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- (71) **Applicant:** BASELL POLYOLEFINE GMBH [DE/DE];
Brühler Straße 60, 50389 Wesseling (DE).
- (72) **Inventors:** PENZO, Giuseppe; P. le Donegani 12, I-44122 Ferrara (IT). MEI, Gabriele; P.le Donegani, I-44122 Ferrara (IT). MEIER, Gerhardus; Eichendorffstrasse 3, 60320 Frankfurt (DE). SCHUELLER, Ulf; Gräbstraße 80, 60486 Frankfurt/M (DE). CIARROCCHI, Antonio; P. le Donegani 12, I-44122 Ferrara (IT).
- (74) **Agent:** SEELERT, Stefan; Industriepark Hoechst, C657, 65926 Frankfurt (DE).

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(54) **Title:** MULTISTAGE PROCESS FOR THE POLYMERIZATION OF OLEFINS

(57) **Abstract:** A process for polymerizing olefins at temperatures of from 30°C to 140°C and pressures of from 1.0 MPa to 10 MPa in the presence of a polymerization catalyst in a multistage polymerization of olefins in at least two serially connected gas-phase polymerization reactors, the process for transferring polyolefin particles from a first gas-phase polymerization reactor to a second gas-phase polymerization reactor comprising the steps of a) discharging polyolefin particles from the first gas-phase polymerization reactor into a separation chamber in which the polyolefin particles are separated from concomitantly discharged reaction gas, the separation chamber being at a lower pressure than the pressure in the first gas-phase polymerization reactor; b) transferring the polyolefin particles within the separation chamber into a lower part of the separation chamber which contains a bed of polyolefin particles which moves from top to bottom of this part of the separation chamber and into which a fluid is introduced in an amount that an upward stream of the fluid in the bed of polyolefin particles above the fluid introduction point is induced, c) withdrawing polyolefin particles from the lower end of said lower part and transferring them to one of at least two lock hoppers working intermittently in parallel; and d) simultaneously pressurizing another of the at least two lock hoppers working intermittently by means of a gas comprising reaction gas coming from the second gas-phase polymerization reactor, and apparatus for the multistage polymerization of olefins, comprising at least two serially connected gas-phase polymerization reactors and a device for transferring polyolefin particles from an up-stream gas-phase polymerization reactor to a downstream gas-phase polymerization reactor, the transferring device comprising - a gas/solid separation chamber placed downstream of the upstream gas-phase polymerization which gas/solid separation chamber is equipped at a lower part with an inlet for introducing a fluid, and - connected to the gas/solid separation chamber at least two lock hoppers, placed in a parallel arrangement, each connected to the downstream gas-phase polymerization reactor.

Multistage process for the polymerization of olefinsField of the invention

5 The present invention relates to a process for polymerizing olefins at temperatures of from 30 °C to 140 °C and pressures of from 1.0 MPa to 10 MPa in the presence of a polymerization catalyst in a multistage polymerization of olefins in at least two serially connected gas-phase polymerization reactors. The invention relates also to an apparatus suitable for carrying out such a process for polymerizing olefins.

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Background of the invention

The polymerization of olefins in two or more serially connected gas-phase reactors allows to produce olefin polymers with improved properties and/or to simplify the existing production processes. This is made possible by choosing polymerization conditions in the second reactor or subsequent reactors different from the reaction conditions existing in the first polymerization reactor. Typically, olefin polymers grow on particles including a catalyst component, which continues to exert a catalytic activity even when the polymer particles are transferred to a successive gas-phase reactor. The polymer resulting from the first gas-phase reactor is transferred to the second gas-phase reactor, where polymerization is continued under different conditions. Therefore, different fractions of polymer can grow on the same particle by maintaining a different composition of the gas-phase mixture in each reactor.

Examples of polymers that may be produced by a multistage gas-phase process include bimodal or multimodal polymers obtained by maintaining a different concentration of a chain terminator, such as hydrogen, in each reactor; and random or heterophasic copolymers obtained by polymerizing different (co)monomers in each reactor. The term "heterophasic copolymer" includes also in-reactor polymer blends.

