[0009] U.S. Patent No. 4,400,468 discloses a process for producing adipic acid from a renewable resource, specifically, biomass such as waste material selected from paper, wood, cornstalks and logging residue. The process involves oxidizing 1,6-hexanediol in the presence of a microorganism, such as *Gluconobacter oxydans* subsp. *oxydans*, to produce adipic acid. No examples are disclosed in this patent regarding any yields obtainable from this process.

[0010] In light of the changing environment toward utilization of cheaper, renewable feedstocks, the discovery of new, industrially scalable methods for the selective and economical production of adipic acid from 1,6-hexanediol could have extraordinary value in the near future.

SUMMARY

[0011] The present disclosure is directed to processes for preparing adipic acid from 1,6-hexanediol, which may be obtained from renewable materials. Generally, the process for preparing adipic acid from 1,6-hexanediol includes chemocatalytically converting 1,6-hexanediol to the adipic acid product in the presence of oxygen and a heterogeneous catalyst that may include platinum and/or gold.

[0011a] In onea ~~first~~ aspect of the present disclosure, there is provided a process for preparing an adipic acid product, the process comprising chemocatically converting 1,6-hexanediol to the adipic acid product by a method comprising reacting the 1,6-hexanediol with oxygen in the presence of a heterogeneous catalyst comprising ~~at least one metal selected from the group consisting of~~ gold ~~and platinum~~.

~~**[0011b]** In a second aspect of the present disclosure, there is provided a process for preparing an adipic acid product, the process comprising reacting 1,6-hexanediol with oxygen in the presence of a catalyst comprising platinum on a zirconia or stabilized zirconia support.~~

~~**[0011c]** In a third aspect of the present disclosure, there is provided a catalyst comprising at least one metal selected from the group consisting of gold and platinum, wherein the at least one metal is on a support, wherein at least the outer surfaces of the support are zirconia or stabilized zirconia, wherein the surface area of the support is equal to or less than about 100 m2/g and the average pore diameter is at least about 10 nm, and wherein the ziroconia or stabilized zirconia comprises tungsten in an amount ranging from about 1 wt% to about 15wt% of the total weight of the support.~~

CLAIMS

We claim:

1. A process for preparing an adipic acid product, the process comprising chemocatically converting 1,6-hexanediol to the adipic acid product by a method comprising reacting the 1,6-hexanediol with oxygen in the presence of a heterogeneous catalyst comprising ~~at least one metal selected from the group consisting of~~ gold ~~and platinum~~.

~~2. The process of claim 1, wherein the catalyst comprises gold.~~

~~3~~2. The process of claim 1, wherein the catalyst further comprises platinum.

~~4. The process of claim 1, wherein the catalyst comprises gold and platinum.~~

~~5~~3. The process of any one of claims 1-~~4~~2, wherein the weight percent of gold to the total weight of the finished catalyst is from about 0.1 wt% to about 10 wt%.

~~6. A process for preparing an adipic acid product, the process comprising reacting 1,6-hexanediol with oxygen in the presence of a catalyst comprising platinum on a zirconia or stabilized zirconia support.~~

~~7~~4. The process of any one of claims 1-~~5~~3, wherein the heterogeneous catalyst comprises a support, ~~wherein~~ the outer surfaces of the support comprise a material selected from the group consisting of zirconia, stabilized zirconia, zirconia-metal or zirconia–metal oxide composites, titania, stabilized titania, titania-metal or titania–metal oxide composites, alumina, silica and mixtures thereof.

~~8~~5. The process of claim ~~6~~4, wherein the surface area of the support is equal to or less than about 220m^2/g and the average pore diameter is at least about 5 nm.

~~9~~6. The process of any one of claims ~~6 or 8~~4-5, wherein the support further comprises tungsten.

~~10~~7. The process of any one of claims 1-~~5~~3, wherein the heterogeneous catalyst comprises a support selected from the group consisting of zirconia, stabilized zirconia, stabilized zirconia- metal or zirconia–metal oxide composite, titania, stabilized titania, stabilized titania-metal or titania–metal oxide composite, and mixtures thereof.

~~11~~8. The process of claim 7 ~~or 10~~, wherein the support is selected from the group consisting of stabilized zirconia, stabilized titania, and mixtures thereof, and the support contains tungsten.

~~12~~9. The process of claim ~~9~~ 6 or ~~11~~8, wherein the tungsten is present in an amount ranging from about 1 wt% to about 15% of the total weight of the support.

~~13~~10. The process of any one of claims ~~7~~4 and ~~10 to 12~~7-9, wherein the support has a surface area equal to or less than about 220m^2/g and an average pore diameter of at least about 5 nm.

~~14~~11. The process of any one of claims ~~7~~4 and ~~10 to 12~~7-9, wherein the support has a surface area equal to or less than about 100m^2/g and an average pore diameter of at least about 10 nm.

