LIQUID OPTICAL ADHESIVE COMPOSITIONS

Field

The present disclosure relates to optically clear adhesives and laminates that include the adhesives.

Background

Optically clear adhesives are finding wide applications in optical displays. Such applications include bonding polarizers to modules of a liquid crystal display (LCD) and attaching various optical films to a glass lens in, for example, mobile hand held (MHH) devices. During use, the display can be subjected to various environmental conditions, such as high temperature and/or high humidity.

It has been observed that adhesives can exhibit a cloud point after subjecting optical laminates of optical films and adhesives to high temperature/humidity accelerated aging tests and subsequently cooling the laminates down to ambient conditions. While still hot, the laminates may be perfectly clear, even when saturated with moisture. But upon cooling they can exhibit a cloud point and turn hazy or "white". Frequently, the haze will disappear over time upon storage of the laminate under ambient conditions. The haze disappearance can often be accelerated by gently heating the optical laminates.

Summary

The present disclosure includes a curable composition comprising a) a solute (meth)acryloyl oligomer having a plurality of pendent, ethylenically unsaturated, free-radically polymerizable functional groups and pendent hydroxyl groups, a M_w of 5k to 30k, a $T_g < 20^oC$ (preferably having a $T_g < 0^oC$); b) a solvent monomer component; and a photoinitiator. In one aspect, a curable adhesive composition is provided that comprises a) a solute (meth)acryolyl oligomer having a Mw of 5 to 30k and a Tg of < 20oC comprising i. greater than 50 parts by weight of (meth)acrylate ester monomer units, ii. 10 to 49 parts by weight of hydroxyl-functional monomer units, iii. 1 to 10 parts by weight of monomer units having pendent acrylate groups, iv. 0 to 20 parts by weight of polar monomer units, v. 0 to 10 parts by weight of silane-functional monomer units, wherein the sum of the monomer units is 100 parts by weight; b) a diluent monomer component, and c) a photoinitiator, wherein the composition comprises no polyethylenically unsaturated monomer or other crosslinking agents.

The composition, when cured, is non-yellowing, exhibits low shrinkage, low birefringence and low sensitivity to moisture (cloud point-resistant), making it suitable for many optical applications including, but not limited to bonding polarizers to modules of a liquid crystal display

optical adhesive composition disposed between the two substrates. In another aspect, an optically clear laminate is provided that comprises a first substrate having at least one major surface; a second substrate having at least one major surface; and the curable adhesive composition as defined herein situated between and in contact with at least one major surface of the first substrate and at least one major surface of the second substrate. The articles of the disclosure may have a thickness greater than about 0.5 millimeters, generally a birefringence (absolute) of less than $1x10^{-6}$, light transmission greater than about 85%, preferably greater than 90%, and a CIELAB b* less than about 1.5 units, preferably less than about 1.0 unit for samples with thickness of 500 microns.

In a further aspect, an optically clear laminate is provided that includes a first substrate having at least one major surface, a second substrate having at least one major surface, and a cloud point-resistant, optically clear adhesive composition situated between and in contact with at least one major surface of the first substrate and at least one major surface of the second substrate, wherein the adhesive has a moisture-vapor transmission rate of at least 400 $g/m^2/day$.

By incorporating hydrophilic moieties in the liquid optical adhesive matrix, haze-free, cloud point-resistant adhesives can be obtained which remain clear even after high temperature/humidity accelerated aging tests. The provided adhesives are suitable for use in, for example, laminating polarizers to optical LCDs, attaching various optical films to glass lenses in mobile handheld devices, and other adhesive application that require optical clarity in various temperature and humidity environments.

Although not wishing to be bound by theory, it is thought that the haze appears when the adhesive becomes saturated with water at elevated temperatures, and the concentration of water exceeds the cloud point when quickly cooled due to poor compatibility of the moisture with the adhesive matrix. This can result in phase separation of small water droplets, which due to a mismatch in refractive index with the adhesive matrix causes haze or a "white" appearance. If the droplets remain very small (e.g., a few hundred nanometers or less) or the water remains fully solubilized in the adhesive under ambient conditions, the adhesive and its bond line with the substrate will stay clear while it re-equilibrates its moisture content with the environment. To facilitate re-equilibration of the moisture with its environment, it is also anticipated that the moisture-vapor transmission rate of the adhesive needs to be high enough to transport the water at a sufficiently high rate to prevent water accumulation which may lead to light scattering and haze.