30 The transfer of the polymer from one gas-phase reactor to another one is a critical step of a multistage polymerization process. A direct discharge of polymer from an upstream reactor to a downstream reactor does not allow maintaining really different polymerization conditions in the downstream reactor, due to the substantial amount of gases and dissolved hydrocarbons associated to the polymer transferred to the downstream reactor.

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A solution that has been proposed is degassing the solid polymer discharged from the upstream reactor, then subjecting the polymer to a compression stage and transferring it to the downstream polymerization reactor. A process according to that solution is disclosed in EP 192 427 A1, which describes a process in which the compression stage is performed by means of the reaction gas mixture of the downstream reactor at a temperature lower by at least 20 °C than the temperature

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of the downstream reactor. EP 050 013 A2 refers to a process for polymerizing an olefin in the gaseous phase in a multiplicity of steps in at least two independent polymerization zones connected to each other by a transfer passage by which a gaseous stream containing the polymer obtained in a first polymerization zone is transferred into a second polymerization zone. The process is characterized in that an inert gas zone is provided in the transfer passage and at least a part of the gas components of the gaseous stream containing the polymer is replaced by an inert gas. A disadvantage of these processes is that the individual steps of the transfer processes are carried out subsequently; that means the operations are performed periodically and therefore not providing a continuous transfer of polymer from the upstream reactor to the downstream polymerization reactor.

EP 1 040 868 A2 discloses a method of multistage gas phase polymerization in which a polymerization of a feed gas mixture at least containing ethylene, an alpha-olefin and hydrogen is carried out in an upstream arranged fluidized-bed reactor. The polymer powder taken up from the upstream arranged fluidized-bed reactor is treated with a gas to lower the content of alpha-olefin gas and hydrogen gas in the polymers powder and then introduced into a downstream arranged reactor. WO 2008/058839 A2 discloses a process for the multistage polymerization of olefins which allows continuously discharging the polymer and the gas reaction mixture from the upstream reactor into a transfer device and continuously feeding polymer from the transfer device to a downstream reactor by using a transfer device comprising a separation chamber, in which the gas reaction mixture is removed from the polymer, and at least a couple of lock hoppers, which work intermittently in parallel. Although both processes reduce the amount of gas components of the reaction gas of the upstream reactor, which are dragged along with the polyolefin particle into the downstream reactor, minor amounts of gas components of the reaction gas of the upstream reactor are still carried over into the downstream reactor.

Thus, it was the object of the present invention to overcome the disadvantages of the prior art and to find a reliable process for continuously transferring polyolefin particles from a first gas-phase polymerization reactor to a second gas-phase polymerization reactor which allows that no or nearly no reaction gas of the first gas-phase polymerization reactor is introduced into the second gas-phase polymerization reactor.

Summary of the invention

We found that this object is achieved by a process for polymerizing olefins at temperatures of from 30°C to 140°C and pressures of from 1.0 MPa to 10 MPa in the presence of a polymerization catalyst in a multistage polymerization of olefins in at least two serially connected gas-phase polymerization reactors, the process for transferring polyolefin particles from a first gas-phase polymerization reactor to a second gas-phase polymerization reactor comprising the steps of

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- a) discharging polyolefin particles from the first gas-phase polymerization reactor into a separation chamber in which the polyolefin particles are separated from concomitantly discharged reaction gas, the separation chamber being at a lower pressure than the pressure in the first gas-phase polymerization reactor;
- b) transferring the polyolefin particles within the separation chamber into a lower part of the separation chamber which contains a bed of polyolefin particles which moves from top to bottom of this part of the separation chamber and into which a fluid is introduced in an amount that an upward stream of the fluid in the bed of polyolefin particles above the fluid introduction point is induced,
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- c) withdrawing polyolefin particles from the lower end of said lower part and transferring them to one of at least two lock hoppers working intermittently in parallel; and
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- d) simultaneously pressurizing another of the at least two lock hoppers working intermittently by means of a gas comprising reaction gas coming from the second gas-phase polymerization reactor.

