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(54) MICROENCAPSULATED LEWIS ACID

MICROENCAPSULIERTE LEWIS-SAUEREN

ACIDE DE LEWIS MICRO-ENCAPSULE

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- **KOBAYASHI S ET AL: "NEW METHODOLOGY FOR COMBINATORIAL SYNTHESIS. PREPARATION OF DIVERSEQUINOLINE DERIVATIVES USING A NOVEL POLYMER-SUPPORTED SCANDIUM CATALYST" JOURNAL OF THE AMERICAN CHEMICAL SOCIETY, AMERICAN CHEMICAL SOCIETY, WASHINGTON, DC, US, vol. 118, 1996, pages 8977-8978, XP002922275 ISSN: 0002-7863**
- **SHU KOBAYASHI ET AL: "A POLYMER-SUPPORTED SCANDIUM CATALYST" JOURNAL OF ORGANIC CHEMISTRY, AMERICAN CHEMICAL SOCIETY. EASTON, US, vol. 61, no. 7, 5 April 1996 (1996-04-05), pages 2256-2257, XP000559278 ISSN: 0022-3263**
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- **KOBAYASHI SHU et al., "A Microencapsulated Lewis Acid. A New Type of Polymer-Supported Lewis Acid Catalyst of Wide Utility in Organic Synthesis", J. AM. CHEM. SOC., 1998, Vol. 120, No. 12, pages 2985-2986, XP002920393**

EP 1 069 127 B1

Description

[0001] The present invention relates to a microencapsulated Lewis acid where a Lewis acid is confined in a network of a polymer gel. The microencapsulated Lewis acid is in a condition where the Lewis acid is fixed on the surface or the inside of a polymer capsule and confined so as to function as a catalyst for organic syntheses.

[0002] The development of catalysts supported on organic polymers has hitherto been a very important theme of organic syntheses. The reason for this is that catalysts supported on organic polymers are very economical in terms of their preparation and the separation from reaction products and industrial application is expected. Furthermore, although some catalysts supported on polymers have been reported so far, the activity of such catalysts is low as compared with carrier-free catalysts and highly active catalysts supported on organic polymers have been very difficult to realize.

[0003] On the other hand, attention is directed to Lewis acids because of the characteristic catalytic activity and selectivity of reactions thereof and in addition, Lewis acids promote catalytic reactions under milder conditions. Therefore Lewis acids are recognized to be industrially very useful. However, Lewis acids decompose in aqueous solutions and are difficult to recover and recycle, and these facts are also true of Lewis acid catalysts supported on polymers. For example, although an aluminum chloride catalyst supported on a crosslinked organic polymer is known and can be easily recovered from the reaction system after using once, the catalyst is difficult to recover from the reaction system after using twice or more so that the recycling thereof is impossible.

[0004] Thus, conventional Lewis acid catalysts are not necessarily easily used from the point of view of preparation of reaction systems, the separation from reaction products, and the recovery and recycling thereof. The catalysts supported on organic polymers are also difficult to recover and recycle so that their use is uneconomic.

[0005] The invention, accordingly, aims to overcome the technical limits of the conventional catalysts supported on polymers and in addition, to solve problems attendant upon the preparation of reaction systems, the separation from reaction products, and the recovery of Lewis acid catalysts having great industrial usefulness, and so to provide novel microencapsulated Lewis acids supported on polymers and catalysts formed of these.

[0006] The invention provides in a first aspect a microencapsulated Lewis acid characterized in that a Lewis acid is supported through coordinate bonds on a microcapsule formed of an organic polymer.

[0007] The invention also provides a microencapsulated Lewis acid as particles or aggregates thereof as a first embodiment; a microencapsulated Lewis acid where the organic polymer is a substantially non-crosslinked polymer prepared by addition polymerization as a second embodiment; a microencapsulated Lewis acid where the organic polymer is a substantially non-crosslinked polymer containing aromatic rings as a third embodiment; a microencapsulated Lewis acid where the organic polymer is a substantially non-crosslinked polymer containing benzene rings as a fourth embodiment; a microencapsulated Lewis acid where the organic polymer is a substantially non-crosslinked polymer containing aromatic rings on the side chains as a fifth embodiment; a microencapsulated Lewis acid where the organic polymer is a substantially non-crosslinked polymer containing benzene rings on the side chains as the sixth embodiment; and a microencapsulated Lewis acid where the Lewis acid is a trifluoromethanesulfonate of a rare earth metal as a seventh embodiment.