~~15~~12. The process of any one of claims 1 to ~~14~~11, wherein reacting the 1,6-hexanediol with oxygen in the presence of the heterogeneous catalyst comprises:

a) combining the 1,6-hexanediol and the heterogeneous catalyst, and optionally a solvent; and

b) contacting the combined 1,6-hexanediol and heterogeneous catalyst and optionally the solvent, with oxygen.

~~16~~13. The process of any one of claims 1 to ~~14~~11, wherein reacting the 1,6-hexanediol with oxygen in the presence of the heterogeneous catalyst and, optionally a solvent comprises:

a) combining the 1,6-hexanediol and the heterogeneous catalyst, and optionally a solvent, at a temperature equal to or less than about 120°C ; and

b) contacting with oxygen the combined 1,6-hexanediol and heterogeneous catalyst, and optionally the solvent.

~~17~~14. The process of any one of claims 1 to ~~14~~11, wherein reacting the 1,6-hexanediol with oxygen in the presence of the heterogeneous catalyst comprises:

a) combining the 1,6-hexanediol and a solvent;

b) contacting the combined 1,6-hexanediol and solvent with a heterogeneous catalyst; and

c) contacting the combined 1,6-hexanediol, solvent, and heterogeneous catalyst with oxygen.

~~18~~15. The process of any one of claims ~~15 to 17~~12-14, wherein the solvent is selected from the group consisting of water, alcohols, ethers, and mixtures thereof.

~~19~~16. The process of any one of claims 1-~~14~~11, wherein reacting the 1,6-hexanediol with oxygen in the presence of the heterogeneous catalyst comprises:

a) contacting the 1,6-hexanediol with water;

b) contacting the 1,6-hexanediol and water with the heterogeneous catalyst; and,

c) contacting the combined 1,6-hexanediol, water, and heterogeneous catalyst with oxygen.

~~20~~17. The process of any one of claims 1 to ~~19~~16, wherein the 1,6-hexanediol is derived from a carbohydrate source.

~~21~~18. The process of any one of claims 1 to ~~20~~17, wherein the reacting the 1,6-hexanediol with oxygen in the presence of a heterogeneous catalyst is carried out under a partial pressure of oxygen ranging from about 50 psig to about 2000 psig.

~~22~~19. The process of any one of claims 1 to ~~20~~17, wherein the reacting the 1,6-hexanediol with oxygen in the presence of a heterogeneous catalyst is carried out under a partial pressure of oxygen ranging from about 50 psig to about 1000 psig.

~~23~~20. The process of ~~any one of claims 1 to 2~~claim 1, wherein the reacting the 1,6-hexanediol with oxygen in the presence of a heterogeneous catalyst is carried out under a partial pressure of oxygen ranging from about 50 psig to about 700 psig.

~~24~~21. The process of any one of claims 1 to ~~23~~20, wherein the reacting the 1,6-hexanediol with oxygen in the presence of a heterogeneous catalyst is carried out at a temperature ranging from about 100°C to about 180°C.

~~25~~22. The process of any one of claims 1 to ~~23~~20, wherein the reacting the 1,6-hexanediol with oxygen in the presence of a heterogeneous catalyst is carried out at a temperature ranging from about 135°C to about 165°C.

~~26~~23. The process of any one of claims 1 to ~~25~~22, wherein the adipic acid product is produced in at least about 80% yield from the 1,6-hexanediol.

~~27~~24. The process of any one of claims 1 to ~~26~~23, wherein the adipic acid product is produced in at least about 90% yield from the 1,6-hexanediol.

~~28~~25. The process of any one of claims 1 to ~~27~~24, wherein the catalyst further comprises palladium.

~~29~~26. The process of any one of claims 1 to ~~28~~25, wherein gold is present in an amount up to about 4 wt% of the total catalyst weight.

~~30~~27. The process of any one of claims 1 to ~~29~~26, wherein platinum is present in an amount up to about 4 wt% of the total catalyst weight.

~~31~~28. The process of any one of claims 1 to ~~28~~25, wherein the catalyst comprises gold and platinum and the gold and platinum are present in an amount, in sum, up to about 4 wt% of the total catalyst weight.

~~32. A catalyst comprising at least one metal selected from the group consisting of gold and platinum, wherein the at least one metal is on a support, wherein at least the outer surfaces of the support are zirconia or stabilized zirconia, wherein the surface area of the support is equal to or less than about 100 m2/g and the average pore diameter is at least about 10 nm, and~~

~~wherein the ziroconia or stabilized zirconia comprises tungsten in an amount ranging from about 1 wt% to about 15wt% of the total weight of the support.~~

~~33. The catalyst of claim 32, wherein the outer surfaces consist essentially of stabilized zirconia.~~

~~34. The catalyst of claim 32 or 33, wherein the catalyst consists essentially of platinum on the support.~~

~~35. The catalyst of claim 32 or 33, wherein the catalyst consists essentially of platinum and gold on the support.~~

~~36. The catalyst of claim 32 or 33, wherein the catalyst further comprises palladium.~~

~~37. The catalyst of any one of claims 32 to 36, wherein the at least one metal is present, in sum, in an amount up to about 4 wt% of the total weight of the catalyst.~~