Furthermore, we have found an apparatus for the multistage polymerization of olefins, comprising

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at least two serially connected gas-phase polymerization reactors and a device for transferring polyolefin particles from an upstream gas-phase polymerization reactor to a downstream gas-phase polymerization reactor, the transferring device comprising

- a gas/solid separation chamber placed downstream of the upstream gas-phase polymerization which gas/solid separation chamber is equipped at a lower part with an inlet for introducing a fluid, and
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- connected to the gas/solid separation chamber at least two lock hoppers, placed in a parallel arrangement, each connected to the downstream gas-phase polymerization reactor.

Brief description of the drawings

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The features and advantages of the present invention can be better understood via the following description and the accompanying drawing which shows schematically a preferred set-up for a multistage gas-phase polymerization of olefins according to the present invention.

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- Suitable olefins for polymerization process of the present invention are especially 1-olefins, i.e. hydrocarbons having terminal double bonds, without being restricted thereto. Suitable olefin monomers can however also be functionalized olefinically unsaturated compounds such as ester or amide derivatives of acrylic or methacrylic acid, for example acrylates, methacrylates, or acrylonitrile. Preference is given to nonpolar olefinic compounds, including aryl-substituted 1-olefins.
- 40
- Particularly preferred 1-olefins are linear or branched C_2 - C_{12} -1-alkenes, in particular linear C_2 - C_{10} -

- 1-alkenes such as ethylene, propylene, 1-butene, 1-pentene, 1-hexene, 1-heptene, 1-octene, 1-decene or branched C₂-C₁₀-1-alkenes such as 4-methyl-1-pentene, conjugated and nonconjugated dienes such as 1,3-butadiene, 1,4-hexadiene or 1,7-octadiene or vinylaromatic compounds such as styrene or substituted styrene. It is also possible to polymerize mixtures of various
- 5 1-olefins. Suitable olefins also include ones in which the double bond is part of a cyclic structure which can have one or more ring systems. Examples are cyclopentene, norbornene, tetracyclododecene or methylnorbornene or dienes such as 5-ethylidene-2-norbornene, norbornadiene or ethylnorbornadiene. It is also possible to polymerize mixtures of two or more olefins.
- 10 The process is in particular suitable in the homopolymerization or copolymerization of ethylene or propylene and is especially preferred for the homopolymerization or copolymerization of ethylene. Preferred comonomers in propylene polymerization are up to 40 wt.-% of ethylene and/or 1-butene, preferably from 0.5 wt.-% to 35 wt.-% of ethylene and/or 1-butene. As comonomers in ethylene polymerization, preference is given to using up to 20 wt.-%, more preferably from
- 15 0.01 wt.-% to 15 wt.-% and especially from 0.05 wt.-% to 12 wt.-% of C₃-C₈-1-alkenes, in particular 1-butene, 1-pentene, 1-hexene and/or 1-octene. Particular preference is given to a process in which ethylene is copolymerized with from 0.1 wt.-% to 12 wt.-% of 1-hexene and/or 1-butene.

- The process for polymerizing olefins of the present invention is carried out by polymerizing in at
- 20 least two gas-phase polymerization reactors, i.e. in reactors in which the solid polymers are obtained from a gas-phase comprising the monomer or the monomers. The polymerization is carried out at pressures of from 1.0 to 10 MPa, preferably from 1.5 to 5 MPa. The polymerization temperature is from 30 to 150°C and preferably from 65 to 125°C.

