

Multistage Method for Producing Titanium Dioxide

5 Field of the invention

The invention relates to manufacturing titanium dioxide by oxidising titanium tetrachloride by a multi-stage method, where liquid titanium tetrachloride is used in the first stage.

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Technological background of the invention

In one of the commercially applied methods for manufacturing titanium dioxide pigment particles, the so-called chloride process, titanium tetrachloride (TiCl_4) is reacted with an oxidising gas, such as oxygen, air, etc., and with specific additives in a tubular reactor to obtain titanium dioxide and chlorine gas:

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The TiO_2 particles are subsequently separated from the chlorine gas. Known additives are AlCl_3 as a rutiliser, and steam or alkali salts as nucleating agents.

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This process is usually performed in a single stage, as described in US 3,615,202 or EP 0 427 878 B1, for example. This kind of reaction is, however, energetically unsatisfactory because, owing to the high activation energy of TiCl_4 oxidation, the educts have to be preheated to such a degree that an adiabatic mixed temperature of the educts of approx. 800 °C is reached before the onset of the reaction in order for the reaction to take place completely. However, the oxidation reaction is highly exothermal, meaning that, following complete, adiabatic conversion, the temperature of the product stream is roughly 900 °C higher than that of the educts. Before the TiO_2 particles are separated from the gaseous reaction products with the help of a filter, this mixture has to be substantially cooled in a cooling section in order to avoid damage to the filter.

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For the purpose of energetic optimisation, multi-stage versions of the chloride process have therefore been developed, in which only part of the educts is heated and added to a first stage. The rest of the educts is added to the second stage after just slight heating, or even without heating. There, the educts are heated by the reaction enthalpy released in the first stage, in turn reacting themselves. TiCl_4 alone or TiCl_4 and oxygen can be added to the

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second stage. In addition to a second stage, it is furthermore possible to provide further stages using slightly heated or cold educts.

For example, EP 0 583 063 B1 describes the two-stage introduction of TiCl_4 into the reactor.

- 5 TiCl_4 with a temperature of at least 450 °C and mixed with AlCl_3 is fed into the hot oxygen stream at a first inlet, and with a temperature of 350 °C to 400 °C and without AlCl_3 at a further inlet.

- 10 The method according to EP 0 852 568 B1 makes provision for not only the TiCl_4 to be added in two stages, but also the oxygen. The objective of this method is effective control of the mean TiO_2 particle size, and thus of the tone of the TiO_2 pigment base material. In this case, TiCl_4 vapour with a temperature of roughly 400 °C is initially introduced into an oxygen stream with a temperature of roughly 950 °C. Formation of the TiO_2 particles and particle growth take place in the downstream reaction zone. Less highly heated TiCl_4 vapour (approx.
15 180 °C) is added at a second inlet. Oxygen with a temperature between 25 °C and 1,040 °C is introduced at the second inlet, the temperature of the mixture being sufficient to initiate the reaction.

- 20 The multi-stage method according to US 6,387,347 B1 is additionally designed to reduce the formation of agglomerates. To this end, the previously heated TiCl_4 stream is divided into two split streams before addition to the reactor. One split stream (about 60 %) is oxidised in the first stage of the reactor, the second split stream (about 40 %) being cooled (de-superheated) by injecting liquid TiCl_4 and then added to the reactor. De-superheating takes place outside the reactor, where the temperature does not drop below the condensation
25 temperature of the overall stream.

- A similar method for manufacturing TiO_2 is described by US 2008/0075654 A1. This patent application comprises the technical teaching that the particle size of the TiO_2 product may be decreased by lowering the entrance temperature of the second TiCl_4 split stream. The effect is increased if the entrance temperature of the second TiCl_4 split stream is lower than the
30 entrance temperature of the first TiCl_4 split stream and the effect is decreased if the temperature ratio is the other way round (see examples 1 and 4).

US 2007/0172414 A1 discloses a multi-stage method for reacting TiCl_4 and O_2 , where gaseous TiCl_4 is fed into the reactor in the first stage, and liquid TiCl_4 in the second stage.

- 35 This method permits energy savings and improvement of the particle size range.

The common feature of all these processes is that the educts fed into the first stage are highly heated. The first stage is thus operated with highly heated oxygen and heated, vaporous TiCl_4 . One disadvantage of this form of the multi-stage reaction is, however, that the mean particle size increases with the proportion of educts in the second and subsequent stages. This effect can probably be explained as follows: two competing reaction pathways are possible when reacting TiCl_4 and oxygen. On the one hand, TiCl_4 and O_2 can react with each other directly in the gas phase (homogeneous gas-phase reaction), as a result of which TiO_2 molecules are formed that grow into particles by colliding and sintering with each other. On the other hand, TiCl_4 can attach itself to the surface of existing TiO_2 particles and react with oxygen there to form TiO_2 . This second reaction pathway does not lead to the formation of new particles, but to an increase in the size of existing particles (surface reaction).

