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A method for mapping local mechanical properties on the nanometer scale by AFM

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A nano-indentation technique using an Atomic Force Microscope (AFM) was applied to characterize the mechanical behaviour of several isotactic polypropylene (iPP) samples.
The samples were solidified from the melt with a CCT (Continuous Cooling Transformation) procedure thanks to a fast quenching apparatus developed by the authors. The quenching conditions spanned a wide range of cooling rates from 2.5 to ca 300 °C/s yielding homogeneous samples ranging from a-monoclinic semicrystalline to mesomorphic ones.
The penetration depth divided by the applied load, a measure of sample compliance, decreases with increasing crystallinity.
Quantitative information about the samples' stiffness was obtained using contact mechanics models.
Moduli derived from a force curve analysis of AFM nanoindentations, the nanoscale moduli, were evaluated by a traditional force balance model (Hertz) and by a model based on an energy balance recently proposed in the literature (Arivuoli et al).
They are close to each other and they decrease with increasing cooling rate according to a relationship that closely resembles the relationship found for bulk samples.
Structure homogeneity, up to the scale of macroscopic samples used to evaluate elastic moduli, allowed a successful comparison of these values with those determined by macroscopic tension test on full size samples (i.e. a few mm), provided that comparable "overall" deformation rates are used (approx. 10-5 m/s).
It was shown that an increase in cooling rate leads to a significant decrease in the material's mechanical response.
Thus, samples obtained by the CCT procedure confirm the possibility to scale down the measurement of mechanical properties by AFM on the typical resolution of nanoindentations.
AFM can thus provide correlations between operating conditions and mechanical properties and can serve as a tool for analysing complex samples with a structure distribution and for mapping properties on a sub-micron scale.