In a yet further aspect, a method of preparing an adhesive is provided that comprises the steps of (i) providing an essentially curable composition as defined herein, (ii) partially polymerizing said composition to provide a partially polymerized mixture exhibiting a Brookfield viscosity of between 1,000 and 500,000 mPas at 20oC and a degree of conversion of monomers to

What is claimed is:

1. A curable adhesive composition comprising:

a) a solute (meth)acryolyl oligomer having a M_w of 5 to 30k and a T_g of < 20°C comprising

i. greater than 50 parts by weight of (meth)acrylate ester monomer units,

ii. 10 to 49 parts by weight of hydroxyl-functional monomer units,

iii. 1 to 10 parts by weight of monomer units having pendent acrylate groups,

iv. 0 to 20 parts by weight of polar monomer units,

v. 0 to 10 parts by weight of silane-functional monomer units,

wherein the sum of the monomer units is 100 parts by weight;

b) a diluent monomer component, and

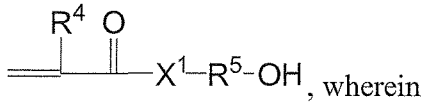
c) a photoinitiator,

wherein the composition comprises no polyethylenically unsaturated monomer or other crosslinking agents.

2. The curable adhesive composition of claim 1 comprising less than 50 wt.% of the diluent monomer component and greater than 50 wt.% of the solute oligomer.

3. The curable adhesive composition of claim 1, wherein the alkanol of the (meth)acrylate ester monomer units of the oligomer have an average carbon number of C_{10}-C_{14}.

4. The curable adhesive composition of claim 1, wherein the hydroxyl functional monomer has the general formula:



, wherein

R^5 is a hydrocarbyl group;

R^4 is -H or C_1-C_4 alkyl; and

X^1 is $–NR^4$- or –O-.

5. The curable adhesive composition of claim 1 wherein the diluent monomer component comprises:

80 to 100 parts by weight of (meth)acrylate ester monomers;

0 to 20 parts by weight of hydroxy-functional monomers;

0 to 5 parts by weight of polar monomers;

0 to 2 parts by weight of silane functional monomers, wherein the sum of the monomer of the diluent monomer component is 100 parts by weight.

6. The curable adhesive composition of claim 1 wherein the oligomer is of the formula: ~$[M^{Ester}]_a$-$[M^{OH}]_{b*}$-$[M^{Polar}]_c$-$[M^{Silyl}]_e$- $[M^{Acryl}]_d$-, where

-$[M^{Ester}]$- represents interpolymerized (meth)acrylate ester monomer units;

-$[M^{OH}]$- represents interpolymerized (meth)acryloyl monomer units having a pendent hydroxy group,

-$[M^{Polar}]$- represents interpolymerized polar monomer units; and

$[M^{Acryl}]$ represents interpolymerized (meth)acryloyl monomer units having a pendent polymerizable (meth)acryloyl group;

$[M^{Silyl}]$ represent optional silane-functional monomer

subscripts a, b*, c, d and represent the parts by weight of each monomer unit.

7. The curable adhesive composition of claim 1 further comprising metal oxide particles having an average particle size of 1 nm to about 100 nm in amounts of 1 to 10 wt.%, relative to the total weight of the curable composition.

8. The curable adhesive composition of claim 1 wherein the hydroxyl-functional monomer is used in amounts such that the curable composition ~~(oligomer + diluent)~~ has a hydroxyl content greater than 6.5×10^{-4} mol OH/g.

9. The curable adhesive composition of claim 1 wherein the oligomer is prepared by an adiabatic polymerization process.

10. An optically clear laminate comprising:

a first substrate having at least one major surface;

a second substrate having at least one major surface; and

the curable adhesive composition of claim 1 situated between and in contact with at least one major surface of the first substrate and at least one major surface of the second substrate.