- 25 The polymerization of olefins of the present invention can be carried out using all customary olefin polymerization catalysts. That means the polymerization can be carried out using Phillips catalysts based on chromium oxide, using titanium-based Ziegler- or Ziegler-Natta-catalysts, or using single-site catalysts. For the purposes of the present invention, single-site catalysts are catalysts based on chemically uniform transition metal coordination compounds. Particularly suitable single-
- 30 site catalysts are those comprising bulky sigma- or pi-bonded organic ligands, e.g. catalysts based on mono-Cp complexes, catalysts based on bis-Cp complexes, which are commonly designated as metallocene catalysts, or catalysts based on late transition metal complexes, in particular iron-bisimine complexes. Furthermore, it is also possible to use mixtures of two or more of these catalysts for the polymerization of olefins. Such mixed catalysts are often designated as
- 35 hybrid catalysts. The preparation and use of these catalysts for olefin polymerization are generally known.

- Preferred catalysts are of the Ziegler type preferably comprising a compound of titanium or vanadium, a compound of magnesium and optionally an electron donor compound and/or a particulate
- 40 inorganic oxide as support.

As titanium compounds, use is generally made of the halides or alkoxides of trivalent or tetravalent titanium, with titanium alkoxy halogen compounds or mixtures of various titanium compounds also being possible. Examples of suitable titanium compounds are TiBr_3 , TiBr_4 , TiCl_3 , TiCl_4 , $\text{Ti}(\text{OCH}_3)\text{Cl}_3$, $\text{Ti}(\text{OC}_2\text{H}_5)\text{Cl}_3$, $\text{Ti}(\text{O-i-C}_3\text{H}_7)\text{Cl}_3$, $\text{Ti}(\text{O-n-C}_4\text{H}_9)\text{Cl}_3$, $\text{Ti}(\text{OC}_2\text{H}_5)\text{Br}_3$, $\text{Ti}(\text{O-n-C}_4\text{H}_9)\text{Br}_3$,
5 $\text{Ti}(\text{OCH}_3)_2\text{Cl}_2$, $\text{Ti}(\text{OC}_2\text{H}_5)_2\text{Cl}_2$, $\text{Ti}(\text{O-n-C}_4\text{H}_9)_2\text{Cl}_2$, $\text{Ti}(\text{OC}_2\text{H}_5)_2\text{Br}_2$, $\text{Ti}(\text{OCH}_3)_3\text{Cl}$, $\text{Ti}(\text{OC}_2\text{H}_5)_3\text{Cl}$, $\text{Ti}(\text{O-n-C}_4\text{H}_9)_3\text{Cl}$, $\text{Ti}(\text{OC}_2\text{H}_5)_3\text{Br}$, $\text{Ti}(\text{OCH}_3)_4$, $\text{Ti}(\text{OC}_2\text{H}_5)_4$ or $\text{Ti}(\text{O-n-C}_4\text{H}_9)_4$. Preference is given to using titanium compounds which comprise chlorine as the halogen. Preference is likewise given to titanium halides which comprise only halogen in addition to titanium and among these especially titanium chlorides and in particular titanium tetrachloride. Among the vanadium compounds,
10 particular mention may be made of the vanadium halides, the vanadium oxyhalides, the vanadium alkoxides and the vanadium acetylacetonates. Preference is given to vanadium compounds in the oxidation states 3 to 5.

In the production of the solid component, at least one compound of magnesium is preferably additionally used. Suitable compounds of this type are halogen-comprising magnesium compounds such as magnesium halides and in particular the chlorides or bromides and magnesium compounds from which the magnesium halides can be obtained in a customary way, e.g. by reaction with halogenating agents. For the present purposes, halogens are chlorine, bromine, iodine or fluorine or mixtures of two or more halogens, with preference being given to chlorine or bromine
20 and in particular chlorine.

Possible halogen-comprising magnesium compounds are in particular magnesium chlorides or magnesium bromides. Magnesium compounds from which the halides can be obtained are, for example, magnesium alkyls, magnesium aryls, magnesium alkoxy compounds or magnesium
25 aryloxy compounds or Grignard compounds. Suitable halogenating agents are, for example, halogens, hydrogen halides, SiCl_4 or CCl_4 and preferably chlorine or hydrogen chloride.

