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(54) **CROSSLINKABLE COMPOSITION**

VERNETZBARE ZUSAMMENSETZUNG

COMPOSITION RÉTICULABLE

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**WO-A1-2008/157468**

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## Description

[0001] The present invention relates to a crosslinkable composition crosslinkable by Real Michael Addition (RMA) reaction wherein a component with at least 2 activated unsaturated groups (hereafter also referred to as the RMA acceptor) and a component with at least 2 acidic protons C-H in activated methylene or methine groups (hereafter also referred to as the RMA donor) react and crosslink to each other in the presence of a strong base catalyst.

[0002] RMA chemistry can be tuned to give very fast curing compositions (also at lower curing temperatures) in coating compositions at acceptable or good pot lives and good material properties, which makes this chemistry very attractive as a basis for coating compositions. Details of RMA cross-linkable compositions using a latent based cross-linking catalyst are described in non-prepublished application PCT/EP2011/055463 which is herewith incorporated by reference.

[0003] WO2008/157468 relates to biodegradable crosslinkable polyvinylpyrrolidone (PVP) polymer. The PVP polymer is used for biodegradable scaffolds etc. The polymer is made crosslinkable by being modified with an acrylate functional group (a Michael Addition acceptor) that can react in a Michael addition reaction with a Michael Addition donor. Suitable donors described are ethoxylated pentaerythritol and thiols.

[0004] EP0808860 describes a resin composition crosslinkable by Real Michael Addition reaction and specifies base catalysed addition of activated methylene (RMA donor) to polarised double bonds (RMA acceptor). Suitable RMA crosslinkable components mentioned are malonate ester containing polymer and an acrylate containing polymer.

[0005] Real Michael addition is activated by strong bases, but also inhibited by the presence of acidic species that will consume these basic catalysts. In tuning the reactivity of coating systems in view of achieving a desirable drying profile, there are various requirements to balance. The drying profile (also referred to as the reaction profile or as the curing profile) is the progress of the cross-linking reaction as a function of time. It is required that the drying profile allows build-up of mechanical properties as fast as possible, to help the productivity of the coater. It is further also required to have a drying profile that is robust, i.e. the reactivity (and hence the resulting drying profile) is not strongly influenced by accidental low levels of acidic contaminants being present.

[0006] On the other hand it is required to have a good appearance of the resulting coating. This implies the need for sufficient levelling you are during the immediate period after application, when the curing coating composition is present as a liquid and capable of such levelling. This also implies the need for absence of artefacts like solvent inclusions or gas inclusions or other surface irregularities that may occur if curing is very fast, especially if it is faster at the surface than in deeper layers, which is often the case if curing occurs at the time scale of solvent evaporation or surface activation of a catalyst. Also film hardness build-up will be affected under conditions in which solvent entrapment occurs.

[0007] The described requirements are to some extent opposing each other. For a fast curing profile, but also for a high robustness against accidental acid contaminants high levels of catalyst are preferred, whereas at the same time such high levels of catalysts may negatively influence surface appearance and hardness development. The object of the invention is to provide an RMA cross-linkable composition that provides a better balance in these apparently counteracting requirements in particular in crosslinkable compositions having a high solid content.

[0008] There is also a desire for crosslinkable compositions that can be simply cured in ambient conditions as opposed to for example compositions comprising photo-latent amine catalysts, known from T. Jung et al Farbe und Lacke Oct 2003. Such photo-latent amine catalysts that do generate a strong base on UV radiation, are not suitable for coating more complex irregular substrates where parts of the surfaces are not reachable with UV or visible light, or for highly pigmented systems.

[0009] According to the invention there is provided a RMA crosslinkable composition for making thick coating layers comprising at least one crosslinkable component comprising reactive components A and B each comprising at least 2 reactive groups wherein the at least 2 reactive groups of component A are acidic protons (C-H) in activated methylene or methine groups (*the RMA donor group*), and the at least 2 reactive groups of component B are activated unsaturated groups (C=C) (*the RMA acceptor group*), to achieve crosslinking by Real Michael Addition (RMA) reaction, said composition further comprising a base catalyst (C), an X-H group containing component (D) that is also a Michael addition donor reactable with component B under the action of catalyst C, wherein X is C, N, P, O or S and a sag control component (E).

[0010] In a preferred cross-linkable composition according to the invention the RMA acceptor groups B are acryloyl groups and preferably the RMA donor groups A predominantly are malonate groups.

[0011] The inventors have found that by using X-H group containing component D as described in an catalysed RMA crosslinkable composition, it is possible to create a reactivity profile comprising an initial induction time of lowered reaction rate directly after application and activation of the system, followed by a relative increase of reactivity in later stages. This induction time can be tuned, to allow a "open time" the period allowing flow and solvent and entrapped air bubbles to escape. The induction time allows a significantly higher amount of flow and levelling of the system, avoiding surface defects that may result from very fast cure without these additives, and better hardness build-up due to reduced solvent entrapment, while still benefiting from the full potential of the catalysts beyond this induction time, thus creating an acceleration of the reaction at later stages to complete crosslinking at higher rate than would be found if simply using

lower catalyst levels. Also the high sensitivity of lower catalyst levels towards accidentally present acid contaminations is avoided.

**[0012]** Although the advantages of the invention are apparent in layers of normal thickness, the crosslinkable composition according to the invention is particularly suitable for making thick layers. Thick layers are considered to be layers having a cured dry thickness of at least 70 micrometers. In thick layer applications the risk of air and solvent inclusions is higher. This is particularly pronounced in RMA crosslinkable compositions that are cured at low temperature in the range from 10 to 60°C where resins are more viscous and levelling is difficult. Further, it is of particular importance that the nature of the solvent, and the relative amounts in a solvent mixture are appropriately chosen to give good appearance of the thick coating, and avoid excessive solvent entrapment and resulting plastization. The criticality of the choice also depends on the way and the temperature of application of the coating composition on the substrate: for example spraying generally results in air inclusion, that must have an opportunity to escape from the film. If the solvent is too volatile, evaporation and cure may be too quick and air bubbles may be entrapped in the cured at coating. There should be sufficient time to allow air to escape from the uncured coating layer. If the solvent is not volatile enough solvent may be entrapped because the coating is cured faster than solvent evaporated, further solvent diffusion being extremely slow at full cure conditions. There should be sufficient 'open time' to allow solvent to escape from the curing coating layer. The skilled person can determine the optimum conditions and choice of the solvent in view of minimizing the air and solvent inclusions. However, this becomes increasingly difficult for thick layers. A particular advantage of the invention is that the open time is significantly increased so that not only good leveling is achieved but also the solvent inclusion and air inclusion is minimized and the criticality of choosing the application conditions and solvent type and amount is reduced.

**[0013]** The effect obtained according to the invention is illustrated in Fig 1 which describes the conversion of the acryloyl (as followed by FTIR at 809 cm<sup>-1</sup>) in the preferred acryloyl/malonate system using succinimid as component D. The crosslinkable composition without component D has a very quick hardness build up (open diamond). The profile of the same composition with component D (closed diamond) shows that the open time modifying component D creates an induction time in the reactivity profile in which the conversion is slowed down and after which the conversion accelerates to give fast cure completion. This effect cannot simply be obtained by choosing a lower amount of catalyst C.

**[0014]** The components in the crosslinkable composition form an acid-base equilibrium system. The reactivity profile of the crosslinkable composition is the result of the choice of relative pKa values of the acidic components A and D in the composition that contribute to the acid-base equilibrium system and the relative reactivity of the deprotonated forms of the components towards component B.

**[0015]** The X-H group in component D has a higher acidity than the C-H groups in component A, preferably being characterized in that component D has a pKa (defined in aqueous environment) of at least one unit, preferably two units, less than that of component A. Preferably the pKa of the X-H group in component D is lower than 13, preferable lower than 12, more preferably lower than 11 most preferably lower than 10. An excessive acidity may create problems with components in the catalyst system; therefore hence the pKa is preferably higher than 7, more preferably 8, more preferably higher than 8.5. The acidity difference assures that on application of the coating, component D is activated (deprotonated) preferentially over component A.

**[0016]** It is preferred that component D has a reactivity in a Michael addition towards component B such that, when present in a mixture alongside the C-H functional groups of component A and a base catalyst, it will convert relatively faster, compared to the C-H of component A. This preference of D converting faster than A helps creating an induction time. Such a preference can be established by formulation both components A and D (or model compounds with similar functional groups) in similar amounts, with a limited amount of a component with similar functional groups as component B (e.g. butylacrylate, such that the amount of RMA donor groups to RMA acceptor groups is 2 to 1), and completing the Michael addition in the presence of a base, and analyzing the results with a suitable technique, e.g. with LC or NMR. The conditions (e.g. temperature) are then best chosen close to the conditions to be used in curing. As a first guideline, this can be done under room temperature conditions.

**[0017]** It is further preferred that component D has a reactivity towards a Michael addition when activated with a base, which is lower by at least a factor 3 compared to that of the C-H groups in component A, when either is tested under comparable conditions in a formulation at room temperature with excess of RMA acceptor groups B, and in presence of a base at least able to deprotonate 1 mole% of the RMA donor. The lower reactivity of D anions towards B compared to that of A anions, helps creating an induction time. When considering its application for other curing temperatures, this relative reactivity is best determined at adjusted temperatures.

**[0018]** The catalyst C is mixed with components A and B shortly before use. Components A and B are usually stored together and should have a long shelf life. Component D can be mixed and stored with catalyst C or with components A and B. In particular in the latter case, in view of maintaining acceptable pot life and shelf life, it is preferred that the X-H group of component D is not too highly reactive towards the Component B (e.g. acryloyl) in absence of the base catalyst C; i.e. without activation by a base. Therefore, it is preferred that the component D has a reactivity in a Michael addition towards component B such that, without base activation, it has a room-temperature half-time when dissolved in buty-

lacrylate of more than 30 minutes, preferably more than 1 hour, preferably more than 2 hours, preferably more than 4 hours, more preferably more than 8 hours, still more preferably more than 24 hours, most preferably more than 72 hours.

**[0019]** Preferably component D is selected from one or more compounds from the group of Compounds D1 comprising C-H acidic protons (X is C) in activated methylene or methine groups and Compounds D2 comprising N-H acidic compound (X is N).

**[0020]** Suitable components D2 are an aza-acidic compounds (X is N) preferably comprising a molecule containing the N-H as part of a group  $-(C=O)-NH-(C=O)-$ , or of a group  $-NH-(O=S=O)-$  or a heterocycle in which the nitrogen of the N-H group is contained in a heterocyclic ring, more preferably component D2 is an imide derivative, preferably an (optionally substituted) succinimide or glutarimide.