[0008] The invention further provides in a further aspect Lewis acid catalysts that are characterized by being formed of the aforesaid microencapsulated Lewis acids.

[0009] Furthermore, the invention provides in another aspect a process for preparing a microencapsulated Lewis acid characterized in that a Lewis acid is supported through coordinate bonds on microcapsules simultaneously on forming the microcapsules from an organic polymer by a microencapsulation process. The microencapsulation process is preferably a phase separation process.

[0010] In the microencapsulated Lewis acid supported through coordinate bonds on an organic polymer according to the invention, the Lewis acid is arranged on the surfaces of capsules and exposed on the polymer in a condition where the acid is confined and enveloped in the complicated room of the inside of capsules, and so may participate in reactions as a catalyst.

In the accompanying drawings:

[0011] Fig. 1 is a graph showing a comparison of reaction activity in Example 15.

[0012] The invention possesses the characteristics as described above. Next, embodiments of the invention will be illustrated below.

[0013] Some examples of Lewis acids supported on polymers have been reported so far (Neckers, D. C., etal., J. Am. Chem. Soc. 94, 9284 (1972); Drago, R. S., et al., J. Am. Chem. Soc., 110, 3311 (1988); Clark, J. H., et al., J. Chem. Soc., Chem. Commun., 1995, 2037; and others). Furthermore, the present inventors also report some examples (Kobayashi, S., et al., J. Org. Chem., 61, 2256 (1996); and Kobayashi, S., et al., J. Am. Chem. Soc., 118, 8977 (1996)).

[0014] These Lewis acids supported on polymers, however, have the disadvantage of having only low catalytic activity as compared with carrier-free Lewis acids.

[0015] Microcapsules formed of organic polymers are also described in Japanese Patent Laid-Open No. 296855/1994. However, the microcapsules have bursting properties which make the recycling thereof impossible and they house the Lewis acids just physically.

[0016] On the other hand, the microencapsulated Lewis acids where Lewis acids are supported through coordinate bonds on organic polymers as described above are easy to prepare and adjust, surprisingly exhibit high catalytic activity, can be separated and recovered from reaction products for recycling, and can be used for a variety of organic synthetic reactions. These microencapsulated Lewis acids are substantially different from conventional organic polymer-supported Lewis acids.

[0017] Microcapsules formed of organic polymers have hitherto been known in the field of pharmaceuticals. The invention presents for the first time the microencapsulation of Lewis acids and utilization thereof to catalysts.

[0018] The microencapsulated Lewis acids of the invention can be provided as fine particles or aggregates having particle sizes of micrometer to nanometer orders. A Lewis acid is supported through coordinate bonds on an organic polymer forming capsules and arranged on the surfaces of the particles or aggregates thereof or exposed and arranged on the polymer in a condition where the Lewis acid is confined and enveloped in the complicated room of the insides of the capsules. In the aggregates, the Lewis acid enveloped is found to be exposed also in conditions of the particles contacting one another. In these conditions, the Lewis acid acts and exhibits a stable action and further higher catalytic activity as compared with the carrier-free Lewis acid.

[0019] Both crosslinked and non-crosslinked organic polymers can be used as the organic polymers as long as the polymers can undergo microencapsulation, but substantially non-crosslinked polymers are preferred. Polymers formed by addition polymerization are more appropriate. More concretely, the polymers are substantially non-crosslinked polymers containing aromatic rings, desirably benzene rings, including polystyrene, styrene/acrylonitrile copolymers, and styrene/MMA copolymers.

[0020] In the Lewis acid supported through coordinate bonds on microcapsules formed of an organic polymer containing benzene rings, it is thought that the mutual interaction between the Lewis acid and n-electrons of the benzene rings causes effective catalytic action.

[0021] "Substantially non-crosslinked polymers" means polymers that are not subjected to crosslinking reaction by the use of crosslinking agents. It is, however, not intended to exclude polymers where a small number of crosslinking structures are produced in the course of preparation of the polymers. That is, the polymers need to contain substantially no crosslinked polymer gel unnecessary to solvents.