Examples of suitable, halogen-free compounds of magnesium are diethylmagnesium, di-n-propylmagnesium, diisopropylmagnesium, di-n-butylmagnesium, di-sec-butylmagnesium, di-tert-butylmagnesium, diamylmagnesium, n-butylethylmagnesium, n-butyl-sec-butylmagnesium, n-butyloctylmagnesium, diphenylmagnesium, diethoxymagnesium, di-n-propyloxymagnesium, diisopropyloxymagnesium, di-n-butyloxymagnesium, di-sec-butyloxymagnesium, di-tert-butylloxymagnesium, diamyloxymagnesium, n-butyloxyethoxymagnesium, n-butyloxy-sec-butyloxymagnesium, n-butyloxyoctyloxymagnesium and diphenoxymagnesium. Among these,
35 preference is given to using n-butylethylmagnesium or n-butyloctylmagnesium.

Examples of Grignard compounds are methylmagnesium chloride, ethylmagnesium chloride, ethylmagnesium bromide, ethylmagnesium iodide, n-propylmagnesium chloride, n-propylmagnesium bromide, n-butylmagnesium chloride, n-butylmagnesium bromide, sec-butylmagnesium chloride, sec-butylmagnesium bromide, tert-butylmagnesium chloride, tert-
40 butylmagnesium chloride, sec-butylmagnesium bromide, tert-butylmagnesium chloride, tert-

butylmagnesium bromide, hexylmagnesium chloride, octylmagnesium chloride, amylmagnesium chloride, isoamylmagnesium chloride, phenylmagnesium chloride and phenylmagnesium bromide.

As magnesium compounds for producing the particulate solids, preference is given to using, apart
5 from magnesium dichloride or magnesium dibromide, the di(C₁-C₁₀-alkyl)magnesium compounds. Preferably, the Ziegler-Natta catalyst comprises a transition metal selected from titanium, zirconium, vanadium, chromium.

Suitable electron donor compounds for preparing Ziegler type catalysts are for example alcohols,
10 glycols, esters, ketones, amines, amides, nitriles, alkoxy silanes and aliphatic ethers. These electron donor compounds can be used alone or in mixtures with other electron donor compounds.

Preferred alcohols are those of formula R¹OH in which the R¹ group is a C₁-C₂₀ hydrocarbon group. Preferably, R¹ is a C₁-C₁₀ alkyl group. Specific examples are methanol, ethanol, iso-
15 propanol and n-butanol. Preferred glycols are those having a total number of carbon atoms lower than 50. Among them particularly preferred are the 1,2 or 1,3 glycols having a total number of carbon atoms lower than 25. Specific examples are ethylenglycol, 1,2-propylenglycol and 1,3-propylenglycol. Preferred esters are the alkyl esters of C₁-C₂₀ aliphatic carboxylic acids and in particular C₁-C₈ alkyl esters of aliphatic mono carboxylic acids such as ethylacetate, methyl-
20 formate, ethylformate, methylacetate, propylacetate, i-propylacetate, n-butylacetate, i-butylacetate. Preferred amines are those of formula NR²₃ in which the R² groups are, independently, hydrogen or a C₁-C₂₀ hydrocarbon group with the proviso that they are not simultaneously hydrogen. Preferably, R² is a C₁-C₁₀ alkyl group. Specific examples are diethylamine, diisopropylamine and triethylamine. Preferred amides are those of formula R³CONR⁴₂ in which R³ and R⁴ are, inde-
25 pendently, hydrogen or a C₁-C₂₀ hydrocarbon group. Specific examples are formamide and acetamide. Preferred nitriles are those of formula R¹CN where R¹ has the same meaning given above. A specific example is acetonitrile. Preferred alkoxy silanes are those of formula R⁵_aR⁶_bSi(OR⁷)_c, where a and b are integer from 0 to 2, c is an integer from 1 to 4 and the sum (a+b+c) is 4; R⁵, R⁶, and R⁷, are alkyl, cycloalkyl or aryl radicals with 1-18 carbon atoms optionally containing heteroa-
30 toms. Particularly preferred are the silicon compounds in which a is 0 or 1, c is 2 or 3, R⁶ is an alkyl or cycloalkyl group, optionally containing heteroatoms, and R⁷ is methyl. Examples of such preferred silicon compounds are methyltrimethoxysilane, dimethyldimethoxysilane, trimethylmethoxysilane and t-butyltrimethoxysilane.

