The effect of cross-link density on the physical and mechanical properties of a monolithic and foamed bio-based polyurethane

J. Andersons[1,*], M. Kirpluks[1]

[1] *Latvian State Institute of Wood Chemistry, Polymer Laboratory, 27 Dzerbenes St., LV-1006 Riga, Latvia, janis.andersons@kki.lv*

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Abstract.
Polyurethane (PU) foams are used as a thermal insulation material in a wide range of applications. Environmental concerns and the need for sustainable development have motivated replacing in PU foam formulations the components derived from petrochemical resources by bio-based ones. To enable optimization the foam characteristics for the intended application, the effect of chemical structure of the PU on its properties needs to be established. The effect of the cross-link density of a bio-based PU, an important characteristic of its chemical structure, on stiffness, strength, toughness, linear thermal expansion, and thermal conductivity of foams is determined experimentally in this study and correlated with foam morphology and characteristics of the monolithic PU. The rigid PU foams considered were developed using only bio-based polyols, derived from tall oil - a by-product in cellulose production. The variation in PU cross-link density was achieved by changing the ratio of polyols possessing high and low OH group functionality. The stiffness and yield strength of monolithic PU were found to increase with growing cross-link density, while the thermal expansion exhibited an opposite trend. Similar response to cross-link density variation was observed also for free-rise PU foams, but the foam morphology, with foam cells being elongated in the rise direction, imparted anisotropy in foam stiffness, strength, toughness, and thermal expansion. Models relating the PU foam characteristics mentioned to foam morphology and properties of the monolithic polymer are considered.