**[0021]** Suitable components D can be chosen on the basis of pKa values as indicated from the group consisting of succinimide (9.5), ethosuximide (9.3), 5,5-dimethylhydantoin (10.2), 1,2,4-triazole (10.2), 1,2,3-triazole (9.4), benzotriazole (8.2), benzenesulfonamide (10.1), nitromethane (10.2), isatine (10.3), uracil (9.9), 4-nitro-2-methylimidazole (9.6), phenol (10.0), ethylacetoacetate (10.7), acetylacetone (9.0), diethylmalonate (13.0).

**[0022]** Other suitable components D2 are hydantoin derivatives, for example 5,5-dimethylhydantoin, sulfonamides, for example aromatic sulfonamides as benzene- or toluenesulfonamide or heterocyclic compounds, for example triazoles or a pyrazoles, or a uracil derivative.

**[0023]** In the crosslinkable composition, the X-H groups in component D are present in an amount corresponding to at least 50 mole%, preferable at least 100 mole%, most preferably at least 150 mole% relative to the amount of base to be generated by catalyst C. The appropriate amount is very much determined by the acid base characteristics of component D relative to component A, and the reactivity of the corresponding anions relative to B, so may vary for different systems. It is noted that the open time improving effect can in some cases be obtained at very small amounts of component D, which is very advantageous because such small amounts do not or not significantly affect the properties of the resulting cured composition; for example the chemical and mechanical properties of a coating. Typically the X-H groups in component D are present in an amount corresponding to no more than 30 mole%, preferably no more than 20, more preferably no more than 10, most preferably no more than 5 mole% relative to C-H donor groups from component A.

**[0024]** It should be noted that component D may be present in its deprotonated form (in acid base equilibrium with other components). Amounts for component D referred to include both the neutral as well as the deprotonated form. This implies that if present in amounts of more than 100% relative to a base catalyst C, components C and D may be in equilibrium such that effectively the deprotonated form of D is present as the dominant species to initiate further RMA cure (rather than coexist as basic (C) and acidic (D) species in the formulation). Preferably, the X-H functionality (number of groups per molecule) of component D is low, preferably less than 4, more preferably less than 2, most preferably it is 1.

**[0025]** The crosslinkable composition may comprise next to one or more different components D a component D1 comprising acidic protons (C-H) in activated methylene or methine groups having a higher acidity than component A and which are also is reactive towards component B, Such component D1 can also contribute to the open time improving effect, however in order to have a significant effect D1 should be typically be present in an amount between 10 - 40 mol% (relative to total RMA C-H), which is a significantly higher amount than for component D.

**[0026]** The difference in acidity of the two C-H acidic components A and D1 is chosen preferably in that wherein the pKa of component D1 is between 0.5 and 6, preferably between 1 and 5 and more preferably between 1.5 and 4 units lower than the pKa of component A. Preferably, component A is a malonate containing component and component D1 is an acetoacetate or acetylacetone containing component, preferably of low C-H functionality (preferably less than 10, more preferably less than 5, most preferably it is no more than 2).

#### Component A

**[0027]** Suitable examples of components A containing activated methylene or methine groups are well known in the art. Preferred are the oligomeric and/or polymeric A group containing components such as, for example, polyesters, polyurethanes, polyacrylates, epoxy resins, polyamides and polyvinyl resins containing groups A in the main chain, pendant or both.

**[0028]** Component A preferably is malonate or acetoacetate. Components containing both malonate and acetoacetate groups in the same molecule are also suitable. Additionally, physical mixtures of malonate and acetoacetate group-containing components are suitable.

**[0029]** In a most preferred embodiment of the crosslinkable composition, component A is a malonate containing compound. It is preferred that in the crosslinkable composition the majority of the activated C-H groups are from malonate, that is more than 50%, preferably more than 60%, more preferably more than 70%, most preferably more than 80% of all activated C-H groups in the crosslinkable composition are from malonate. In another embodiment, the crosslinking composition comprises a component A, for example a polymer, wherein more than 50%, preferably more than 70%, more preferably more than 80% and most preferably more than 90% of the activated C-H groups are from malonate and a separate component, for example another polymer, oligomer or monomer, comprising activated C-H groups not

from malonate, for example acetoacetate.

**[0030]** Especially preferred malonate group-containing components for use with the present invention are the malonate group-containing oligomeric or polymeric esters, ethers, urethanes and epoxy esters containing 1-50, more preferably 2-10, malonate groups per molecule. In practice polyesters and polyurethanes are preferred. It is also preferred that such malonate group-containing components have a number average molecular weight ( $M_n$ ) in the range of from about 100 to about 5000, more preferably, 250-2500, and an acid number of about 2 or less. Also monomalonates can be used as they have 2 reactive C-H per molecule. Monomeric malonates can, in addition, be used as reactive diluents.

#### Component B

**[0031]** Components B generally can be ethylenically unsaturated components in which the carbon-carbon double bond is activated by an electron-withdrawing group, e.g. a carbonyl group in the  $\alpha$ -position. Suitable components B are known in the art, for example acryloyl esters, acrylamides, alternatively polyesters based upon maleic, fumaric and/or itaconic acid (and maleic and itaconic anhydride and polyesters, polyurethanes, polyethers and/or alkyd resins containing pendant activated unsaturated groups. Acrylates, fumarates and maleates are preferred. Most preferably, the component B is an unsaturated acryloyl functional component.

**[0032]** It is also especially preferred that the acid value of the activated unsaturated group-containing components (as of any of other component used in the composition) is sufficiently low to not substantially impair activity of the catalyst, so preferably less than about 2, most preferably less than 1 mg KOH/g. As exemplified by the previously incorporated references, these and other activated unsaturated group-containing components, and their methods of production, are generally known to those skilled in the art, and need no further explanation here. Preferably the functionality is 2-20, the equivalent weight (EQW: average molecular weight per reactive functional group) is 100-2000, and the number average molecular weight preferably is  $M_n$  200-5000.

**[0033]** The advantages of the invention are particularly manifest in critically difficult compositions comprising not only a high solids content but also aimed at a high crosslinking density, with relative high concentrations and functionalities of functional groups, for example in case the component A is a compound, in particular an oligomer or polymer, comprising an average of 2 to 30, preferably 4 to 20 and more preferably 4 - 10 activate C-H per polymer chain.

**[0034]** It is also possible that component A and B are present in hybrid molecules containing both types of functional groups.

**[0035]** Typically, the concentrations of the functional groups in components A and B, and their relative stoichiometry, are chosen such that good film properties following cure may be expected, with efficient use of these functional groups. Typically, stoichiometries C-H/C=C are chosen to be from 0.1 to 10, preferably 0.5 to 3, more preferably 0.7 to 3, most preferably 0.8/1.5. For this ratio, the X-H of component D is added to the C-H groups of component A.

#### Component C

**[0036]** The base catalyst C can in principle be any known catalyst suitable for catalyzing RMA reactions. Preferably, in view of achieving good pot-life in combination with low temperature curing, the crosslinkable composition comprises a catalyst system C comprising a strong based blocked by a volatile acid which is activated by evaporation of this acid. A suitable catalyst system C comprises a strong based blocked by a carbon dioxide, or the blocked catalytic species are of formula  $\text{ROCO}_2^-$ , R being a optionally substituted alkyl, preferably C1 - C4 radical or hydrogen, preferably the catalyst comprises a blocked base anion and a quaternary ammonium or phosphonium cation. It is preferred that the crosslinking catalyst is utilized in an amount ranging between 0.001 and 0.3 meq/g solids, preferably between 0.01 and 0.2 meq/g solids, more preferably between 0.02 and 0.1 meq/g solids (meq/g solids defined as mmoles base relative to the total dry weight of the crosslinkable composition, not counting particulate fillers or pigments). Alternatively, the catalyst system C is activated by reaction of an epoxy component with a tertiary amine, or an anion.

**[0037]** For the  $\text{CO}_2$  deblocking catalyst systems, it was surprisingly found that significantly better potlife could be achieved in a composition wherein component A is a malonate, which composition further comprises 0.1 - 10 wt %, preferably 0.1 - 5, more preferably 0.2 - 3 and most preferably 0.5 - 2 wt% water (relative to total weight of the coating composition). Preferably, the amount of water is chosen in an effective amount to increase gel time with at least 15 minutes, preferably at least 30 min, more preferably at least 1 h, even more preferably at least 5h, and most preferably at least 24h, 48 h. or at least 10%, 50% or 100% compared to the same composition without water.

#### Component E

**[0038]** For preparing thick coating layers having a dry thickness of at least 70, 80, 90, or more than 100 and in particular at least 125 micrometer the cross linking composition preferably also comprises a sag control agent (SCA). At low temperature curing conditions used in RMA curing the choice of the SCA is particularly important in view of obtaining

good surface and optical properties. Suitable SCA's having low haze are described in EP0198519 which describes a thixotropic coating composition comprising (1) a binder and (2) 0.1 to 30 percent by weight of solid particles of a diurea sag control agent, having a particle size of from 0.01 to 50 microns, which is the reaction product of (a) a symmetrical aliphatic or homocyclic diisocyanate and (b) a monoamine or diamine containing at least a primary amino group and an ether group. EP0192304 describes suitable SCA's based on isocyanurate.

**[0039]** Preferred SCA's for low temperature use are described in EP1641887 and EP1641888 which are a rheology control agents (SCA) obtainable by reacting one or more polyisocyanates with one or more monoamines or by reacting one or more polyamines with one or more monoisocyanates to form a polyurea compound, wherein at least one of the mono- or polyamine or mono- or polyisocyanate is optically active, not as racemic mixture, having a chiral carbon atom adjacent to an amine or isocyanate group.

**[0040]** Most preferred SCA's are described in EP1902081 describing a thixotropic agent SCA comprising a first polyurea reaction product of a first polyisocyanate with a first amine and a second polyurea reaction product of a second polyisocyanate with a second amine different from the first polyurea reaction product precipitated in the presence of the colloidal particles of the first reaction product. This SCA is used in the examples. EP1838747 describes a blend of 2 SCA's having different melting temperatures.

**[0041]** SCA is preferably made in the donor resin but can also be made in the acceptor resin composition by in-situ reacting the isocyanate with a amine compound.

**[0042]** The crosslinking composition can comprise a solvent. For CO<sub>2</sub> deblocking catalyst systems, the inventors further found that advantages can be achieved in pot life if in the crosslinkable composition at least part of the solvent is a primary alcohol solvent. The solvent can be a mixture of a non-alcoholic solvent and an alcohol solvent. Preferably, the alcohol is present in an amount of at least 1, preferably 2, more preferably 3, most preferably at least 5, even more preferably at least 10 wt % relative to the total weight of the crosslinkable composition and in view of VOC constraints preferably at most 45, preferably at most 40 wt%, most preferably less than 30wt%.

