It is desirable to provide an improved method of producing ethylene oxide which resolves some of the issues associated with operating the epoxidation reaction at optimal efficiency.

BRIEF DESCRIPTION

The present ~~invention~~ disclosure allows the production of the same amount of alkylene oxide at both higher efficiency (resulting in raw material savings, and less greenhouse gas generation) and lower temperature (resulting in less by-product impurities and less Ag sintering) than earlier processes. Higher selectivity and lower operating temperatures can be achieved through the use of this ~~invention~~ disclosure without the need for a control system capable of automatically maintaining constant productivity or conversion. Operation at lower temperatures can enable longer catalyst lifetimes as well. The present ~~invention~~ disclosure allows the determination of a set of operating conditions that results in a higher efficiency, for a given productivity, than would be obtained by earlier processes.

In a first aspect, there is provided a method of producing ethylene an oxide comprising:

passing a reaction mixture comprising ethylene, oxygen and a gaseous chlorine-containing promoter species over a supported catalyst comprising silver and a promoting amount of rhenium to undergo an epoxidation reaction at a first operating condition to form ethylene oxide in a reactor;

and subsequently performing the epoxidation reaction within the reactor at a preferred operating condition prior to reaching a cumulative ethylene oxide production of about 50000 kmol m^{-3} of catalyst;

and operating the reactor at the preferred operating condition over a period yielding a production of at least 250 kmole ethylene oxide per cubic meter of the catalyst;

wherein the preferred operating condition is characterized by an efficiency of the epoxidation reaction toward ethylene oxide, wherein the efficiency is lower than that of a maximum efficiency achievable at an operating temperature corresponding to the preferred operating condition; wherein the preferred operating condition is further characterized by a productivity of the epoxidation reaction, wherein the productivity of the epoxidation reaction at the preferred operating condition is higher than that obtained at the maximum efficiency

achievable at the operating temperature corresponding to the preferred operating condition; and wherein the preferred operating condition is further characterized by an overall catalyst chloriding effectiveness value that is higher than when the epoxidation reaction is performed at the maximum efficiency achievable at the operating temperature corresponding to the preferred operating condition.

In one embodiment, a method of producing an alkylene oxide is provided. The method includes passing a reaction mixture comprising alkylene, oxygen and a gaseous chlorine-containing promoter species over a supported catalyst containing silver and a promoting amount of rhenium to undergo an epoxidation reaction at a first operating condition to form an alkylene oxide in a reactor. The method further includes subsequently performing the epoxidation reaction within the reactor at a preferred operating condition. The preferred operating condition is characterized by an efficiency of the epoxidation reaction toward the alkylene oxide where the efficiency is lower than that of a maximum efficiency achievable at an operating temperature corresponding to the preferred operating condition.

In another embodiment, a method of determining a preferred operating condition of an epoxidation reaction over a catalyst containing silver and a promoting amount of rhenium in the presence of a gaseous chlorine-containing promoter species is provided. The method includes determining a derivative of efficiency to productivity of the epoxidation reaction as a function of overall catalyst chloriding effectiveness value at a fixed operating temperature. The preferred operating condition is characterized by the derivative which is in a range of about -1 to about -4 when the efficiency of the epoxidation reaction to form alkylene oxide is expressed in percent and productivity of the epoxidation

reaction is expressed as the concentration of alkylene oxide in the reactor outlet stream, in mole percent.

In yet another embodiment, a method of determining a preferred operating condition of an epoxidation reaction in the presence of a supported catalyst containing silver and a promoting amount of rhenium in the presence of a gaseous chlorine-containing promoter species is provided. The method includes generating a first data set on efficiency and productivity of the epoxidation reaction at at least three overall catalyst chloriding effectiveness values at a first temperature. The method further includes determining a maximum efficiency value at the first temperature from the first data set. The method further includes selecting a range of efficiency values lower than the maximum efficiency value. The range of efficiency values corresponds to higher productivity of the epoxidation reaction than that achievable when the epoxidation reaction is operated at maximum efficiency and at the first temperature. The range of efficiency values corresponds to the preferred operating condition.

In a second aspect, there is provided a system to produce ethylene oxide as defined above, the system comprising the reactor and a controller, wherein the controller is operable to determine the preferred operating condition and wherein the reactor is operated at the preferred operating condition.

In a third aspect, there is provided a process for preparing a 1,2-diol, a 1,2-diol ether, a 1,2-carbonate or an alkanolamine comprising converting the ethylene oxide prepared by the methods as defined above or the system as defined above into the 1,2-diol, 1,2-diol ether, 1,2-carbonate or alkanolamine.