[0022] In the organic polymers containing aromatic rings, the aromatic rings in the molecular structure can be those forming the main chain of the polymer or those existing in the side chains. From the viewpoint of the mutual interaction by coordinate bonds between a Lewis acid and n-electrons of a benzene ring, for example, in the case of polystyrene or copolymers or block copolymers of styrene and another monomer, organic polymers that are formed by addition polymerization and contain benzene rings on the side chains are more preferred.

[0023] The organic polymers containing aromatic rings can have a variety of molecular structures such as a polyolefin structure, a polyester structure, a polyether structure, and a polyamide structure as long as the polymers contain aromatic rings in their structures. Copolymers of various monomers can also be included therein. Although the molecular weight thereof is not particularly limited, polymers having a weight average molecular weight of about 10,000 to about 2,000,000 are generally usable.

[0024] The support of the Lewis acids on microcapsules formed of these organic polymers can be carried out by various methods. Interfacial polymerization, phase separation (coacervation), and interfacial precipitation are known as simple methods. In the invention, phase separation (coacervation) is preferably applied.

[0025] Lewis acids forming the microencapsulated Lewis acid of the invention are those defined as electron-pair acceptors and a variety of Lewis acids are usable. Although known Lewis acids such as $AlCl_3$ or BF_3 can also be used, examples of Lewis acids used preferably in the invention include organic metallic compounds of rare earth metals of scandium (Sc), yttrium (Y), and lanthanide (Ln) series, for example, trifluoromethanesulfonates of rare earth metals such as scandium trifluoromethanesulfonate (scandium triflate) yttrium triflate, and lanthanide triflates (Ln = La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, and Lu). Above all, scandium compounds that the present inventors have found are stable in an aqueous phase and are preferably exemplified. Of these, a typical Lewis acid is scandium triflate [$SC(OTf)_3$].

[0026] The amount of Lewis acid supported on microcapsules formed of an organic polymer is not particularly limited and can be selected depending upon the Lewis acid used, the organic polymer used, the purpose of use of the microencapsulated Lewis acid adopted, and the use. For example, when the aforesaid polymers having a weight average molecular weight of about 10,000 to about 2,000,000 are used, the weight ratio of Lewis acid to organic polymer in general is 1:100 or more, and preferably from 1:3 or less to 1:50 or more as a standard.

[0027] In the invention, the microencapsulated Lewis acids as described above are used as catalysts for a variety of organic synthetic reactions.

[0028] The microencapsulated Lewis acids can be used as catalysts in both embodiments of a batchwise reaction

system and a flow reaction system, for example, for a variety of organic synthetic reactions such as imino-aldol condensation, Mannich-type reaction, aldol reaction, Michael reaction, and Friedel-Crafts reaction. In addition, the catalysts of the invention are found to have high reaction activity and to bring about high reaction yields (selectivity) as compared with single carrier-free Lewis acids. A very significant action where the microencapsulated Lewis acids recovered from reaction mixtures also exhibit high reaction activity on recycling is confirmed.

[0029] Of course, when the microencapsulated Lewis acids are recovered by separation from reaction products, recovery as a solid (particles) can be very easily carried out.

EXAMPLES

[0030] The embodiments of the invention are illustrated in further detail through the following examples, but these are not to be construed as limiting the invention.

EXAMPLE 1

[0031] A microencapsulated Lewis acid of the invention was prepared according to the following procedure. A Phase separation (coacervation) microencapsulation process was adopted in this procedure.

[0032] First, 1.000 gram of polystyrene having a weight average molecular weight of 280,000 was dissolved in 20 ml of cyclohexane at a temperature of 40˚C and subsequently, 0.200 gram of scandium triflate [$Sc(OTf)_3$] was added to the resulting solution.

[0033] The resulting mixture separated was stirred at the aforesaid temperature for 1 hour and gradually cooled to 0˚C. Phase separation (coacervation) arose to form a scandium triflate covered with polystyrene. Thirty ml of hexane was added thereto to harden the particle walls of microcapsules.

[0034] After further stirring for 1 hour, the microcapsule particle product was washed with acetonitrile several times and then dried at 50˚C.

[0035] Since 0.08 gram of scandium triflate was recovered in the procedure described above, it was confirmed that 0.120 gram of scandium triflate was supported on the microcapsules.

[0036] The total weight of the microencapsulated Lewis acid was 1.167 grams (acetonitrile also contained therein).

[0037] The IR absorption spectrum (KBr) thereof is shown in the following Table 1.