**[0043]** The alcohol solvent preferably is one or more primary alcohols, more preferably a mono-alcohol having 1 to 20, preferably 1 - 10, more preferably 1 - 6 carbon atoms, preferably selected from the group of ethanol, n-propanol, n-butanol, n-amyl alcohol and butylglycol

**[0044]** In summary the crosslinkable composition according to the invention comprises

- a. between 5 and 95 wt% of a component A with at least 2 acidic protons C-H in activated methylene or methane, and
- b. between 5 and 95 wt% of a component B with at least 2 activated unsaturated groups (wt% relative to the total weight of the crosslinkable composition) and
- c. a catalyst system C that contains, or is able to generate a basic catalyst capable of activating the RMA reaction between components A and B, at levels of 0.0001 and 0.5 meq/g solid components
- d. component D in an amount such that the amount of X-H in component D is at least 50 mole % relative to base generated by component C, and less than 30 mole % of C-H active groups from component A,
- e. optionally additional different C-H containing component D(1) in an amount such that the amount of C-H groups in component D(1) are present in an amount between 5 and 50 mol % preferably 10 -40 mol% (to total RMA donor C-H)
- f. a sag control component E,
- g. optionally between 0.1 and 80 wt% of solvent (preferably less than 45wt%), preferably organic solvent preferably containing at least 1wt% of a primary alcohol and,
- h. optionally between 0.1 and 10 wt% water optionally at least 0.5wt% water.

**[0045]** Considering that the crosslinkable composition is a 2K composition which is only formed shortly before the actual use, the invention also relates to a kit of parts for the manufacture of the composition according to the invention comprising a part 1 comprising components A and B and part 2 comprising component C and D or alternatively a part 1 comprising components A, B and D and part 2 comprising component C.

**[0046]** The invention also relates to the use of the component D as described above as an additive to RMA crosslinkable compositions, in particular for preparing thick coating layers having a dry thickness of at least 50, preferably at least 60, 75, 100 and more preferably at least 125 micrometer, for the improvement of the open time of the crosslinkable composition and for the improvement of the appearance and hardness of the resulting cured composition, in particular a coating.

**[0047]** In the crosslinkable composition is in such a way the nature and amount of component D is chosen to yield, under the application and curing conditions chosen, an increase in time to get to a 30% conversion level, of at least 3, preferably 5, more preferably 10 minutes, preferably less than 60, more preferably less than 30 minutes, when compared to the same composition without component D.

**[0048]** The invention also relates to the use of the crosslinking composition according to the invention in a method for the manufacture of coating compositions, films or inks and to coating compositions, inks or films comprising the crosslinking composition according to the invention and further application oriented additives for example one or more coating

additives like pigments, co-binder, solvents etc. It was found that RMA crosslinkable coating compositions, in particular also the composition for preparing thick layers herein described in thick layer applications, preferably have aminosilane as promoters of adhesion to substrates in particular on metal substrates like steel. Surprisingly high adhesion promotion was observed even at very low amounts between 0.1 and 2 wt% and even lower than 1.5, 1 % or 0.5wt% (total wt of the crosslinkable composition).

**[0049]** The invention also relates to a process for making a coating layer having a fully cured dry thickness of at least 70, 75, 80 or 100 and more preferably at least 125 micrometer and having a good surface appearance and hardness of the resulting cured composition comprising mixing the components A, B, D with catalyst D shortly before use to form a coating composition according to the invention, applying a layer of the coating composition on a substrate and allowing the curing thereof at temperature between 0 and 60 °C.

#### Succinimid examples

**[0050]** The foregoing more general discussion of the present invention will be further illustrated by the following specific examples, which are exemplary only.

**[0051]** *Molecular weights* were measured by GPC in THF, and expressed in polystyrene equivalent weights.

**[0052]** *Viscosities* were measured with a TA Instruments AR2000 Rheometer, using a cone and plate setup (cone 4cm 1°) at 1 Pa stress.

**[0053]** *Tube and ball method for pot life determination:* A flat bottomed test tube (internal diameter 15 mm, length 12.5 cm), carrying two marks, 5 cm apart is filled with 20 ml of paint. A steel ball with a diameter of 8 mm is added, and the tube is closed with a snap cap. The tube is held under an angle of 10° and the steel ball is allowed to roll on the wall of the test tube. The time needed to roll between the two marks is taken as a measure for the viscosity. The time needed to double in viscosity is taken as the pot life. If necessary this time is calculated by linear interpolation between two measurements. This method was used for the pigmented formulations. For the clear formulations, a glass test tube (length 12 cm, diameter 13 mm) was filled with a stainless steel ball of 12 mm diameter, and the formulation to be studied to leave a very limited head space, and closed. Time was recorded for the ball to fall and pass a distance of 5 cm when the tube was tilted vertically. An average was taken over 2 measurements.

**[0054]** *Drying recorder drying time:* For determining the recorder drying time, paint was applied on a glass panel with a doctor blade with a 90µ gap. The drying time was measured with a Gardco electronic drying time recorder, type DT-5020, set on a cycle time of 60 minutes. Drying time was recorded as the time were the stylus left no more visible trace on the film.

**[0055]** *TNO cotton ball drying times:* Dust-dry and tack-free times were measured according to the so-called TNO method with a wad of cotton-wool. Dust-dry time means the time needed for the coating after dropping the wad on the surface of the coating and after leaving it there for 10 seconds, to get no residue of the wool-cotton sticking onto the surface after blowing away the wad. For tack-free time the same holds but now a weight load of 1 kg is applied on the wad for 10 seconds.

**[0056]** *Persoz hardness measurement:* Persoz pendulum hardness was measured in a climatized room at 23°C, and 55+/-5% relative humidity. Hardness is measured with a pendulum acc. Persoz as described in ASTM D 4366. For the gradient layer thickness panels, hardness is measured at different spots and corresponding layer thickness is measured. If necessary the hardness at a certain layer thickness is calculated by linear interpolation of the measurement at two different layer thicknesses. Layer thicknesses were measured with a Fischer Permascope MP40E-S.

**[0057]** *Optical evaluation sprayed pigmented paints:* Paint was sprayed with a devilbiss spraygun, nozzle FF-1.4 with an air pressure of 3.5 bar. The paint was sprayed in a continuous layer over the entire surface of a 55x10 cm steel panel. A consecutive layer was sprayed starting 10 cm from the right edge. Several layers were built up, moving to the right so that a layer thickness gradient was build up from the left to right. Films were allowed to dry horizontally at 23°C, 45%RH. Layer thicknesses were measured with a Fischer Permascope MP40E-S. At 100 µ layer thickness, a picture was taken with an Olympus SZX10 microscope (1X magn) equipped with a digital camera.

**[0058]** *Wavescan analysis:* The panels as described above were analyzed using the Wavescan II of Byk instruments. Data were stored using Autochart software from Byk. Analysis was done in the direction perpendicular to the thickness gradient. In this instrument the light of small laser diode is reflected by the surface of the sample under an angle of 60°, and the reflected light is detected at the gloss angle (60° opposite). During the measurement, the "wave-scan" is moved across the sample surface over a scan length of approx. 10 cm, with a data point being recorded every 0.027mm. The surface structure of the sample modulates the light of the laser diode. The signal is divided into 5 wavelength ranges in the range of 0.1-30mm and processed by mathematical filtering. For each of the 5 ranges a characteristic value (Wa 0.1-0.3mm, Wb 0.3-1.0mm, Wc 1.0-3.0mm, Wd 3.0-10mm, We 10-30mm) as well as the typical wave-scan-values long-wave (LW, approx. 1-10mm) and shortwave (SW, approx. 0.3-1mm) is calculated. Low values mean a smooth surface structure. Additionally a LED light source is installed in the wave-scan DOI and illuminates the surface under 20 degrees after passing an aperture. The scattered light is detected and a so-called dullness value (du, <0.1mm) is measured. By

using the three values of the short wave range  $W_a$ ,  $W_b$  and  $du$  a DOI value is calculated. (see Osterhold e.a., Progress in Organic Coatings, 2009, vol. 65, no4, pp. 440-443).

**[0059]** The following abbreviations were used for chemicals used in the experiments: DiTMPTA is di-trimethylolpropane-tetraacrylate (obtained from Aldrich (MW = 466 g/mol)) or used as Sartomer SR355 (supplied commercially by Sartomer); Disperbyk 163 is a dispersant commercially supplied by Byk; Byk 310 and 315 are additives commercially supplied by Byk; Kronos 2310 is a TiO<sub>2</sub> pigment commercially supplied by Kronos, TBAH is tetrabutylammonium hydroxide, BuAc is Butyl acetate, MEK is Methyl ethyl ketone (2-Butanone); EtAcAc is ethyl acetoacetate; DEC is diethyl carbonate; IPA is isopropanol; RT is room temperature.

#### Preparation of malonate polyester A

**[0060]** Into a reactor provided with a distilling column filed with Raschig rings were brought 17.31 mol of neopentyl glycol, 8.03 mol of hexahydrophthalic anhydride and 0.0047 mol of butyl stannic acid. The mixture was polymerised at 240 °C under nitrogen to an acid value of 0.2mg KOH/g. The mixture was cooled down to 130 °C and 10.44 mol of diethylmalonate was added. The reaction mixture was heated to 170 °C and ethanol was removed under reduced pressure. The nearly colourless material was cooled down and diluted with 420g of butyl acetate to a 90% solid content. The final resin had an acid value of 0.3mg KOH/g solids, an OH value of 20 mg KOH/g solids and a weight average molecular weight of 3400 Da.

#### Catalyst solution C1

**[0061]** Catalyst solution was prepared by reacting 59.4 g a TBAH solution (40% in water) with 13.5 g DEC (reacting overnight at RT), with 14.5 g isopropanol as co-solvent, following the corresponding ethocarbonate species development. Titration indicated that blocking was complete, and that the concentration of blocked base was 0.83 meq/g solution.

#### Catalyst solution C2

**[0062]** To 43.6 g of a 45% aqueous solution of TBAH were added 36.6 g of isopropanol and 60g of DEC. After standing overnight the mixture was filtered over paper. Titration showed that the catalyst contained 0.52 meq of blocked base per gram solution.

#### Comparative example formulation 1, example formulations 1-4

**[0063]** Formulations were prepared based on a malonate donor resin A, DiTMPTA as acryloyl donor resin, and the indicated amount of succinimide, and thinned to a viscosity of 160 mPas with a mixture of MEK/BuAc 1:1 by volume. This was mixed with an amount of catalyst solution C1. Listed in table A are the details of the overall composition. Catalyst amounts are 50 meq/g solids, water levels are 1.8 wt%, isopropanol at 0.7 wt%, ethanol level estimated at 0.2wt%.