35 Preferred electron donor compounds are selected from the group consisting of amides, esters, and alkoxy silanes.

Catalysts of the Ziegler type are usually polymerized in the presence of a cocatalyst. Preferred cocatalysts are organometallic compounds of metals of groups 1, 2, 12, 13 or 14 of the Periodic
40 Table of Elements, in particular organometallic compounds of metals of group 13 and especially

organoaluminum compounds. Preferred cocatalysts are for example organometallic alkyls, organometallic alkoxides, or organometallic halides.

5 Preferred organometallic compounds comprise lithium alkyls, magnesium or zinc alkyls, magnesium alkyl halides, aluminum alkyls, silicon alkyls, silicon alkoxides and silicon alkyl halides. More preferably, the organometallic compounds comprise aluminum alkyls and magnesium alkyls. Still more preferably, the organometallic compounds comprise aluminum alkyls, preferably trialkylaluminum compounds. Preferably, the aluminum alkyls comprise, for example, trimethylaluminum, triethylaluminum, tri-isobutylaluminum, tri-n-hexylaluminum and the like.

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The process of the present invention is carried out in at least two serially connected gas-phase polymerization reactors. Suitable gas-phase polymerization reactors are, for example, horizontally or vertically stirred gas-phase reactors, multizone gas-phase reactors, or gas-phase fluidized-bed reactors. Reactors of these types are generally known to those skilled in the art.

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Preferred gas-phase polymerization reactors are fluidized-bed polymerization reactors in which the polymerization takes place in a bed of polymer particles which is maintained in a fluidized state by feeding in reaction gas at the lower end of a reactor, usually below a gas distribution grid having the function of dispensing the gas flow, and taking off the gas again at its upper end. The reaction gas is then returned to the lower end to the reactor via a recycle line equipped with a compressor and a heat exchanger. The circulated reaction gas is usually a mixture of the olefins to be polymerized, inert gases such as nitrogen and/or lower alkanes such as ethane, propane, butane, pentane or hexane and optionally a molecular weight regulator such as hydrogen. The use of nitrogen or propane as inert gas, if appropriate in combination with further lower alkanes, is preferred. The velocity of the reaction gas has to be sufficiently high firstly to fluidize the mixed bed of finely divided polymer present in the tube serving as polymerization zone and secondly to remove the heat of polymerization effectively. The polymerization can also be carried out in a condensing or super-condensing mode, in which part of the circulating reaction gas is cooled to below the dew point and returned to the reactor separately as a liquid and a gas-phase or together as a two-phase mixture in order to make additional use of the enthalpy of vaporization for cooling the reaction gas.

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Preferred gas-phase polymerization reactors are further multizone circulating reactors which are, for example, described in WO 97/04015 and WO 00/02929 and have two interconnected polymerization zones, a riser, in which the growing polymer particles flow upward under fast fluidization or transport conditions and a downcomer, in which the growing polymer particles flow in a densified form under the action of gravity. The polymer particles leaving the riser enter the downcomer and the polymer particles leaving the downcomer are reintroduced into the riser, thus establishing a circulation of polymer between the two polymerization zones and the polymer is passed alternately a plurality of times through these two zones. It is further also possible to operate the two

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polymerization zones of one multizone circulating reactor with different polymerization conditions by establishing different polymerization conditions in its riser and its downcomer. For this purpose, the gas mixture leaving the riser and entraining the polymer particles can be partially or totally prevented from entering the downcomer. This can for example be achieved by feeding a barrier

