

1 **Supplementary Information**

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4 **Preparation and Performance Study of CTBN/Nano-SiC Composite**

5 **Toughened Xanthoceras sorbifolia Oil-based Adhesive**

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24

Contents

25 **S1** Synthesis Procedures of MXOEA and AEXO

26 **S2** Preparation of Silane Coupling Agent-Modified Nano-SiC

27 **S3** Detailed Process Parameters for Plywood Preparation

28 **S4** Methods for Determining Mechanical Properties of Plywood Specimens and

29 Adhesive

30 **S5** FTIR spectra of MXOEA, AX, and AX-IEM10

31

32 **S1 Synthesis Procedures of MXOEA and AEXO**

33

34 **S1.1 Synthesis Procedure of MXOEA**

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36 Under a nitrogen atmosphere, 105 g of Xanthoceras sorbifolia oil (XO) was mixed with 70 g
37 of diethanolamine and 1.62 g of sodium methoxide as a catalyst. The mixture was stirred at 80°C
38 for 20 min, then heated to 120°C and reacted at 520 rpm for 4 h. After cooling, the Xanthoceras
39 sorbifolia oil-based diol (XOEA) was obtained with a mass yield of 98.62% (based on XO).
40 Subsequently, XOEA and methacrylic anhydride (MAA) were reacted at a mass ratio of 1:2, using
41 4-dimethylaminopyridine (DMAP, 2% by mass of XOEA) as a catalyst, at 65°C and 520 rpm for 5
42 h. After the reaction, the product was washed successively with saturated NaHCO₃ solution and
43 saturated NaCl solution, and then subjected to rotary evaporation to obtain Xanthoceras sorbifolia
44 oil dimethacrylate (MXOEA) with a mass yield of 81.40% (based on XOEA).

45

46 **S1.2 Synthesis Procedure of AEXO**

47

48 50 g of XO, 1.5 g of cation exchange resin, and 45 mL of glacial acetic acid were mixed
49 uniformly. 125 mL of 30% H₂O₂ solution was slowly added dropwise at room temperature. The
50 mixture was then heated to 65°C and stirred continuously at 500 rpm for 3 h to obtain epoxidized
51 Xanthoceras sorbifolia oil (EXO). The product was washed successively with saturated Na₂CO₃
52 solution and saturated NaCl solution until neutral, and then purified by rotary evaporation,
53 yielding a mass yield of 89.50% (based on XO). Subsequently, 100 g of the obtained EXO was
54 mixed with 3.75 g of triphenylphosphine (PPh₃) and 1.25 g of hydroquinone as a polymerization
55 inhibitor. 50 g of acrylic acid (AA) was slowly added dropwise at 80°C, followed by heating to
56 100°C and reaction at 500 rpm for 4 h to obtain acrylated epoxidized Xanthoceras sorbifolia oil
57 (AEXO). The reaction product was likewise washed with saturated Na₂CO₃ solution and saturated
58 NaCl solution until neutral, and purified by rotary evaporation, yielding a mass yield of 83.46%
59 (based on EXO).

60

61 **S2 Preparation Process of Silane Coupling Agent Modified Nano-SiC**

62

63 Interfacial interactions exist between nanoparticles and the organic resin matrix. The u
64 se of coupling agents can enhance the bonding between them, ensuring good adhesion bet
65 ween the filler and the matrix, and improving bonding strength and durability. Silane coup
66 ling agents commonly used in resins include γ -aminopropyltriethoxysilane (KH-550) and γ -
67 glycidoxypropyltrimethoxysilane (KH-560). Compared with KH-550, KH-560 possesses long
68 -chain methylene groups and flexible ether bonds, which can effectively resist external stre
69 ss and disperse stress concentration. This helps to alleviate point-like and local stresses in
70 the bonding area, improving overall bonding strength and durability. Therefore, KH-560 w
71 as used to modify SiC in this study.