**Table A**

Code	Comp1	Ex1	Ex2	Ex 3	Ex4
malonate ester A / g	15.0	15.0	15.0	15.0	15.0
di-TMPTA / g	6.6	6.6	6.6	6.6	6.6
succinimide / mg	0	149	174	199	298
mole % succinimide on cat	0	150	175	200	300
MEK/BuAc (1:1) / g	4.5	4.5	4.5	4.5	4.5
catalyst C1 / g	1.2	1.2	1.2	1.2	1.2

**[0064]** Of these formulations, the drying behaviour at room temperature for films leading to a dry film thickness of around 70-75  $\mu$  was followed with TNO cotton ball drying tests, and Persoz pendulum hardness development was determined; also these results are listed in Table B.



Table B

Code	Comp1	Ex1	Ex2	Ex3	Ex4
mole % succinimide on cat	0	150	175	200	300
TNO-drying					
dust-dry (min)	10'	25'	25'	30'	65'
tack-free (min)	10'	30'	30'	35'	70'
Persoz hardness (sec) after time at RT:					
4h	31			107	132
1 night	42			126	152
1 week	66	131	137	146	231

**[0065]** It can be seen that whereas comparative example 1 shows an extremely fast drying, the actual Persoz hardness levels are low presumably due to solvent entrapment in the system. Moreover, the appearance of this comparative example 1 is poor. Upon addition of low levels of succinimide (slightly higher than the levels of catalyst used), some retardation of the drying is seen, but still giving drying times considered as fast; however, it can also be observed that the Persoz hardness development is strongly improved. Simultaneously, the example films with succinimide exhibit a better appearance than comparative example 1.

**[0066]** Example formulations 5-7, and comparative example formulations 2-3 were prepared as pigmented paints, having compositions as tabulated in Table C (amounts in grams).

Table C

Code	Ex5	Ex6	Ex7	Comp2	Comp3
Sartomer SR355	38.19	38.19	38.19	38.19	39.19
Disperbyk 163	2.39	2.39	2.39	2.39	2.39
Kronos 2310	80.12	80.12	80.12	80.12	80.12
malonate polyester A	58.70	67.69	67.69	58.70	67.69
Sartomer SR 355	4.22	1.15	1.15	4.22	4.22
EtAcAc	4.81	0.00	0.00	4.81	0.00
Byk 310/315 [1:4 by mass]	0.60	0.60	0.60	0.60	0.60
succinimide	0.79	0.79	1.58	0.00	0.00
BuAc	2.52	2.52	2.52	2.52	2.52
MEK	7.20	7.20	7.20	7.20	7.20
catalyst solution C2	9.34	9.34	9.34	9.34	9.34
recorder drying time (min)	14	15	44	4.3	8
potlife (min)	39	35	37	17	29
Persoz hardness (sec) after 24 h (50 mu dry film)	147	147	145	85	66

**[0067]** Pot life of these pigmented paints were measured, and drying times of these paints drawn onto glass panels were determined with a drying recorder. These paints were also applied by spraying onto a steel panel to obtain gradient film thickness panel. Persoz hardness at 50 mu dry film thickness was determined after 24 hr RT cure; microscope

pictures were taken of the resulting coatings on these panels at approximately 100  $\mu$  dry film thickness (Appendix: Photographs). Also, pot life of these paints were measured. Results are included in table C.

**[0068]** It can be observed from a comparison of comparative example 3 with examples 6 and 7, that the addition of succinimide to the formulation gives clear advantages in Persoz hardness build-up, and some advantage in pot life. Example 7, with a higher level of succinimide, shows a significant increase in drying time, the 44 minute value can however still be considered as an acceptable to good value. Appearance of panels from examples 6 and 7 is much better than that of panels from comparative example 3, as can be judged from comparing the microscope photographs, comparative example 3 showing many more defects (Appendix: Photographs).

**[0069]** Similar conclusions can be drawn from a comparison of comparative example 2, with example 5, now based on a formulation with acetoacetate included besides malonate as RMA donor groups. Example 5 (with succinimide added) exhibits higher Persoz hardness, a better pot life, and a better appearance (Appendix: Photographs) than comparative example 2 (not containing succinimide).

**[0070]** Example 8 was prepared and evaluated in a similar way as discussed above for example 5-7, the composition and results given below in table D (amounts in grams). It can be seen that the additional presence of 1,2,4-triazole (when compared to example 6) leads to a significant improvement in pot-life, other advantages being retained.

Table D

Code	Ex8
Sartomer SR355	38.19
Disperbyk 163	2.39
Kronos 2310	80.12
Malonate polyester A	67.69
Sartomer SR 355	1.15
EtAcAc	0.00
Byk 310/315 [1:4 by mass]	0.60
1,2,4-triazole	0.96
Succinimide (s)	0.79
BuAc	2.52
MEK	7.20
catalyst solution C2	9.34
recorder drying time (min)	16
Potlife (min)	70
Persoz hardness (sec) after 24 h (50 $\mu$ dry film)	147

**[0071]** Example formulations 9 and 10, and comparative example formulations 4 and 5 were formulated and evaluated along similar lines, now also including Wavescan analysis to have a quantitative indication of the quality of the appearance. Compositions and results are given in Table E (amounts in grams).

Table E

Code	Ex9	Ex10	Comp4	Comp5
Sartomer	19.07	19.07	19.07	19.07
Disperbyk 163	1.19	1.19	1.19	1.19
Kronos 2310	40.01	40.01	40.01	40.01
Malonate polyester A	29.35	33.85	29.35	33.85

(continued)

Code	Ex9	Ex10	Comp4	Comp5
Sartomer SR 355	2.11	0.58	2.11	0.58
EtAcAc	2.41	-	2.41	-
Byk 310/315 [1:4 by mass]	0.30	0.30	0.30	0.30
Succinimide	0.40	0.40	-	-
BuAc	1.26	1.26	1.26	1.26
MEK	3.60	3.60	3.60	3.60
Catalyst solution C2	4.67	4.67	4.67	4.67
Persoz hardness (s) at 50 $\mu$	122	125	97	93
Layer thickness ( $\mu$ )	51	56	58	58
du (dullness)	6.30	6.40	8.80	11.30
Longwave	3.80	1.90	5.30	7.80
Shortwave	2.20	6.40	18.20	24.10
DOI (Dorigon)	94.10	93.90	91.50	88.40
Layer thickness ( $\mu$ )	92	93	92	86
du (dullness)	5.90	8.70	11.60	23.40
Longwave	1.00	3.70	11.50	25.10
Shortwave	9.50	24.90	29.70	60.60
DOI (Dorigon)	94.10	90.20	88.10	74.90

**[0072]** Example formulation 9 can be compared with comparative formulation example 4, example formulation 10 can be compared with comparative formulation example 5, difference being the presence of low amounts of succinimide. It can from both comparisons be concluded that the presence of succinimide, besides the improved Persoz hardness, leads to significantly improved values for longwave and shortwave roughness, dullness and DOI.

#### Example 11: Impact on conversion kinetics

**[0073]** The conversion of the acryloyls in the system can be followed by FTIR, focusing on the 809 cm<sup>-1</sup> band characteristic of the acryloyl. Doing that, the impact of added succinimide on total conversion can be made visible. Two systems were formulated (according to compositions of comparative example 1 (without succinimide) and example formulation 1 (with 150% succinimide relative to solids). Figure 1 compares the conversion of these systems after application on top of an ATR crystal, the IR beam probing the deepest layers, close to the substrate. Initial conversion of the formulation without the succinimide is fast, which is also the cause for solvent entrapment and potential appearance problems. It can be seen that the addition of succinimide, even at these very low levels, leads to a significant retardation of the initial conversion; simultaneously, it illustrates that after this initial retardation period, the conversion rate is accelerating, so that the rate of cure towards higher conversions is still fast after this initial delay.

#### Example 12. Determination of Michael addition reactivity of succinimide

**[0074]** 5 grams of succinimide (50.5 mmole) were dissolved in a mixture of 42 grams of butyl acrylate and 42 grams of methanol, and maintained at room temperature as such, or after adding a strong base (9.82 grams of a 1.12 meq/g solution of tetrabutylammonium hydroxide in methanol, 11 meq). Subsequently, the concentration of succinimide is

determined as a function of time by taking samples, neutralizing with a known excess of HCl in water, and backtitration with a KOH solution. Without base initiation, no significant loss of succinimide N-H in this solution is observed in two weeks. With the base added, the succinimide concentration can be seen to decrease with time, as illustrated in the table F below. Succinimide concentration is expressed as % relative to the theoretical level based on used amounts.

Table F

Time (min)	Succinimide remaining (%)
3	99
30	87
60	77
120	60
180	48

**[0075]** At this catalyst level ([succinimide]/[base] = 5), it takes about an hour to lose 25% of the succinimide acidic protons to be consumed. Under these conditions, dimethylmalonate (instead of succinimide) would react much faster with the acrylate.

### THICK LAYERS EXAMPLES

**[0076]** *Pot-life measurement:* A flat bottomed test tube (internal diameter 15 mm, length 12.5 cm), carrying two marks, 5 cm apart is filled with 20 ml of paint. A steel ball with a diameter of 8 mm is added, and the tube is closed with a snap cap. The tube is held under an angle of 10° and the steel ball is allowed to roll on the wall of the test tube. The time needed to roll between the two marks is taken as a measure for the viscosity. The time needed to double in viscosity is taken as the pot life. If necessary this time is calculated by linear interpolation between two measurements. This method was used for the pigmented formulations.

**[0077]** *Drying time:* For determining the recorder drying time, paint was applied on a glass panel with a doctor blade with a 90µ gap. The drying time was measured with a Gardco electronic drying time recorder, type DT-5020, set on a cycle time of 60 minutes. Drying time was recorded as the time were the stylus left no more visible trace on the film.

**[0078]** *Viscosity measurement:* The viscosity of the resins was measured with a Physica MCR300 viscosimeter, using measuring cone CP50-1 at 23°C.

**[0079]** *Persoz hardness measurement:* Persoz pendulum hardness was measured in a climatized room at 23°C, and 55+/-5% relative humidity. Hardness is measured with a pendulum acc. Persoz as described in ASTM D 4366. For the gradient layer thickness panels, hardness is measured at different spots and corresponding layer thickness is measured. If necessary the hardness at a certain layer thickness is calculated by linear interpolation of the measurement at two different layer thicknesses.

