KEY WORDS: Relaxation, nanoindentation, strain rate.

Small scale characterization of material’s mechanical behavior has been performed for fifty years using indentation tests. Many developments have been made in order to improve the reliability of both measurements and interpretations. However, determination of material’s time dependent mechanical properties by means of nanoindentation techniques is still to be enhanced. It is proposed to investigate the indentation relaxation – i.e. constant displacement – test as an alternative to the commonly used indentation creep – i.e. constant load – test. Effects of loading strain rate on the measured relaxation behavior are studied, analytically, from a linear viscoelastic model. It is shown that constant strain rate loading guarantees a depth-independent measure of the relaxation behavior. Moreover, indentation strain rate (ISR) affects the relaxation spectrum up to a critical time constant (see figure 1). These effects, highlighted analytically, are confirmed experimentally on PMMA.

Limitations of the indentation relaxation test are also discussed. Two main difficulties arise from this kind of experiment. Acquisition of reliable measurements is limited, for long time characterization, by the system drift and, for short time, by the displacement control loop. A particular care has been taken in tuning the control feedback gains to limit displacement overshoot. Very low drift rate has been attained – under 0.015 nm.s⁻¹ – This allowed for measurements at constant displacement up to 600 s.

Figure 1 – (a) First order approximation of the relaxation spectrum of PMMA calculated after constant strain rate loading (ISR). t’ is considered as the time from the beginning of the hold segment. Error bars represent the standard deviation calculated on five experiments, note that for some points, markers are larger than error bars. (b) Critical time, defined by the time at which relaxation spectra merge into a master curve, versus indentation strain rate (ISR). Experimental data are estimated from (a).

References