

A new environmentally friendly wood mixed film prepared by dynamic imine adhesive

Lei Xiao Zhi-Ping Su*

(Sichuan Agricultural University, Chengdu, 611134, China)

Abstract: In the modern era, as the wood industry rapidly develops, the use of formaldehyde-based adhesives in the production of artificial boards is increasingly being supplanted by bio-based alternatives. This is due to the fact that traditional adhesives, primarily composed of petroleum-derived materials like urea formaldehyde resin, release free formaldehyde during their application, posing significant threats to both the environment and human health. Consequently, the development of eco-friendly wood adhesives that minimize the use of petroleum, emit no formaldehyde, has emerged as a critical priority. To date, bio-based adhesives have demonstrated the potential to replace traditional ones, thanks to their sustainability, biodegradability, and environmental friendliness; however, they share a common flaw with all biomass materials—they are prone to mold growth. Moreover, the difficulty in recycling ordinary adhesives after disposal contributes to the waste of resources. This research introduces a dynamic covalent network formed by imine-bonds, employing linear dynamic imine adhesive (DIA) made from benzaldehyde and diethylenetriamine, characterized by a lower glass transition temperature. Owing to the antibacterial properties imparted by the CN double bond in imine, it is ensured that biobased materials will not mold or deteriorate; Additionally, with no formaldehyde emissions, the use of DIA is notably greener and healthier. The novel wood adhesive developed in this study was blended with wood fibers to create an eco-friendly wood composite film (WHF). The thermally driven dynamic network exchange properties of DIA facilitate rapid stress relaxation in WHF, significantly enhancing its heat treatment performance. WHF exhibits good interfacial compatibility with wood fibers, forming multiple hydrogen bonding interactions at interfaces, thus endowing WHF with superior mechanical properties. The tensile strength, flexural strength, Young's modulus, and flexural modulus of WHF reach 32.5 MPa, 1.38 GPa, 57.2 MPa, and 4.53 GPa, respectively. The dynamic network switching properties of DIA endow WHF with robust thermally driven adaptability, allowing it to exhibit thermoplastic characteristics and self-healing capabilities. WHF can be reshaped into various forms upon heating and subsequently returns to its original state. The mechanical properties of a damaged WHF can be significantly retained after repair. Additionally, DIA's dynamic switching properties allow WHF to reshape crushed materials into new WHF through hot pressing. The reversibility of dynamic imine bonds in WHF facilitates efficient chemical degradation, allowing for complete closed-loop recycling and offering a novel approach to mitigating resource waste. Furthermore, the recycled wood fibers and DIA retain the capability to re-produce WHF. After five months of biodegradation in natural soil, the quality of WHF has diminished by over half. In light of these findings, WHF shows significant promise as a novel wood composite film.

通过动态亚胺胶黏剂制备的一种新型环保型木质复合膜

肖雷, 苏治平*

(四川农业大学 成都 611134)

摘要: 现如今木材工业的快速发展, 甲醛基胶黏剂在人造板制造行业使用占比逐渐被生物基胶黏剂逐渐替代。因为以脲醛树脂等石油原料为主的传统的胶黏剂在使用过程中产生的游离甲醛会对环境和人类健康产生危害。因此, 制备出减少石油资源利用, 无甲醛的释放, 绿色环保的木材胶黏剂成为了当今的重点。迄今为止, 生物基胶黏剂具有替代传统胶黏剂的潜力, 因为它们具有可持续性, 可生物降解的和环境友好但具有生物基通有的缺陷——易发霉。但是普通的胶黏剂难以做到废弃后再回收利用, 造成了资源的浪费。本研究课题通过引入基于亚胺键的动态共价网络, 使用对苯二甲醛和二乙烯三胺所制备的线性动态亚胺胶黏剂 (DIA), 具有更低的玻璃化转变温度。因为亚胺键中的 CN 双键具备的抗菌性, 证明不会像生物基材料发霉变质; 且不存在甲醛的释放, DIA 的利用过程更加的绿色健康。通过本研究制备的新型木材胶黏剂, 将其与木纤维共混制备了环保型木质复合膜 (WHF), DIA 的热驱动动态网络交换特性为 WHF 提供了快速的应力松弛行为, 极大地提高了其热处理性能。WHF 与木纤维具有良好的界面相容性, 各界面之间形成了多种氢键相互作用, 使 WHF 具有优异的力学性能。WHF 的抗拉强度、抗弯强度、杨氏模量和抗弯模量分别达到 32.5 MPa、1.38 GPa、57.2 MPa 和 4.53 GPa。DIA 的动态网络交换特性也为 WHF 提供了良好的热驱动动态自适应能力, 可以使 WHF 具备热塑性能和自修复能力。WHF 经过加热后可以塑造成各种形状, 而后经过加热仍能恢复原状; 收到损伤的 WHF 在经过修复后的其力学性能可以得到很大程度的保存。同时, DIA 的动态交换特性使 WHF 能够实现破碎材料在热压后重塑成全新的 WHF。而动态亚胺键的可逆性赋予了 WHF 优异化学降解能力, 可以完全实现闭环回收, 对资源浪费提供了很好的新解决途径。此外, 回收的木纤维和 DIA 保留了再次制备 WHF 的能力。在自然土壤中生物降解 5 个月后, WHF 的质量下降了一半以上。综合以上结果, WHF 作为新型的拇指复合膜有很大的前景。