**[0080]** Reported molecular weights were measured by GPC, and expressed in polystyrene equivalent weights.

**[0081]** The following abbreviations were used for chemicals used in the experiments: DiTMPTA is di-trimethylolpropane-tetraacrylate (obtained from Aldrich, (MW = 466 g/mol)) or used as Sartomer SR355 (commercially available by Sartomer); Disperbyk 163 is a dispersant commercially supplied by Byk; Byk 310 and 315 are additives commercially supplied by ByK; Kronos 2310 is a TiO<sub>2</sub> pigment commercially supplied by Kronos; TBAH is tetrabutylammonium hydroxide; BuAc is Butyl acetate, MEK is Methyl ethyl ketone (2-Butanone); EtAcAc is ethyl acetoacetate; DEC is diethyl carbonate; IPA is isopropanol; RT is room temperature.

### Preparation of resin A

**[0082]** Into a reactor provided with a distilling column filed with Raschig rings were brought 17.31 moles of neopentyl glycol, 8.03 moles of hexahydrophthalic anhydride and 0.0047 moles of butyl stannic acid. The mixture was polymerised at 240 oC under nitrogen to an acid value of 0.2mg KOH/g. The mixture was cooled down to 130 oC and 10.44 moles of diethylmalonate were added. The reaction mixture was heated to 170 oC and ethanol was removed under reduced pressure. The resin was cooled down and diluted with 420g of butyl acetate to a 90% solid content. The final resin has an acid value of 0.3mg KOH/g solids, a OH value of 20 mg KOH/g solids and a weight average molecular weight of 3400 Da.

Preparation of resin B

**[0083]** To 757 g of the resin A were added 45 g of butyl acetate. The mixture was brought to 30° under stirring. At 30°C 3.560 g of (S)-1-Phenylethylamine (ChiPros® ex BASF) were added. The funnel was rinsed with 10 grams of butyl acetate which were added to the mixture. 2.47 grams of hexamethyldiisocyanate dissolved in 16.2 g of butyl acetate were added drop wise through a funnel in 4 minutes under vigorous stirring (forming first sag control agent (SCA) by reaction with the (S)-1-Phenylethylamine). The temperature rose to 38°C. The funnel was rinsed with 6.4 g of butyl acetate, which were added to the mixture, which was kept stirring for 15 more minutes. Subsequently, 6.41 grams of butyl amine were added (for forming the second SCA with hexamethyldiisocyanate) and the funnel was rinsed with 10 g of butyl acetate. 5.06 g of hexamethyldiisocyanate, dissolved in 25.70 g of butyl acetate were added drop wise through a funnel in 15 minutes under vigorous stirring. The temperature rose to 45°C. The funnel was rinsed with 10 g of butyl acetate which was added to the mixture. The mixture was stirred for 10 minutes and then diluted with 50 of butyl acetate. The mixture was cooled under stirring to 35°C. The final resins had a solids content of 72.5%. The viscosity of the resin was 10 Pas at 1 sec-1 and 0.58 Pas at 1000 spec-1.

Catalyst solution C1

**[0084]** To 43.6 g of a 45% aqueous solution of tetrabutyl ammonium hydroxide were added 36.6 g of isopropanol and 60 g of diethylcarbonate. After standing overnight the mixture was filtered over paper and 14.5 g of succinimide were dissolved in it.

Catalyst solution C2

**[0085]** 54.6 g of tetrabutylammonium succinimide (available from Sigma Aldrich) was dissolved in 45.4 g of isopropanol. Acid base titration gives a concentration of 1.529 meq/g of product. This catalyst does not include a carbonate catalyst.

Catalyst solution C3

**[0086]** A catalyst solution C3 was prepared as catalyst solution C1, except that the succinimide was omitted.

Example 1: Preparation of paint 1

**[0087]** Paint 1 was made by dispersing 91.44 g of Kronos 2310 in 43.85 g of Sartomer SR355 with the aid of 2.73 g of Disperbyk 163. To this were added 29.94 g of the resin A and 46.17 g of the resin B. Subsequently, 4.82 of Sartomer SR355 and 5.5 g of ethyl acetoacetate, 0.14 g of Byk 310 and 0.55 g of Byk 315 were added. The paint was finally diluted with 4.02 g of butylacetate and 9.37 g of methylethylketone. 11.58 g of catalyst solution C1 were stirred into 258.26 g of the paint 1. The mixture was sprayed on a 30x20 cm steel plate of 0.5 mm thickness tin plate into which were punched 12, 1cm diameter holes, 2 cm apart. The paint was sprayed with increasing layer thickness. After spraying the panel was kept vertically. The paint could be sprayed up to 150 micron as a haze free film without the production of tears on the borders of the holes.

Example2: Preparation of paint 2

**[0088]** Paint 2 was prepared in a similar way as paint 1, except that the 46.17g of resin B was entirely replaced by a mixture of 39.38g of the resin A and 6.78 g of butylacetate, so paint 2 only contains resin A and by consequence has no SCA. In a similar way catalyst C1 was added and the paint 2 was sprayed in similar way. The coating developed a haze free film up to 150 micron but severe tears developed from a layer thickness of 50 microns on.

Example 3: Preparation of paint 3

**[0089]** Paint 3 was prepared the same way as paint 2, except that 1.6 g of catalyst solution C2 was added to 100g of paint. The paint dried in a haze- and wrinkle-free film, even at a thickness of up to 150 micron. The coating did develop tears from a layer thickness of 50 microns on.

Comparative experiment: Preparation of paint CE1

**[0090]** Comparative paint CE1 was prepared similar to paint 2, except that the ethylacetoacetate was replaced by 4.5 g of resin A. 4.16 g of catalyst solution C3 was added to the paint CE1 and sprayed in a similar fashion as the paint 1.

Not only developed the paint tears from a thickness of 50 micron on, it also showed pronounced wrinkling at layer thicknesses of 60 micron and higher.

Overview re paint compositions and catalyst solution

	acetoacetate	Succinimide	SCA	Appearance
Paint 1	yes	yes	yes	No wrinkling, no sagging up to 150 mu
Paint 2	yes	yes	no	No wrinkling up to 150 mu, sagging from 50 mu
Paint 3	yes	TBA-Succinimide	no	No wrinkling up to 150 mu, sagging from 50 mu
CE1	No	no	no	wrinkling from 60 mu and sagging from 50 mu

#### Example 4

**[0091]** Formulations were prepared, spray-applied to bonder panels and dried at RT. The appearance of the panels was analyzed with a Byk Wavescan instrument. Pendulum hardness (in sec, after 1 day), and longwave/shortwave numbers (lower is better) are reported in the table below, along with composition data. The catalyst solution was similar to C-1, with a concentration of 0.7 meq/g; thinner used was a 1:1 (by wt) mixture of butylacetate and MEK. The advantageous effect of the formulations according to the invention on appearance can be seen.

	COMP	A	B	C	D	E
Sartomer SR355	177.0	175.3	172.3	171.9	171.2	170.5
Disperbyk 163	11.1	11.0	10.8	10.8	10.7	10.7
Kronos 2310	371.0	367.7	361.3	360.5	359.0	357.5
Resin A	298.0	218.7	237.0	236.5	235.5	234.5
SCA resin B	0.0	91.1	98.8	98.6	98.2	97.8
Sartomer SR355	17.0	16.8	5.7	5.7	5.7	5.7
EtAcAc	16.5	16.4	0.0	0.0	0.0	0.0
Byk 310/315 [1:4]	2.8	2.8	3.0	3.0	3.0	3.0
Succinimide	0.0	4.3	4.2	4.2	4.2	4.2
Benzotriazole	0.0	0.0	2.2	4.4	8.6	12.5
MEK	33.0	33.1	36.0	35.9	35.8	35.6
BuAc	11.7	11.6	12.6	12.6	12.5	12.5
PrOH	5.6	5.5	6.0	6.0	6.0	5.9
Thinner	46.2	45.9	50.0	49.9	49.7	49.5
catalyst solution (0.7 meq/g)	25.0	24.7	23.2	23.2	23.1	23.0
layer thickness (μm)	75	73.9	71.7	75	74.7	77.1
hardness						
Persoz	50	134	127	128	124	130
Longwave	17	2.4	5.5	4.5	3.8	2.9
Shortwave	35	11.7	17.9	15.5	9.8	8.5
layer thickness (μm)		144	142	143	143	150
hardness						
Persoz		64	65	67	67	76
Longwave		2.2	2.3	2.1	1.4	2.1
Shortwave		12	11.4	9.9	7.6	14.7

#### Claims

1. An RMA crosslinkable composition for making thick coating layers comprising at least one crosslinkable component comprising reactive components A and B each comprising at least 2 reactive groups wherein the at least 2 reactive

groups of component A are acidic protons (C-H) in activated methylene or methine groups (*the RMA donor group*), and the at least 2 reactive groups of component B are activated unsaturated groups (C=C) (*the RMA acceptor group*), to achieve crosslinking by Real Michael Addition (RMA) reaction, said composition further comprising a base catalyst (C), an X-H group containing component (D), of a nature different from A, that is also a Michael addition donor reactable with component B under the action of base catalyst C, wherein X is C, N, P, O or S and a sag control component (E).

2. The crosslinkable composition according to claim 1, in which the RMA acceptor groups B are acryloyl groups
3. The crosslinkable composition according to claim 1 or 2, in which the RMA donor groups A originate for more than 50% from malonate groups.
4. The crosslinkable composition according to any of claims 1-3, the X-H group of component D being **characterized by** a pKa (defined in aqueous environment) of at least one unit, preferably two units, less than that of the dominant type of C-H groups in component A.
5. The crosslinkable composition according to any of claims 1-4, wherein the pKa of the X-H group in component D is lower than 13, preferable lower than 12, more preferably lower than 11, most preferably lower than 10; and is preferably higher than 7, more preferably 8, more preferably higher than 8.5.
6. The crosslinkable composition according to claims 1 - 5, wherein component D is selected from one or more components from the group of
  - a. component D(1) comprising C-H acidic protons (X is C) in activated methylene, methyl or methine groups,
  - b. component D(2) comprising N-H acidic compound (X is N)
7. The crosslinkable composition according to claim 6 wherein component D(1) is an acetoacetate and/or acetylacetone.
8. The crosslinkable composition according to claims 1 - 6 wherein N-H group containing component D contains the N-H group as part of a group Ar-NH-(C=O)-, -(C=O)-NH-(C=O)-, or of a group -NH-(O=S=O)- or is a heterocycle in which the nitrogen of the N-H group is contained in a heterocyclic ring.
9. The crosslinkable composition according to claim 8, wherein component D is chosen from the group of imide derivatives, preferably cyclic, preferably an optionally substituted succinimide or glutarimide, hydantoin derivatives, preferably 5,5-dimethylhydantoin, a sulfonamide, preferably an aromatic sulfonimide as benzene- or toluenesulfonamide, N-H group containing heterocycles, preferably a triazole, benzotriazole, pyrazole, nitro-imidazoles or uracil, preferably chosen from the group of succinimides, triazoles and pyrazoles.
10. The crosslinkable composition according to claims 1 - 9 wherein C-H groups in component D(1) are present in an amount between 5 and 50 mol % preferably 10 - 40 mol% (to total RMA donor C-H)
11. The crosslinkable composition according to anyone of claims 1 - 10 comprising
  - a. between 5 and 95 wt% of a component A with at least 2 acidic protons C-H in activated methylene or methine, and
  - b. between 5 and 95 wt% of a component B with at least 2 activated unsaturated groups (wt% relative to the total weight of the crosslinkable composition) and
  - c. a catalyst C that contains, or is able to generate a basic catalyst capable of activating the RMA reaction between components A and B, at levels of 0.0001 and 0.5 meq/g solid components,
  - d. component D in an amount such that the amount of X-H in component D is at least 50 mole % relative to base generated by component C, and less than 30 mole% of C-H active groups from component A,
  - e. optionally additional different C-H containing component D(1) in an amount such that the amount of C-H groups in component D(1) are present in an amount between 5 and 50 mol % preferably 10 - 40 mol% (to total RMA donor C-H)
  - f. a sag control component E,
  - g. optionally between 0.1 and 80 wt% of solvent (preferably less than 45wt%), preferably organic solvent preferably containing at least 1wt% of a primary alcohol and,
  - h. optionally between 0.1 and 10 wt% water, optionally at least 0.5wt% water.