72

73 **S2.1 Raw Material Pretreatment**

74

75 The nano-SiC powder (average particle size of 40 nm) was placed in a vacuum dryin
76 g oven and dried at 80°C for 12 h to remove adsorbed moisture.

77

78 **S2.2 Preparation of KH-560 Hydrolyzate**

79

80 An appropriate amount of anhydrous ethanol was taken, and γ -glycidoxypropyltrimetho
81 xysilane (KH-560, 97%) was added at 2% of the total system mass. The pH was adjusted
82 to 4-5 using oxalic acid ($C_6H_7O_4$), and the mixture was allowed to stand at room tempera
83 ture for 30 min to complete the activation of the coupling agent, yielding a transparent hy
84 drolyzate.

85

86 **S2.3 Surface Modification of Nano-SiC**

87

88 The dried nano-SiC powder was weighed and dispersed in anhydrous ethanol, followe
89 d by ultrasonic treatment at 60 Hz in an ice-water bath for 1 h to achieve thorough dispe
90 rsion of the particles. The above hydrolyzate was slowly added dropwise to the ethanol di

91 spersion of nano-SiC. After the addition was completed, the mixture was transferred to a
92 constant-temperature oil bath at 70°C and reacted under mechanical stirring at 300 rpm fo
93 r 3 h.

94

95 **S2.4 Post-Reaction Treatment**

96

97 After the reaction, the mixture was cooled to room temperature and centrifuged at 80
98 00 rpm for 15 min to collect the precipitate. The precipitate was washed three times with
99 anhydrous ethanol, with centrifugation performed after each wash. The washed product was
100 dried in a vacuum drying oven at 50°C for 12 h to obtain KH-560 modified nano-SiC m
101 aterial, which was then sealed and stored for further use.

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106 **S3 Detailed Processing Parameters for Plywood Preparation**

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108 **S3.1 Veneer Materials**

109

110 The plywood adopted a five-layer structure, with the top ply made of Linden wood, t
111 he cross ply made of Spruce wood, and the core ply made of Ayous wood.

112

113 **S3.2 Adhesive Application and Assembly**

114

115 The prepared CTBN-SiC composite modified Xanthoceras sorbifolia oil-based adhesive
116 was placed in a vacuum oven for degassing to remove internal bubbles and residual volati
117 le substances. The adhesive was uniformly applied onto the surface of the veneers, with t
118 he adhesive application amount controlled at 180 g/m² (per single side). Assembly was car
119 ried out with perpendicular grain orientation, where the grain direction of the top ply was
120 perpendicular to that of the cross ply, and the grain direction of the cross ply was perpen
121 dicular to that of the core ply.

122

123 **S3.3 Aging and Hot Pressing**

124

125 After assembly, the mat was subjected to open aging at room temperature for 15 min,
126 and then placed in a hot press for hot pressing at 120°C and 1.0 MPa for 480 s.

127

128 **S3.4 Cooling and Post-Treatment**

129

130 After hot pressing, the mat was immediately wrapped with plastic wrap and slowly c
131 ooled in an insulation chamber to prevent warping or cracking caused by a sudden temper
132 ature drop. After cooling to room temperature, the cured mat was processed into standard
133 test specimens and finished blade shapes.

134

135

136 **S4 Methods for Determining the Mechanical Properties of Plywood Specimens**
137 **and Bulk Adhesive**

138

139 **S4.1 Determination of Modulus of Rupture and Modulus of Elasticity**

140

141 The modulus of rupture and modulus of elasticity of the plywood specimens were det
142 ermined using a microcomputer-controlled electronic universal testing machine (WDW-20A,
143 Tianchen Machine Manufacturing Co., Ltd., China). The specimen length was set to (20t
144 \pm 50) mm based on the thickness t, the width was 50 mm, the span was 20t mm, and th
145 e loading rate was 20 mm/min.

146

147 **S4.2 Determination of Impact Strength**

148

149 The impact strength of the bulk adhesive was determined using a Charpy impact teste
150 r, and the specimen dimensions were 80 mm \times 10 mm \times 4 mm.