Table 1

The weight of the capsules was 1.167 g which contained acetonitrile. IR (KBr) 3062, 3030 (vCH), 1946, 1873, 1805 (δCH). 1601. 1493 (benzene rings). 1255 ($\nu_{25}SO_2$). 1029 (ν_5SO_2), 756 (vC-S), 696 (vS-O) cm^{-1}. Cf. $Sc(OTf)_3$: 1259 ($\nu_{25}SO_2$), 1032 (ν_2SO_2). 769 (νC-S), 647 (νS-O) cm^{-1}; polystylene: 3062. 3026 (vCH). 1944, 1873, 1803 (δCH). 1600, 1491 (benzene rings) cm^{-1}.

On the basis of a scanning electron microscope (SEM) and a scandium energy dispersion X-ray (EDX) map, a microcapsule structure was unable to be identified in the strict sense. It was confirmed, however, that fine particles were in a tightly collective condition and scandium triflate was arranged on the surfaces of polymer microcapsules.

EXAMPLE 2

[0038] The microencapsulated Lewis acid prepared in Example 1 was used as a catalyst and an imino-aldol reaction was carried out as shown in Table 2.

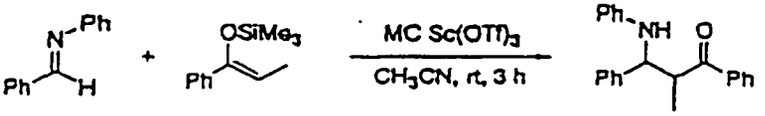
[0039] The reaction was carried out by use of the microcapsule particle product containing 0.120 gram of scandium triflate [MC $Sc(OTf)_3$] by a flow process through a circulating column in acetonitrile solvent at room temperature for 3 hours. That is, 1.167 grams of the aforesaid [MC $Sc(OTf)_3$] as a catalyst was placed in a column (1.6 x 15 cm) and 10 ml of acetonitrile was added thereto. A mixture of 0.50 mmol of aldimine and 0.60 mmol of silyl enolate in 5 ml of acetone was added and the solution was circulated at room temperature for 3 hours.

[0040] The solution was recovered and concentrated under vacuum. The resulting crude product was purified by chromatography on silica gel.

[0041] The microencapsulated Lewis acid [MC $Sc(OTf)_3$] was recovered and recycled to use seven times.

[0042] The yields of reactions also are included in Table 2.

Table 2



Use[a]	1	2	3	4	5	6	7
Yield/%	90	90	88	89	89	88	90

[a]Recevered catalyst was used successively (Use 2.3.4_)

[0043] It was confirmed that the aminocarbonyl compound as a reaction product was prepared in very high yields and further, recycling of the catalyst caused no reduction in yields.

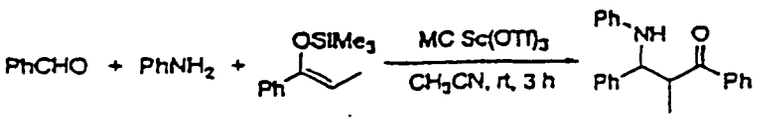
[0044] This shows that the catalyst of the invention exerts an extremely significant action beyond expectation.

EXAMPLE 3

[0045] Similarly to Example 2, a Mannich type reaction was carried out wherein three starting materials were used as shown in Table 3.

[0046] Similarly to Example 2, high yields were obtained as shown in Table 3. In addition, it was also confirmed that recycling of the catalyst caused no reduction in yield.

Table 3



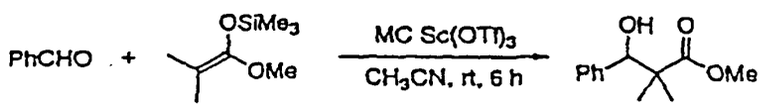
1 st use, 90% yield; 2nd use, 96% Yield; 3rd use, 93% yield

EXAMPLE 4

[0047] The microencapsulated Lewis acid [MC $Sc(OTf)_3$] prepared in Example 1 was used as a catalyst and an aldol reaction was carried out in a batchwise system as shown in Table 4. The reaction time was 6 hours.

[0048] Table 4 reveals that a hydroxycarbonyl compound was prepared in yields higher than 90 percent and an extremely high yield of 95 percent was maintained even after the catalyst was used three times through recycling.