The former mechanism is favoured in the single-stage oxidation reaction, because virtually no particles are present at the time of reaction of the TiCl_4 and the O_2 . In the two-stage and multi-stage reaction, however, unburned TiCl_4 is added to a stream of TiO_2 particles, meaning that the reaction mechanism shifts in favour of the surface reaction in comparison with the single-stage reaction. The result is an increase in the mean particle size. Though the velocity of the surface reaction may be decreased so that the mean particle size increases to a lesser degree by lowering the temperature of the reactants (TiCl_4 , O_2) in one split stream by de-superheating – as described in US 6,387,347 B1 and US 2008/0075654 A1. Yet, in the end the increase of the mean particle size must be counteracted by increased addition of KCl or another growth inhibitor. However, these inhibitors are highly corrosive, resulting in increased corrosion of the equipment and a greater maintenance effort.

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Object and brief description of the invention

The object of the present invention is to create a multi-stage method for manufacturing titanium dioxide by oxidising titanium tetrachloride, that is energetically favourable and overcomes the aforementioned disadvantages of the known methods.

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The object is solved by a multi-stage method for manufacturing titanium dioxide particles by reacting titanium tetrachloride with an oxygen-containing gas in a tubular reactor, characterised in that liquid TiCl_4 is fed into a preheated, oxygen-containing gas stream in a first stage, where the molar ratio of O_2 : TiCl_4 is greater than 1 and a gas suspension containing initial TiO_2 particles is formed, and gaseous TiCl_4 is fed into the gas suspension

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containing the initial TiO_2 particles in a second stage.

Further advantageous embodiments of the invention are described in the sub-claims.

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Description of the invention

The method according to the invention differs from the known multi-stage chloride processes for manufacturing titanium dioxide in that the TiCl_4 is introduced into the oxidation reactor in liquid form in a first stage and in gaseous form in a second stage. In the first stage, the liquid TiCl_4 is reacted with an excess of preheated oxygen, as a result of which the liquid TiCl_4 ignites even in cold form without preheating. Due to the excess of oxygen, only very fine TiO_2 particles are formed in the reaction zone of the first stage, then functioning as nuclei for particle growth in the subsequent stages.

15 The second stage of the oxidation process is operated like a conventional first stage, where heated, gaseous TiCl_4 is introduced into the hot, oxygen-containing gas stream in the reactor.

The molar ratio of $\text{O}_2 : \text{TiCl}_4$ in the first stage is more than 1, preferably at least 10 and particularly 20 to 200.

In the first stage at most 20 % of the total TiCl_4 quantity is dosed, preferably at most 10 % and in particular at most 2 %.

25 The method according to the invention can also encompass a third and, where appropriate, further process stages. It is furthermore possible to introduce TiCl_4 in liquid form in the third stage, or in one or more further stages. It is moreover possible, following the first stage, to additionally introduce oxygen-containing gas in at least one of the further stages. Beyond this, the oxygen-containing gas introduced in at least one of the further stages can be unheated gas with a temperature of roughly 25 °C. In this context, attention must be paid to ensuring that all the TiCl_4 added is reacted into TiO_2 .

Compared to conventional two-stage or multi-stage oxidation of TiCl_4 , the particles formed by the method according to the invention are finer. In the conventional multi-stage methods like e.g. US 2008/0075654 A1 the TiO_2 particle size is influenced by a thermal effect in that the surface growth of the TiO_2 particles is slowed down by a lower temperature. Yet the present

method is characterized in that in the first stage only nuclei are formed which act as seed crystals in the second oxidation stage. The smaller particle size is possibly also favoured by the fact that the injected TiCl_4 droplets are more homogeneously mixed into the oxygen-containing gas stream than a TiCl_4 gas, as a result of which a homogeneous gas-phase reaction can increasingly take place.

The method according to the invention offers the possibility, to a certain extent, of controlling the mean particle size of the end product by setting the quantity of liquid TiCl_4 in the first stage. Compared to conventional methods, precise setting of a particular particle size then requires no KCl or other growth inhibitor, or at least a smaller quantity. This also reduces the maintenance effort for the reactor facility.

Examples

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The following examples are intended for further explanation of the invention and are not intended to restrict the invention in any way.