151

152 **S4.3 Determination of Dry-State and Wet-State Bonding Strength**

153

154 The dry-state and wet-state bonding strength tests were conducted in accordance with
155 relevant standards: dry-state specimens were tested directly; wet-state specimens were imme
156 rsed in water at 63°C for 3 h, then removed and cooled for 10 min before testing. The s
157 pecimen dimensions were uniformly 100 mm \times 25 mm, and the loading rate was 5 mm/
158 min.

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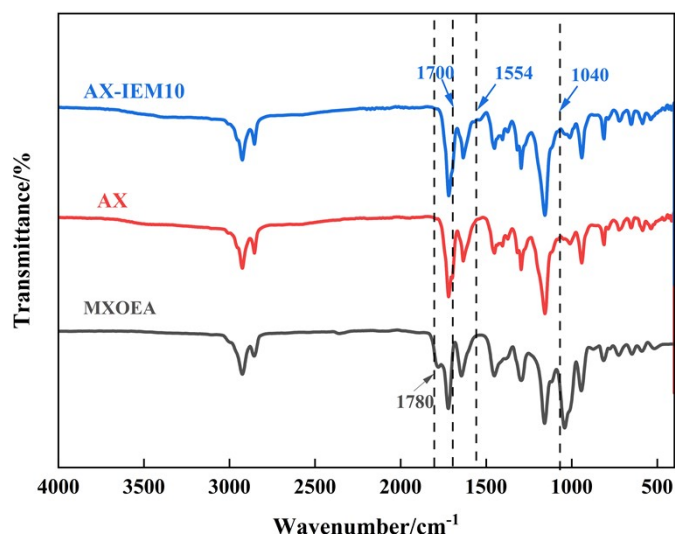
160 **S4.4 Application Performance Validation**

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162 To comprehensively evaluate the performance of the adhesive in practical application
163 scenarios, the pressed laminated plywood specimens were further processed into application
164 components with a specific structure (using table tennis blades as prototypes components) t
165 o demonstrate the forming state of the developed adhesive in actual products.

166 S5 FTIR spectra of MXOEA, AX, and AX-IEM10.

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Fig. 1 FTIR spectra of MXOEA, AX, and AX-IEM10.

171

172 Fourier transform infrared (FTIR) spectroscopy was performed on MXOEA, adhesive AX
173 (Xanthoceras sorbifolia oil-based adhesive without IEM), and AX-IEM10 (Xanthoceras sorbifolia
174 oil-based adhesive with 10% IEM), and the results are shown in Fig. 1. MXOEA exhibited a
175 stretching vibration peak of the methacrylate carbonyl group (C=O) at 1782 cm⁻¹ and a symmetric
176 stretching vibration peak of the ester bond (C-O-C) at 1040 cm⁻¹, indicating the successful
177 introduction of diester groups into its structure. In the FTIR spectrum of AX, the carbonyl peak of
178 MXOEA shifted to 1720 cm⁻¹ and overlapped with the ester peak of AEXO, while the
179 characteristic ester peak at 1040 cm⁻¹ disappeared due to the formation of the crosslinked network,
180 indicating that the reactive double bonds in MXOEA were fully converted during the curing
181 process via free radical polymerization, forming a crosslinked structure with AEXO. Compared
182 with AX, AX-IEM10 exhibited a new peak at 1700 cm⁻¹ attributed to the urethane bond (-NH-CO-
183 O-), and a peak at 1554 cm⁻¹ corresponding to the N-H bending vibration of the urethane group [1],
184 confirming that the isocyanate groups (-NCO) of IEM reacted with the hydroxyl groups of AEXO.
185 Furthermore, no characteristic peak of -NCO was observed around 2270 cm⁻¹, indicating that the
186 isocyanate groups were fully involved in the reaction. These results demonstrate that IEM was
187 successfully incorporated into the crosslinked network through chemical bonding, and the double
188 bonds in MXOEA were efficiently converted during the curing process via free radical
189 polymerization.

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