DRAWINGS

These and other features, aspects, and advantages of the present invention will become better understood when the following detailed description is read with reference to the accompanying drawings in which like characters represent like parts throughout the drawings, wherein:

FIG. 1 is a flowchart of a method of determining a preferred operating condition according to embodiments of the present invention;

FIG. 2 is a flowchart of another method of determining a preferred operating condition according to one embodiment of the present invention;

FIG. 3 is an illustration of a plot of efficiency against productivity of an epoxidation reaction obtained using the method shown in FIG.2, in accordance with embodiments of the present invention;

FIG. 4 is a flowchart of yet another method of determining a preferred operating condition according to embodiments of the present invention;

FIG. 5 is an illustration of a plot of efficiency against productivity of an epoxidation reaction obtained using the method shown in FIG.4, in accordance with embodiments of the present invention;

WHAT IS CLAIMED IS:

1. A method of producing ethylene ~~an alkylene~~ oxide comprising:

passing a reaction mixture comprising ethylene ~~alkylene~~, oxygen and a gaseous chlorine-containing promoter species over a supported catalyst comprising silver and a promoting amount of rhenium to undergo an epoxidation reaction at a first operating condition to form ethylene ~~an alkylene~~ oxide in a reactor;

and subsequently performing the epoxidation reaction within the reactor at a preferred operating condition prior to reaching a cumulative ethylene oxide production of about 50000 kmol m^{-3} of catalyst;

and operating the reactor at the preferred operating condition over a period yielding a production of at least 250 kmole ethylene oxide per cubic meter of the catalyst;

wherein the preferred operating condition is characterized by an efficiency of the epoxidation reaction toward ethylene ~~the alkylene~~ oxide, ~~and~~ wherein the efficiency is lower than that of a maximum efficiency achievable at an operating temperature corresponding to the preferred operating condition; wherein the preferred operating condition is further characterized by a productivity of the epoxidation reaction, wherein the productivity of the epoxidation reaction at the preferred operating condition is higher than that obtained at the maximum efficiency achievable at the operating temperature corresponding to the preferred operating condition; and wherein the preferred operating condition is further characterized by an overall catalyst chloriding effectiveness value that is higher than when the epoxidation reaction is performed at the maximum efficiency achievable at the operating temperature corresponding to the preferred operating condition.

~~2. The method of claim 1, wherein the preferred operating condition is characterized by a productivity of the epoxidation reaction, wherein the productivity of the epoxidation reaction at the preferred operating condition is higher than that obtained at the maximum efficiency achievable at the operating temperature.~~

~~3. The method of any one of claims 1 or 2, wherein the preferred operating condition is further characterized by an overall catalyst chloriding effectiveness value that is~~

~~higher than when the epoxidation reaction is performed at maximum efficiency and at the operating temperature corresponding to the preferred operating condition.~~

2. ~~4.~~ The method of ~~any one of~~ claims ~~1, 2, or 3,~~ wherein subsequently performing the epoxidation reaction at the preferred operating condition comprises varying at least one of a temperature of the first operating condition, or an overall catalyst chloriding effectiveness value of the first operating condition.

3. ~~5.~~ The method of any one of claims 1 or 2 ~~through 4~~ further comprising determining the preferred operating condition.

~~6. The method of any one of claims 1 through 5, wherein the alkylene oxide is selected from a group consisting of ethylene oxide and propylene oxide.~~

4. ~~7.~~ The method of any one of claims 1 through ~~6~~ 3, wherein the gaseous chlorine-containing promoter species is selected from a group consisting of C1-C8 chlorohydrocarbons and any mixtures thereof.

5. ~~8.~~ The method of any one of claims 1 through ~~7~~ 4, wherein the catalyst comprises rhenium in a range of about 180 ppmw to about 2000 ppmw.

6. ~~9.~~ The method of any one of claims 1 through ~~8~~ 5, wherein the catalyst further comprises at least one co-promoter, wherein the co-promoter comprises halides and/or oxyanions of elements other than oxygen having an atomic number of 5 to 83 comprising nitrogen, sulfur, manganese, tantalum, molybdenum, and tungsten. ~~and being from the groups 3b to 7b, and 3a to 7a, of the Periodic Table.~~

7. ~~10.~~ The method of any one of claims 1 through ~~9~~ 6, wherein the catalyst further comprises at least one co-promoter selected from a group consisting of Group IA metals, Group IIA metals, phosphorus, boron, manganese, sulfur, molybdenum, tungsten, chromium, titanium, hafnium, zirconium, vanadium, thallium, thorium, tantalum, niobium, gallium, germanium and any mixtures thereof.