Table 4



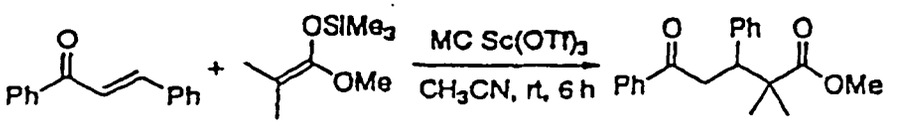
1st use, 92% yield; 2nd use, 97% yield; 3rd use, 95% yield

EXAMPLE 5

[0049] Similarly to Example 4, a Michael reaction was carried out according to a batchwise system as shown in Table 5.

[0050] It was confirmed that use of the microencapsulated Lewis acid catalyst of the invention makes it possible to maintain a high reaction yield in spite of recycling of the catalyst as shown in Table 5.

Table 5



1st use, 92% yield; 2nd use, 97% yield; 3rd use, 95% yield

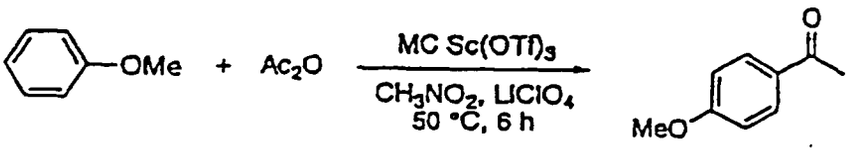
EXAMPLE 6

[0051] Similarly to Example 4, a Friedel-Crafts acylation reaction was carried out as shown in Table 6.

[0052] The reaction was carried out in nitromethane in the coexistence of $LiClO_4$ at a temperature of 50˚C for 6 hours.

[0053] It was confirmed that a yield of 81 percent was obtained even after the catalyst was used three times through recycling and a high level of yield was maintained as shown in Table 6.

Table 6



1st use, 76% yield; 2nd use, 76% yield; 3rd use, 81% yield

EXAMPLE 7

[0054] An allylation reaction of an aldehyde was carried out as shown in Table 7. The reaction was carried out by a batchwise system according to the following procedure.

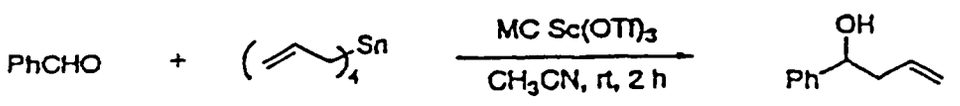
[0055] That is, 1.167 grams of the microencapsulated Lewis acid containing 0.120 gram of scandium triflate [MC Sc $(OTf)_3$] prepared in Example 1 was used as a catalyst and a mixture of 0.50 mmol of an aldehyde and 0.30 mmol of tetraallyl tin in 5 ml of acetonitrile was mixed with the catalyst at room temperature.

[0056] The resulting mixture was stirred at the same temperature for 2 hours. After filtration, the filtrate was concentrated under vacuum and the resulting crude product was purified by chromatography on silica gel.

[0057] The catalyst was used three times through recycling.

[0058] The yields of reactions were shown in Table 7.

Table 7



Use[a]	Yield/%
1	92
2	91
3	90

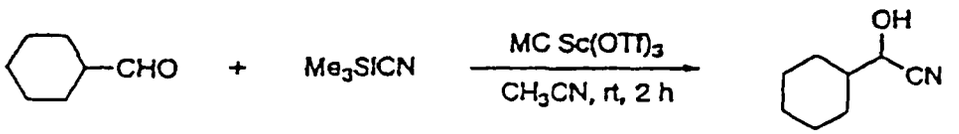
[0059] It was confirmed that a yield higher than 90 percent was maintained in spite of repeated recycling.

EXAMPLE 8

[0060] Similarly to Example 7, a cyanidation reaction of an aldehyde was carried out as shown in Table 8.

[0061] It was confirmed that the catalyst of the invention maintained a high yield in spite of recycling.

Table 8



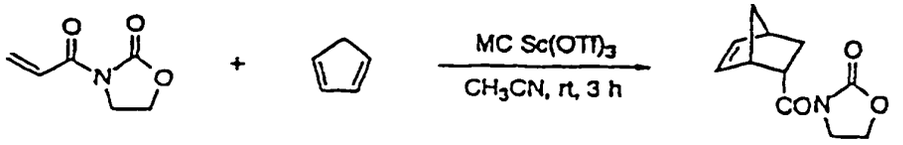
Use	Yield /%.
1	79
2	78
3	74

EXAMPLE 9

[0062] Similarly to Example 7, a Diels-Alder reaction was carried out as shown in Table 9.

