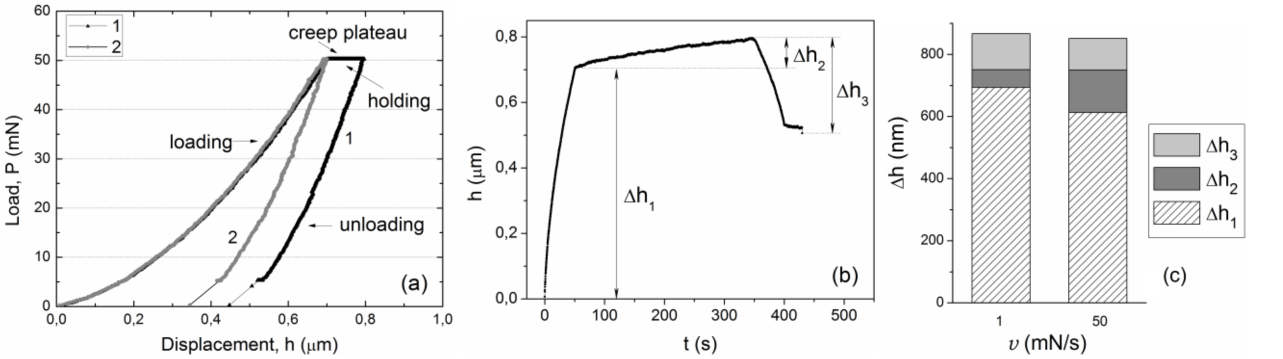


*Fig. 1. a – P(h) curves for indentations made with $t_h$ = 300 s (1) and 5 s (2), v = 50 mN/s; b – displacement-time dependency corresponding to curve 1; c – change of deformation (penetration depth) during loading ($\Delta h_1$), holding under the load ($\Delta h_2$ = 300 s) and unloading ($\Delta h_3$) with the change of loading rate.*

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