8. ~~11.~~ The method of any one of claims 1 through ~~10~~ 7, wherein the reactor is operated at the preferred operating condition over a period yielding a production of at least 500 kmole ethylene oxide per m^3 of the catalyst. ~~for a cumulative alkylene oxide production of at least 250 kmole per m^3 of the catalyst~~.

9. ~~12.~~ A system to produce ethylene ~~alkylene~~ oxide according to any of the preceding claims, the system comprising the reactor and a controller, wherein the controller is operable to determine the preferred operating condition and wherein the reactor is operated at the preferred operating condition.

~~13. A method of determining a preferred operating condition of an epoxidation reaction in presence of a supported catalyst comprising silver and a promoting amount of rhenium, and in presence of a gaseous chlorine-containing promoter species; comprising: determining a derivative of efficiency to productivity of the epoxidation reaction as a function of the overall catalyst chloriding effectiveness value at a fixed operating temperature, wherein the preferred operating condition is characterized by a derivative which is in a range of about -1 to about -4 when the efficiency of the epoxidation~~

reaction to form alkylene oxide is expressed in percent and productivity of the epoxidation reaction is expressed as the concentration of alkylene oxide in the reactor outlet stream in mole percent.

14. A method of determining a preferred operating condition of an epoxidation reaction in presence of a catalyst comprising silver and a promoting amount of rhenium, and in presence of a gaseous chlorine-containing promoter species; comprising:

a) generating a first data set on efficiency and productivity of the epoxidation reaction at at least three overall catalyst chloriding effectiveness values at a first temperature;

b) determining a maximum efficiency value at the first temperature from the first data set; and

c) selecting a range of efficiency values lower than the maximum efficiency value, wherein the range of efficiency values correspond to higher productivity of the epoxidation reaction than that corresponding to the maximum efficiency value, and wherein the range of efficiency values correspond to the preferred operating condition.

15. The method of claim 14, wherein determining the maximum efficiency value comprises generating a first plot, or using a program, or using a mathematical equation or any combinations thereof.

16. The method of claim 15 further comprising generating the first plot by generating a first curve with a first maximum by plotting efficiency against productivity and wherein the first maximum corresponds to the maximum efficiency value; and

selecting a first region on the first curve corresponding to the preferred operating condition, wherein the first region lies to the right of the first maximum of the first curve when abscissa of the plot is productivity of the epoxidation reaction.

17. The method of any one of claims 14 through 16 further comprising:

a) generating a second data set on efficiency and productivity of the epoxidation reaction at at least three overall catalyst chloriding effectiveness values at a second temperature;

b) generating a second curve with a second maximum by plotting the second data set on the first plot, wherein the second maximum corresponds to maximum efficiency at the second temperature;

c) drawing a tangent line across the first curve and the second curve, wherein a slope of the tangent line is in a range of about -1 to about -4 when the efficiency of the epoxidation reaction is expressed in percent and productivity of the epoxidation reaction is expressed as the concentration of alkylene oxide in the reactor outlet stream in mole percent; and

d) selecting a second region corresponding to the preferred operating condition, wherein the second region lies on the tangent line.

18. The method of claim 14 further comprising:

a) generating a second data set on efficiency and productivity of the epoxidation reaction at at least three overall catalyst chloriding effectiveness values at a second temperature;

b) generating a contour plot of efficiency and productivity as functions of overall catalyst chloriding effectiveness value and temperature by plotting the first data set and the second data set to obtain at least one third curve and at least one fourth curve respectively, wherein the at least one third curve corresponds to efficiency of the epoxidation reaction and wherein the at least one fourth curve corresponds to productivity of the epoxidation reaction; and

c) selecting a third region corresponding to the preferred operating condition, wherein the third region falls on the at least one fourth curve and is

~~determined by the at least one third curve having the highest efficiency that meets the at least one fourth curve.~~

~~19. The method of claims 15, 16 and 17, wherein obtaining at least one of the first curve, the second curve, the at least one third curve and the at least one fourth curve comprises mathematically fitting at least one of the first curve, the second curve, the at least one third curve and the at least one fourth curve.~~

10. ~~20.~~ A process for preparing a 1,2-diol, a 1,2-diol ether, a 1,2-carbonate or an alkanolamine comprising converting the ethylene ~~an alkylene~~ oxide prepared by the methods of any one of ~~the foregoing~~ claims 1-8 or the system of claim 9 into the 1,2-diol, 1,2-diol ether, 1,2-carbonate or alkanolamine.