[0063] The catalyst supported on a polymer of the invention was found to have excellent catalytic activity and to exhibit maintenance of the high activity in recycling.

Table 9



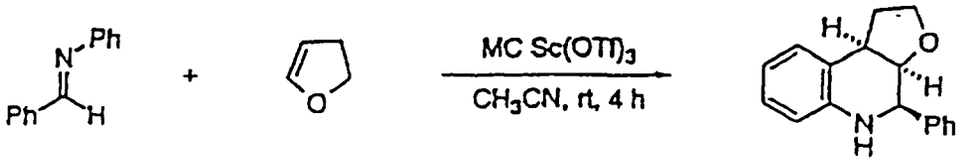
Use	Yield/%
1	77
2	79
3	80

EXAMPLE 10

[0064] Similarly to Example 2, an Aza Diels-Alder reaction was carried out as shown in Table 10.

[0065] Recylcing of the catalyst was found to maintain a high yield.

Table 10



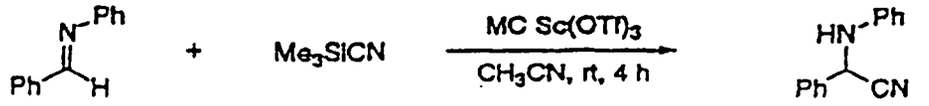
Use	Yield/%
1	80
2	78
3	78

EXAMPLE 11

[0066] Similarly to Example 2, a cyanidation reaction was carried out as shown in Table 11.

[0067] Recycling of the catalyst was found to maintain high yields of the same level as that in use of the virgin catalyst.

Table 11



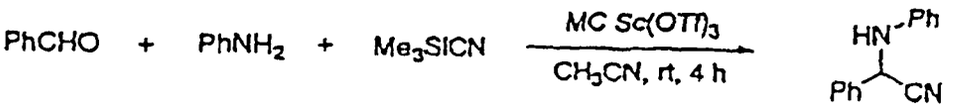
Use	Yield/%
1	77
2	77
3	76

EXAMPLE 12

[0068] Similarly to Example 11, a cyanidation reaction was carried out wherein three starting materials were used as shown in Table 12.

[0069] Recycling of the catalyst gave yields higher than that in use of the virgin catalyst.

Table 12



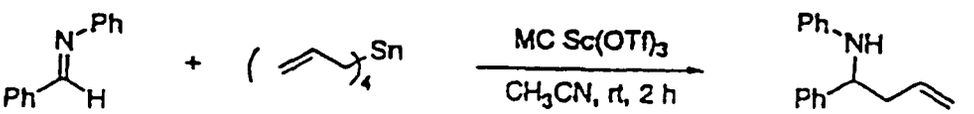
Use	Yield/%
1	70
2	71
3	75

EXAMPLE 13

[0070] Similarly to Example 2, an allylation reaction was carried out as shown in Table 13.

[0071] It was confirmed that the catalyst was able to maintain high reaction yields in spite of recycling.

Table 13



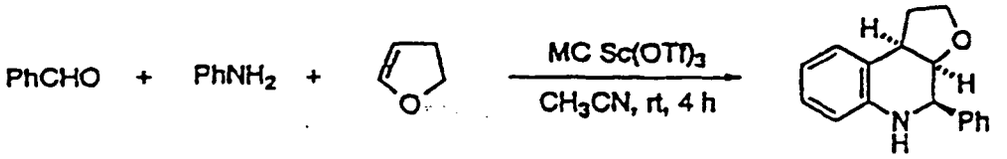
Use[a]	Yield/%
1	85
2	87
3	83

EXAMPLE 14

[0072] Similarly to Example 2, Quinoline synthesis was carried out as shown in Table 14.

[0073] It was confirmed that the catalyst was able to maintain high reaction yields in spite of recycling.

Table 14



Use	Yield/%
1	68
2	69
3	69

EXAMPLE 15

[0074] In the imino-aldol reaction of Example 2, catalytic activity was compared between the microencapsulated Lewis acid [MC $Sc(OTf)_3$] of the invention and the carrier-free catalyst $Sc(OTf)_3$.