12. A kit of parts for the manufacture of the composition according to claims 1 - 11 comprising a part 1 comprising components A and B and part 2 comprising component C and D or part 1 comprising components A, B and D and part 2 comprising component C.

13. Use of the crosslinkable composition according to anyone of claims 1 - 11 for the manufacture of coating compositions, films or inks.

14. Coating composition comprising the crosslinking composition according to anyone of claims 1 - 11 and further comprising one or more coating additives like pigments, co-binder, solvents etc.

15. The use of the component D described in any one of the preceding claims as an additive to RMA cross-linkable compositions for preparing thick coating layers having a dry thickness of at least 50, preferably at least 60, 75, 100 and more preferably at least 125 micrometer and having a good surface appearance and hardness of the resulting cured composition, in particular in a coating.

16. A RMA coating additive mixture comprising two or more different X-H group containing components D that are Michael addition donor reactable with a component B comprising at least 2 activated unsaturated groups (C=C) (RMA acceptor group) under the action of a base catalyst C, wherein X is C, N, P, O or S, comprising

a. one or more components D1 comprising C-H acidic protons in activated methylene or methine groups, preferably in substituted or unsubstituted acetoacetate or acetoacetyl groups and

b. one or more components D different from component D1, preferably comprising N-H containing components D2.

## Patentansprüche

1. RMA-vernetzbare Zusammensetzung zur Herstellung von dicken Beschichtungsschichten, die wenigstens eine vernetzbare Komponente umfasst, welche reaktive Komponenten A und B umfasst, die jeweils wenigstens 2 reaktive Gruppen umfassen, wobei die wenigstens 2 reaktiven Gruppen der Komponente A saure Protonen (C-H) in aktivierten Methylen- oder Methingruppen (der RMA-Donorgruppe) sind und die wenigstens 2 reaktiven Gruppen der Komponente B aktivierte ungesättigte Gruppen (C=C) (die RMA-Akzeptorgruppe) sind, um eine Vernetzung durch reale Michael-Additionsreaktion (RMA) zu erreichen, wobei die Zusammensetzung weiterhin einen Basenkatalysator (C), eine die Gruppe X-H enthaltende Komponente (D), die anderer Natur als A ist, d.h. einen Michael-Additions-Donor, der unter der Einwirkung des Basenkatalysators C mit Komponente B reagieren kann, wobei X = C, N, P, O oder S ist, und eine Antiablaufkomponente (E) umfasst.

2. Vernetzbare Zusammensetzung gemäß Anspruch 1, wobei die RMA-Akzeptorgruppen B Acryloylgruppen sind.

3. Vernetzbare Zusammensetzung gemäß Anspruch 1 oder 2, wobei die RMA-Donorgruppen A zu mehr als 50% auf Malonatgruppen zurückgehen.

4. Vernetzbare Zusammensetzung gemäß einem der Ansprüche 1 bis 3, wobei die X-H-Gruppe der Komponente D durch einen pKa-Wert (in wässriger Umgebung definiert) gekennzeichnet ist, der wenigstens eine Einheit, vorzugsweise zwei Einheiten, weniger beträgt als der des dominanten Typs von C-H-Gruppen in Komponente A.

5. Vernetzbare Zusammensetzung gemäß einem der Ansprüche 1 bis 4, wobei der pKa-Wert der X-H-Gruppe in Komponente D kleiner als 13, vorzugsweise kleiner als 12, besonders bevorzugt kleiner als 11, am meisten bevorzugt kleiner als 10 ist und vorzugsweise höher als 7, besonders bevorzugt höher als 8,5 ist.

6. Vernetzbare Zusammensetzung gemäß Anspruch 1 bis 5, wobei Komponente D ausgewählt ist aus einer oder mehreren Komponenten aus der Gruppe von

a. Komponente D(1), die saure C-H-Protonen (X = C) in aktivierten Methylen-, Methyl- oder Methingruppen umfasst;

b. Komponente D(2) eine saure N-H-Verbindung (X = N) umfasst.

7. Vernetzbare Zusammensetzung gemäß Anspruch 6, wobei Komponente D(1) ein Acetoacetat und/oder Acetylac-



ton ist.

8. Vernetzbare Zusammensetzung gemäß Anspruch 1 bis 6, wobei die eine Gruppe N-H enthaltende Komponente D die N-H-Gruppe als Teil einer Gruppe Ar-NH-(C=O)-, -(C=O)-NH-(C=O)- oder einer Gruppe -NH-(O=S=O)- enthält oder ein Heterocyclus ist, bei dem das Stickstoffatom der N-H-Gruppe in einem heterocyclischen Ring enthalten ist.
9. Vernetzbare Zusammensetzung gemäß Anspruch 8, wobei Komponente D aus der Gruppe der Imidderivate, vorzugsweise cyclische, vorzugsweise eines gegebenenfalls substituierten Succinimids oder Glutarimids, Hydantoin-Derivate, vorzugsweise 5,5-Dimethylhydantoin, einem Sulfonamid, vorzugsweise einem aromatischen Sulfonamid, wie Benzol- oder Toluol-sulfonamid, eine N-H-Gruppe enthaltenden Heterocyclen, vorzugsweise einem Triazol, Benzotriazol, Pyrazol, Nitroimidazolen oder Uracil, ausgewählt ist und vorzugsweise aus der Gruppe der Succinimide, Triazole und Pyrazole ausgewählt ist.
10. Vernetzbare Zusammensetzung gemäß Anspruch 1 bis 9, wobei C-H-Gruppen in Komponente D(1) in einer Menge zwischen 5 und 50 Mol-%, vorzugsweise 10 bis 40 Mol-% (bezogen auf Gesamt-RMA-Donor-C-H), vorhanden sind.
11. Vernetzbare Zusammensetzung gemäß einem der Ansprüche 1 bis 10, umfassend:
  - a. zwischen 5 und 95 Gew.-% einer Komponente A mit wenigstens 2 sauren Protonen C-H in aktiviertem Methylen oder Methin; und
  - b. zwischen 5 und 95 Gew.-% einer Komponente B mit wenigstens 2 aktivierten ungesättigten Gruppen (Gew.-%, bezogen auf das Gesamtgewicht der vernetzbaren Zusammensetzung); und
  - c. einen Katalysator C, der einen basischen Katalysator, der die RMA-Reaktion zwischen den Komponenten A und B aktivieren kann, in Mengen von 0,0001 und 0,5 mäß/g feste Komponenten enthält oder einen solchen erzeugen kann;
  - d. Komponente D in einer solchen Menge, dass die Menge an X-H in Komponente D wenigstens 50 Mol-%, bezogen auf die durch Komponente C erzeugte Base, und weniger als 30 Mol-% an aktiven C-H-Gruppen aus Komponente A beträgt;
  - e. gegebenenfalls eine zusätzliche andere C-H enthaltende Komponente D(1) in einer solchen Menge, dass die Menge der C-H-Gruppen in Komponente D(1) in einer Menge zwischen 5 und 50 Mol-%, vorzugsweise 10 bis 40 Mol-% (bezogen auf Gesamt-RMA-Donor-C-H), vorhanden sind;
  - f. eine Antiablaufkomponente E;
  - g. gegebenenfalls zwischen 0,1 und 80 Gew.-% Lösungsmittel (vorzugsweise weniger als 45 Gew.-%), vorzugsweise organisches Lösungsmittel, das vorzugsweise wenigstens 1 Gew.-% eines primären Alkohols enthält; und
  - h. gegebenenfalls zwischen 0,1 und 10 Gew.-% Wasser, gegebenenfalls wenigstens 0,5 Gew.-% Wasser.
12. Komponentensystem für die Herstellung der Zusammensetzung gemäß Anspruch 1 bis 11, umfassend ein Teil 1, das die Komponenten A und B umfasst, und Teil 2, das die Komponenten C und D umfasst, oder ein Teil 1, das die Komponenten A, B und D umfasst, und Teil 2, das die Komponente C umfasst.
13. Verwendung der vernetzbaren Zusammensetzung gemäß einem der Ansprüche 1 bis 11 zur Herstellung von Beschichtungszusammensetzungen, Filmen oder Tinten.
14. Beschichtungszusammensetzung, die die vernetzende Zusammensetzung gemäß einem der Ansprüche 1 bis 11 umfasst und weiterhin ein oder mehrere Beschichtungsadditive, wie Pigmente, Cobindemittel, Lösungsmittel usw., umfasst.
15. Verwendung der Komponente D, die in einem der vorstehenden Ansprüche beschrieben ist, als Additiv für RMA-vernetzbare Zusammensetzungen zur Herstellung von dicken Beschichtungsschichten mit einer Trockendicke von wenigstens 50, vorzugsweise wenigstens 60, 75, 100 und besonders bevorzugt wenigstens 125 Mikrometer, mit einem guten Oberflächenerscheinungsbild und Härte der resultierenden gehärteten Zusammensetzung, insbesondere in einer Beschichtung.
16. RMA-Beschichtungsadditivgemisch, umfassend zwei oder mehr verschiedene X-H-Gruppen enthaltende Komponenten D, bei denen es sich um Michael-Additions-Donoren handelt, die gegenüber einer Komponente B, die wenigstens 2 aktivierte ungesättigte Gruppen (C=C) (die RMA-Akzeptorgruppe) enthält, unter der Einwirkung eines Basenkatalysators C reaktiv sind, wobei X = C, N, P, O oder S ist, umfassend:

- a. eine oder mehrere Komponenten D1, die saure C-H-Protonen in aktivierten Methylen- oder Methingruppen umfasst, vorzugsweise in substituierten oder unsubstituierten Acetoacetat- oder Acetoacetylgruppe; und  
 b. eine oder mehrere Komponenten D, die von Komponente D1 verschieden sind und vorzugsweise N-H enthaltende Komponenten D2 umfassen.