Example 1:

To manufacture 10 t/h TiO_2 pigment, 3,500 Nm^3/h oxygen are heated to 1,650 °C and fed into a tubular reactor. Approx. 250 kg/h liquid TiCl_4 are injected into the oxygen stream. The TiCl_4 reacts with a small proportion of the oxygen, forming very fine TiO_2 and chlorine gas. The mixture of oxygen, chlorine and TiO_2 is passed into a second section of the tubular reactor, into which 24 t/h gaseous TiCl_4 with a temperature of 450 °C are introduced. A quantity of 1.5% by weight AlCl_3 is admixed into this TiCl_4 stream. The TiCl_4 - AlCl_3 gas stream reacts with the hot oxygen, forming TiO_2 and chlorine gas, where the TiO_2 from the first stage serves as a nucleating agent. A TiO_2 sufficiently fine for use as a white pigment is obtained in this way, even without adding a further growth inhibitor.

Example 2:

To manufacture 10 t/h TiO_2 pigment, 2,800 Nm^3/h oxygen are heated to 1,650 °C and fed into a tubular reactor. Approx. 200 kg/h liquid TiCl_4 are injected into the oxygen stream. The TiCl_4 reacts with a small proportion of the oxygen, forming very fine TiO_2 and chlorine gas. The mixture of oxygen, chlorine and TiO_2 is passed into a second section of the tubular reactor, into which 12 t/h gaseous TiCl_4 with a temperature of 450 °C are introduced. A quantity of 1.5% by weight AlCl_3 is admixed into this TiCl_4 stream. The TiCl_4 - AlCl_3 gas stream

reacts with the hot oxygen, forming TiO_2 and chlorine gas, where the TiO_2 from the first stage serves as a nucleating agent.

The mixture of gas and TiO_2 is passed into a third section of the tubular reactor, where 700 Nm^3/h unheated oxygen with a temperature of roughly 25°C and 12 t/h liquid TiCl_4 are injected consecutively. These two streams are heated by the gas-solid stream from the second stage and react to form TiO_2 and chlorine gas. A TiO_2 sufficiently fine for use as a white pigment is obtained in this way, even without adding a further growth inhibitor.

Compared to Example 1, the embodiment in this example is particularly advantageous in that it saves energy because only part of the oxygen and TiCl_4 requires preheating. The oxygen and TiCl_4 streams added in the third section of the reactor are heated with the help of the heat of reaction released in stages 1 and 2.

CLAIMS

1. A method for manufacturing titanium dioxide particles by reacting titanium tetrachloride with an O₂ containing gas in a tubular reactor using a multi-stage method comprising:

feeding liquid TiCl₄ into a preheated, oxygen-containing gas stream in a first stage of a reactor to form a gas suspension containing initial TiO₂ particles; wherein the molar ratio of O₂ : TiCl₄ in the first stage is greater than about 1; and feeding gaseous TiCl₄ into the gas suspension in a second stage of the reactor.

2. The method of Claim 1, wherein the molar ratio of O₂ : TiCl₄ in the first stage is at least 10.

3. The method of Claim 1, wherein the molar ratio of O₂ : TiCl₄ in the first stage is from about 20 to about 200.

4. The method of Claim 1, wherein the reactor has one or more further stages after the second stage and gaseous or liquid TiCl₄ is introduced into at least one of the one or more further stages.

5. The method of Claim 1 further comprising introducing an oxygen-containing gas into at least one stage following the first stage.

6. The method of Claim 5 wherein the oxygen-containing gas introduced into at least one stage following the first stage is unheated.

7. The method of Claim 1, wherein the liquid TiCl₄ fed into the first stage is at most about 20% of total TiCl₄ fed into all the stages of the reactor.

8. The method of Claim 7, wherein the molar ratio of O_2 : $TiCl_4$ in the first stage is from about 20 to about 200.
9. The method of Claim 7, wherein the reactor has one or more further stages after the second stage and gaseous or liquid $TiCl_4$ is introduced into at least one of the one or more further stages.
10. The method of Claim 7 further comprising introducing an unheated oxygen-containing gas into at least one stage following the first stage.
11. The method of Claim 1, wherein the liquid $TiCl_4$ fed into the first stage is at most about 10% of total $TiCl_4$ fed into all the stages of the reactor.
12. The method of Claim 11, wherein the molar ratio of O_2 : $TiCl_4$ in the first stage is from about 20 to about 200.
13. The method of Claim 11, wherein the reactor has one or more further stages after the second stage and gaseous or liquid $TiCl_4$ is introduced into at least one of the one or more further stages.
14. The method of Claim 11 further comprising introducing an unheated oxygen-containing gas into at least one stage following the first stage.
15. The method of Claim 1, wherein the liquid $TiCl_4$ fed into the first stage is at most about 2% of total $TiCl_4$ fed into all the stages of the reactor.
16. The method of Claim 15, wherein the molar ratio of O_2 : $TiCl_4$ in the first stage is from about 20 to about 200.
17. The method of Claim 15, wherein the reactor has one or more further stages after the second stage and gaseous or liquid $TiCl_4$ is introduced into at least one of the one or more further stages.

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18. The method of Claim 15 further comprising introducing an unheated oxygen-containing gas into at least one stage following the first stage.