[0075] The amounts of Sc $(OTf)_3$ in the respective catalysts were identically 0.120 gram.

[0076] The relationship between reaction times and yields is shown in Fig. 1. Fig. 1 reveals that the catalyst of the invention (A in the figure) has high reaction activity and allows the imino-aldol reaction to proceed much more rapidly as compared with the carrier-free catalyst $Sc(OTf)_3$ (B in the figure).

[0077] As described in detail, in the invention, Lewis acids useful as catalysts for a variety of organic synthetic reactions are supported through coordinate bonds on polymers to exert a very significant action so that the preparation, recovery, and recycling thereof are easy, the activity as a catalyst is high and the high activity is maintained also in recycling.

Claims

1. A microencapsulated Lewis acid **characterized in that** a Lewis acid is supported through coordinate bonds on microcapsules formed of an organic polymer.

2. A microencapsulated Lewis acid as claimed in claim 1 which exists in particles or aggregates thereof.

3. A microencapsulated Lewis acid as claimed in claim 1 or claim 2 wherein the organic polymer is a substantially non-crosslinked-polymer formed by addition polymerization.

4. A microencapsulated Lewis acid as claimed in claim 1 or claim 2 wherein the organic polymer is a substantially non-crosslinked polymer containing aromatic rings.

5. A microencapsulated Lewis acid as claimed in claim 4 wherein the organic polymer is a substantially non-crosslinked polymer containing benzene rings.

6. A microencapsulated Lewis acid as claimed in claim 4 wherein the organic polymer is a substantially non-crosslinked polymer containing aromatic rings on the side chains.

7. A microencapsulated Lewis acid as claimed in claim 6 wherein the organic polymer is a substantially non-crosslinked polymer containing benzene rings on the side chains.

8. A microencapsulated Lewis acid as claimed in any one of claims 1 to 7 wherein the Lewis acid is a trifluoromethanesulfonate of a rare earth metal.

9. A microencapsulated Lewis acid catalyst formed of any one of the microencapsulated Lewis acids of claims 1 to 8.

10. A process for preparing a microencapsulated Lewis acid **characterized in that** a Lewis acid is supported through coordinate bonds on microcapsules on forming the microcapsules from an organic polymer by a microencapsulation process.

11. A process as claimed in claim 10 wherein the microencapsulation process is a phase separation process.

Patentansprüche

1. Eine mikroverkapselte Lewissäure, **dadurch gekennzeichnet, dass** eine Lewissäure durch koordinative Bindungen auf Mikrokapseln, gebildet aus organischem Polymer, geträgert ist.

2. Eine wie in Anspruch 1 beanspruchte mikroverkapselte Lewissäure, die in Teilchen oder Aggregaten davon vorliegt.

3. Eine wie in Anspruch 1 oder Anspruch 2 beanspruchte mikroverkapselte Lewissäure, wobei das organische Polymer ein im Wesentlichen nicht vernetztes Polymer ist, gebildet durch Additionspolymerisation.

4. Eine wie in Anspruch 1 oder Anspruch 2 beanspruchte mikroverkapselte Lewissäure, wobei das organische Polymer ein im Wesentlichen nicht vernetztes Polymer ist, das aromatische Ringe enthält.

5. Eine wie in Anspruch 4 beanspruchte mikroverkapselte Lewissäure, wobei das organische Polymer ein im Wesentlichen nicht vernetztes Polymer ist, das Benzolringe enthält.

6. Eine wie in Anspruch 4 beanspruchte mikroverkapselte Lewissäure, wobei das organische Polymer ein im Wesentlichen nicht vernetztes Polymer ist, das aromatische Ringe an den Seitenketten enthält.

7. Eine wie in Anspruch 6 beanspruchte mikroverkapselte Lewissäure, wobei das organische Polymer ein im Wesentlichen nicht vernetztes Polymer ist, das Benzolringe an den Seitenketten enthält.

8. Eine wie in irgendeinem der Ansprüche 1 bis 7 beanspruchte Lewissäure, wobei die Lewissäure ein Trifluormethansulfonat eines Seltenerdmetalls ist.

9. Ein mikroverkapselter Lewissäurekatalysator, gebildet aus irgendeinem der mikroverkapselten Lewissäuren der Ansprüche 1 bis 8.