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## Revendications

1. Composition réticulable AMR pour fabriquer des couches de revêtement épaisses comprenant au moins un composant réticulable comprenant des composants réactifs A et B comprenant chacun au moins 2 groupes réactifs dans laquelle les au moins 2 groupes réactifs de composant A sont des protons acides (C-H) dans des groupes méthylène ou méthine activé (*le groupe donneur AMR*), et les au moins 2 groupes réactifs de composant B sont des groupes insaturés activés (C=C) (*le groupe accepteur AMR*), pour réaliser une réticulation par réaction d'Addition de Michael Réelle (AMR), ladite composition comprenant en outre un catalyseur de base (C), un composant (D) contenant un groupe X-H, d'une nature différente de A, qui est également un donneur d'addition de Michael pouvant réagir avec le composant B sous l'action du catalyseur de base C, dans laquelle X est C, N, P, O ou S et un composant de commande de coulure (E).
2. Composition réticulable selon la revendication 1, dans laquelle les groupes accepteurs AMR B sont des groupes acryloyle.
3. Composition réticulable selon la revendication 1 ou 2, dans laquelle les groupes donneurs AMR A proviennent, pour plus de 50 %, de groupes malonate.
4. Composition réticulable selon l'une quelconque des revendications 1-3, le groupe X-H du composant D étant **caractérisé par** une pKa (définie dans un environnement aqueux) d'au moins une unité, de préférence deux unités, inférieure à celle du type dominant de groupes C-H dans le composant A.
5. Composition réticulable selon l'une quelconque des revendications 1-4, dans laquelle le pKa du groupe X-H dans le composant D est inférieure à 13, de préférence inférieure à 12, plus préférablement inférieure à 11, idéalement inférieure à 10 ; et est de préférence supérieure à 7, plus préférablement 8, plus préférablement supérieure à 8,5.
6. Composition réticulable selon les revendications 1-5, dans laquelle le composant D est sélectionné parmi un ou plusieurs composants du groupe de
  - a. composant D(1) comprenant des protons acides C-H (X est C) dans des groupes méthylène, méthyle ou méthine activés,
  - b. composant D(2) comprenant un composant acide N-H (X est N).
7. Composition réticulable selon la revendication 6 dans laquelle le composant D(1) est un acétoacétate et/ou un acétylacétone.
8. Composition réticulable selon les revendications 1-6 dans laquelle le composant D contenant un groupe N-H contient le groupe N-H comme partie d'un groupe Ar-NH-(C=O)-, -(C)-NH-(C=O)-, ou d'un groupe -NH-(O=S=O)- ou est un hétérocycle dans lequel l'azote du groupe N-H est contenu dans un cycle hétérocyclique.
9. Composition réticulable selon la revendication 8, dans laquelle le composant D est choisi dans le groupe de dérivés d'imide, de préférence cycliques, de préférence un succinimide ou glutarimide éventuellement substitué, de dérivés d'hydantoïne, de préférence de la 5,5-diméthylhydantoïne, d'un sulfonamide, de préférence un sulfonamide aromatique tel que le benzène- ou toluènesulfonamide, d'hétérocycles contenant un groupe N-H, de préférence un triazole, un benzotriazole, un pyrazole, des nitro-imidazoles ou de l'uracile, de préférence choisis dans le groupe de succinimides, de triazoles et de pyrazoles.
10. Composition réticulable selon les revendications 1-9 dans laquelle les groupes C-H du composant D(1) sont présents en une quantité entre 5 et 50 % en mole, de préférence 10-40 % en mole (sur le total de C-H donneur ARM).
11. Composition réticulable selon l'une quelconque des revendications 1-10 comprenant

- a. entre 5 et 95 % en poids d'un composant A avec au moins 2 protons acides C-H dans du méthylène ou méthine activé, et
- b. entre 5 et 95 % en poids d'un composant B avec au moins 2 groupes insaturés activés (% en poids par rapport au poids total de la composition réticulable) et
- c. un catalyseur C qui contient, ou est apte à générer, un catalyseur de base capable d'activer la réaction AMR entre les composants A et B, à des niveaux de 0,0001 et 0,5 meq/g de composants solides,
- d. un composant D en une quantité telle que la quantité de X-H dans le composant D est au moins de 50 % en mole par rapport à la base générée par le composant C, et inférieure à 30 % en mole des groupes actifs C-H issus du composant A,
- e. éventuellement un composant D(1) contenant un C-H différent supplémentaire en une quantité telle que la quantité des groupes C-H dans le composant D(1) se trouve entre 5 et 50 % en mole, de préférence 10-40 % en mole (sur le total de C-H donneur AMR)
- f. un composant de commande de coulure E,
- g. éventuellement entre 0,1 et 80 % en poids de solvant (de préférence moins de 45 % en poids), de préférence de solvant organique contenant de préférence au moins 1 % en poids d'un alcool primaire et,
- h. éventuellement entre 0,1 et 10 % en poids d'eau, éventuellement au moins 0,5 % en poids d'eau.

12. Ensemble de parties pour la fabrication de la composition selon les revendications 1-11 comprenant une partie 1 comprenant des composants A et B et une partie 2 comprenant des composants C et D ou une partie 1 comprenant des composants A, B et D et une partie 2 comprenant un composant C.

13. Utilisation de la composition réticulable selon l'une quelconque des revendications 1-11 pour la fabrication de compositions, de films ou d'encres de revêtement.

14. Composition de revêtement comprenant la composition réticulable selon l'une quelconque des revendications 1-11 et comprenant en outre un ou plusieurs additifs de revêtement tels que des pigments, un co-liant, des solvants, etc.

15. Utilisation du composant D décrit selon l'une quelconque des revendications précédentes en tant qu'additif à des compositions réticulables AMR pour préparer des couches de revêtement épaisses ayant une épaisseur à sec d'au moins 50, de préférence d'au moins 60, 75, 100 et plus préférablement d'au moins 125 micromètres et ayant de bons aspect et dureté de surface de la composition durcie obtenue, en particulier dans un revêtement.

16. Mélange d'additifs de revêtement ARM comprenant deux, ou plus, composants D contenant un groupe X-H différents qui sont un donneur d'addition de Michael pouvant réagir avec un composant B comprenant au moins 2 groupes insaturés activés (C=C) (groupe accepteur AMR) sous l'action d'un catalyseur de base C, dans lequel X est C, N, P, O ou S, comprenant

- a. un ou plusieurs composants D1 comprenant des protons acides C-H dans des groupes méthylène ou méthine activé, de préférence dans des groupes acétoacétate ou acétoacétyle substitué ou non substitué et
- b. un ou plusieurs composants D différents du composant D1, de préférence comprenant des composants D2 contenant N-H.

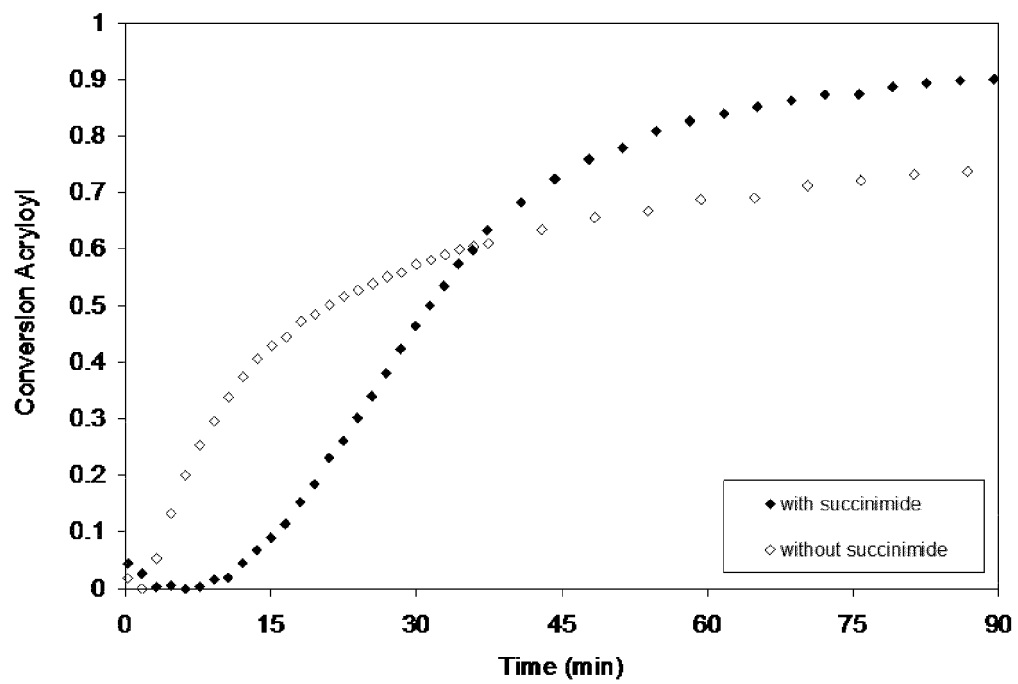
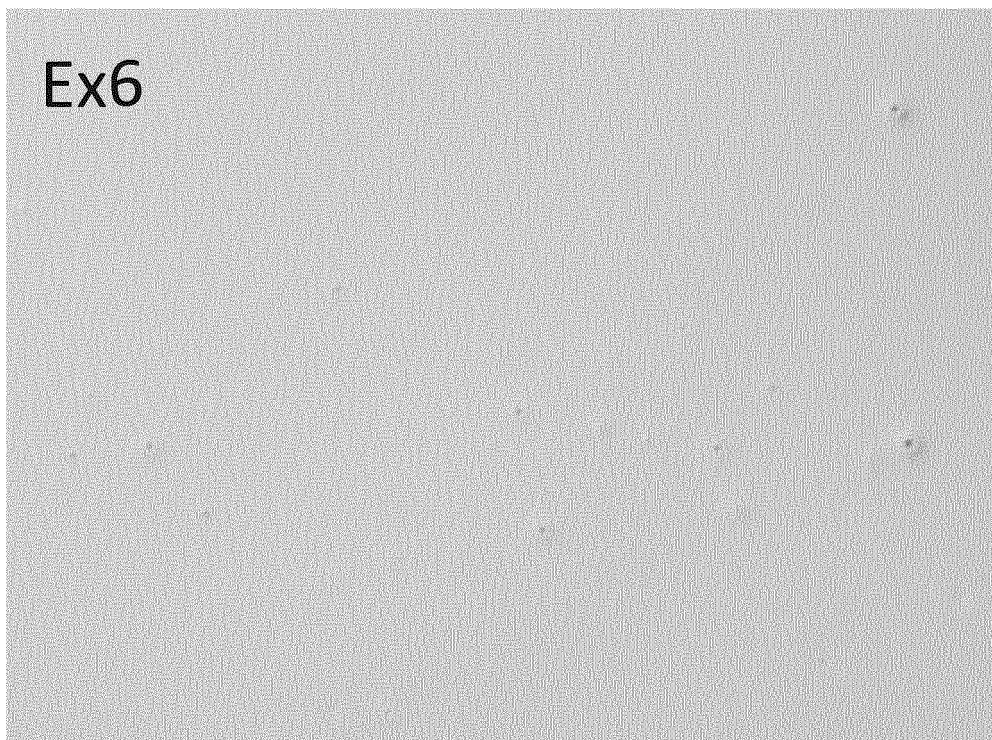