10. Ein Verfahren zur Herstellung einer mikroverkapselten Lewissäure, **dadurch gekennzeichnet, dass** eine Lewissäure durch koordinative Bindungen auf Mikrokapseln bei der Bildung der Mikrokapseln aus einem organischen Polymer durch ein Mikroverkapselungsverfahren geträgert wird.

11. Ein wie in Anspruch 10 beanspruchtes Verfahren, wobei das Mikroverkapselungsverfahren ein Phasentrennverfahren ist.

Revendications

1. Acide de Lewis micro-encapsulé **caractérisé en ce qu'**un acide de Lewis est supporté par l'intermédiaire de liaisons de coordination sur des microcapsules constituées d'un polymère organique.

2. Acide de Lewis micro-encapsulé selon la revendication 1, qui existe sous forme de particules ou d'agrégats de celle-ci.

3. Acide de Lewis micro-encapsulé selon la revendication 1 ou la revendication 2, dans lequel le polymère organique est un polymère essentiellement non réticulé formé par polymérisation par addition.

4. Acide de Lewis micro-encapsulé selon la revendication 1 ou la revendication 2, dans lequel le polymère organique est un polymère essentiellement non réticulé contenant des noyaux aromatiques.

5. Acide de Lewis micro-encapsulé selon la revendication 4, dans lequel le polymère organique est un polymère essentiellement non réticulé contenant des noyaux benzène.

6. Acide de Lewis micro-encapsulé selon la revendication 4, dans lequel le polymère organique est un polymère essentiellement non réticulé contenant des noyaux aromatiques sur les chaînes latérales.

7. Acide de Lewis micro-encapsulé selon la revendication 6, dans lequel le polymère organique est un polymère essentiellement non réticulé contenant des noyaux benzène sur les chaînes latérales.

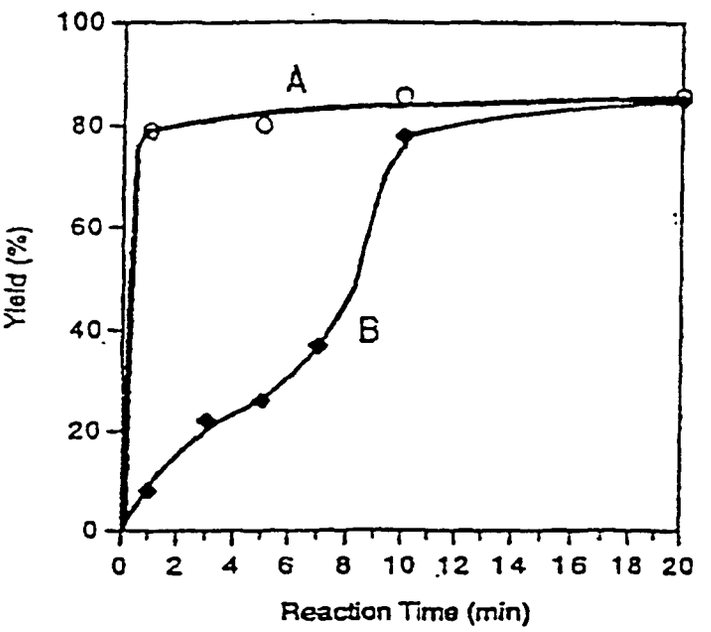
8. Acide de Lewis micro-encapsulé selon l'une quelconque des revendications 1 à 7, dans lequel l'acide de Lewis est un trifluorométhanesulfonate d'un métal de terre rare.

9. Catalyseur de type acide de Lewis micro-encapsulé formé de l'un quelconque des acides de Lewis micro-encapsulés selon les revendications 1 à 8.

10. Procédé de préparation d'un acide de Lewis micro-encapsulé **caractérisé en ce qu'**un acide de Lewis est supporté par l'intermédiaire de liaisons de coordination sur des microcapsules en formant les microcapsules à partir d'un polymère organique selon un procédé de micro-encapsulation.

11. Procédé selon la revendication 10, dans lequel le procédé de micro-encapsulation est un procédé de séparation de phase.

Fig. 1


100
80
60
40
20
0
Yield (%)
A
B
0 2 4 6 8 10 12 14 16 18 20
Reaction Time (min)

REFERENCES CITED IN THE DESCRIPTION

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