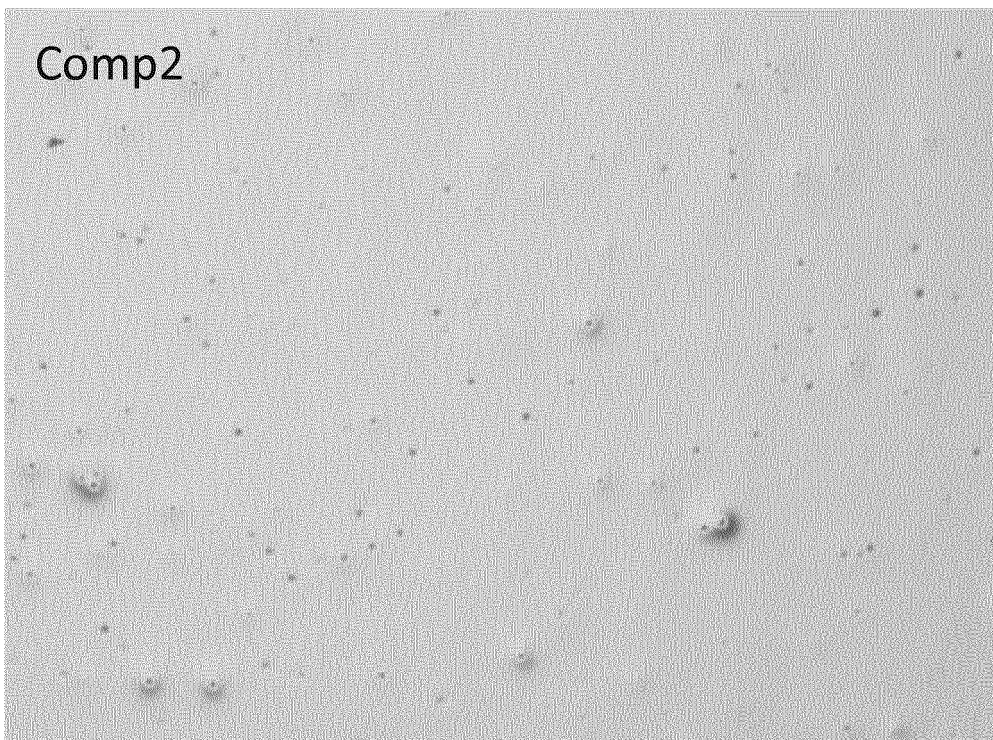
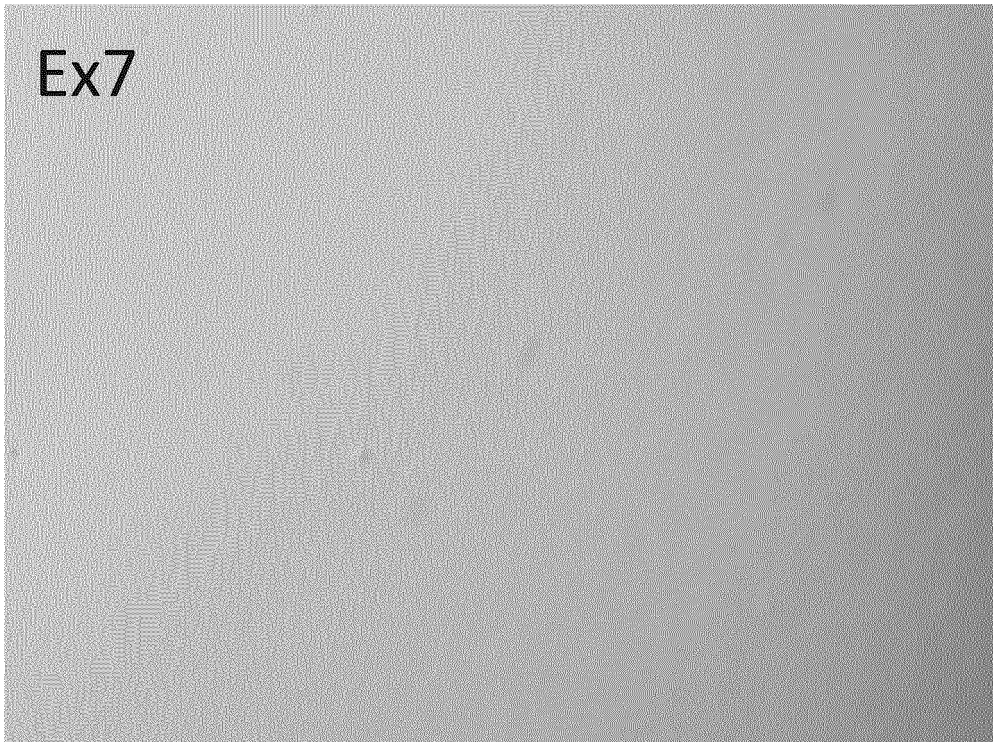
Fig. 1

**Fig. 2**



**Fig. 3**

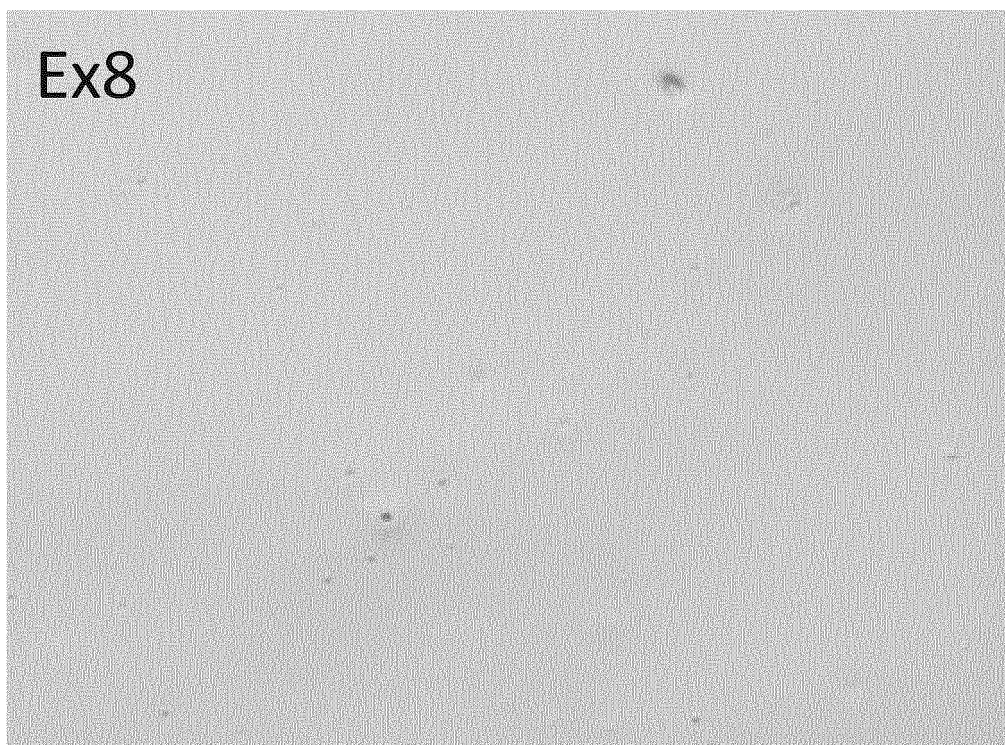
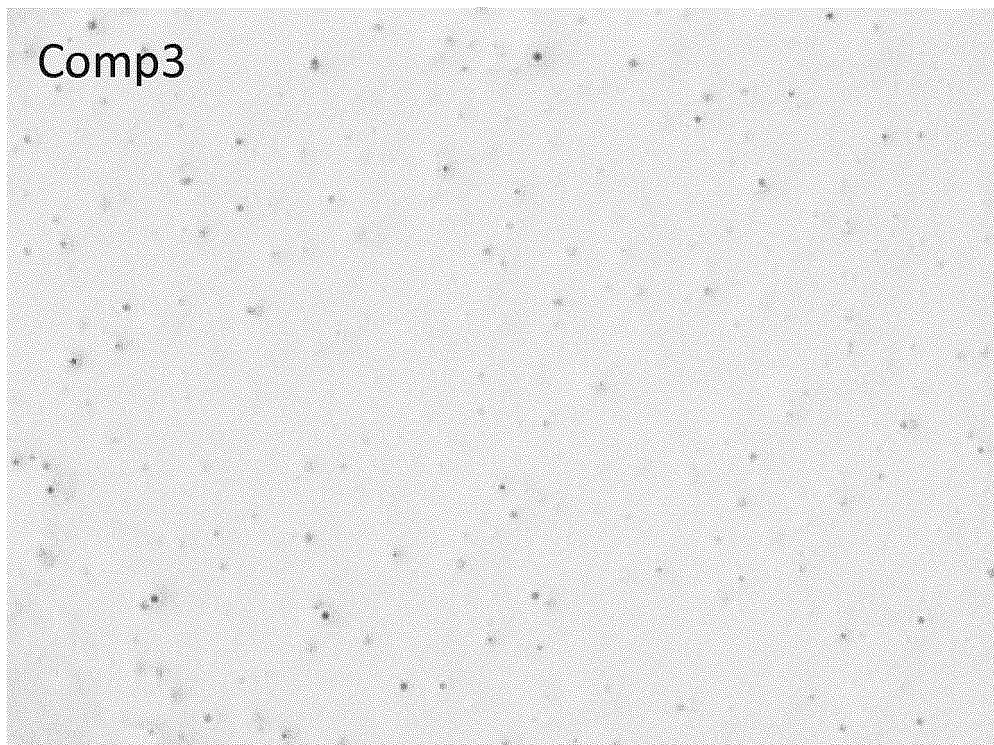
**Fig.4**



**Fig.5**



**Fig. 6**



**Fig. 7**

## REFERENCES CITED IN THE DESCRIPTION

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