5 fluid in form of a gas and/or a liquid mixture into the downcomer, preferably in the upper part of the downcomer. The barrier fluid should have a suitable composition, different from that of the gas mixture present in the riser. The amount of added barrier fluid can be adjusted in a way that an upward flow of gas countercurrent to the flow of the polymer particles is generated, particularly at the top thereof, acting as a barrier to the gas mixture entrained among the particles coming from

10 the riser. In this manner it is possible to obtain two different gas composition zones in one multizone circulating reactor. Furthermore it is also possible to introduce make-up monomers, comonomers, molecular weight regulators such as hydrogen and/or inert fluids at any point of the downcomer, preferably below the barrier feeding point. Thus, it is also easily possible to create varying monomer, comonomer and hydrogen concentrations along the downcomer resulting in a further

15 differentiation of the polymerization conditions.

In especially preferred gas-phase polymerization reactors, the polymerization is carried out in the presence of a C₃-C₅ alkane as polymerization diluent and preferably in the presence of propane, especially in the case of homopolymerization or copolymerization of ethylene.

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The obtained polyolefin particles have a more or less regular morphology and size, depending on the catalyst morphology and size, and on polymerization conditions. Depending on the catalyst used, the polyolefin particles usually have a mean diameter of from a few hundred to a few thousand micrometers. In the case of chromium catalysts, the mean particle diameter is usually from

25 about 300 to about 1600 µm, and in the case of Ziegler type catalysts the mean particle diameter is usually from about 500 to about 3000 µm.

The process for polymerizing olefins according to the present invention is carried out in a multistage polymerization of olefins in at least two serially connected gas-phase polymerization reactors. Beside the minimum two gas-phase polymerization reactors, the multistage polymerization of olefins may comprise however also further, additional polymerization stages carried out in additional reactors. These additional polymerization reactors can be any kind of low-pressure polymerization reactors such as gas-phase reactors or suspension reactors. If the multistage polymerization of olefins includes polymerization in suspension, the suspension polymerization is preferably

30 carried out upstream of the gas-phase polymerization. Suitable reactors for carrying out such a suspension polymerization are for example loop reactors or stirred tank reactors. Suitable suspension media are inter alia inert hydrocarbons such as isobutane or mixtures of hydrocarbons or else the monomers themselves. Such additional polymerization stages, which are carried out in suspension, may also include a pre-polymerization stage. If the multistage polymerization of olefins comprises additional polymerization stages carried out in gas-phase, the additional gas-phase

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polymerization reactors can be any type of gas-phase reactors like horizontally or vertically stirred gas-phase reactors, fluidized-bed reactors or multizone circulating reactors. Such additional gas-phase polymerization reactors may be arranged at any point of the reactor cascade of the present invention.

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According to the process for polymerizing olefins of the present invention the process for transferring polyolefin particles from a first gas-phase polymerization reactor to a second gas-phase polymerization reactor comprises the steps of discharging polyolefin particles from the first gas-phase polymerization reactor into a separation chamber; transferring the polyolefin particles within
10 the separation chamber into a lower part of the separation chamber which contains a bed of polyolefin particles which moves from top to bottom of this part of the separation chamber and into which a fluid is introduced; withdrawing polyolefin particles from the lower end of this part of the separation chamber and transferring them to one of at least two lock hoppers working intermittently in parallel; and simultaneously pressurizing another of the at least two lock hoppers
15 working intermittently by means of a gas comprising reaction gas coming from the second gas-phase polymerization reactor.

The discharging of polyolefin particles from the first gas-phase polymerization reactor into the separation chamber, in which the polyolefin particles are separated from concomitantly discharged reaction gas, can be carried out by various discontinuous or continuous methods pneumatically or with the aid of mechanical discharge systems. What methods are especially suitable for the process of the present inventions depends inter alia on the nature of the first gas-phase polymerization reactor. For fluidized-bed reactors, the discharging can e.g. be accomplished by discontinuously withdrawing the polyolefin particles from the fluidized-bed reactor through one or
20 more discharge lines. Such a process for discharging polyolefin particles is for example described in WO 2012/175469 A1. The discharging of polyolefin particles is however preferably carried out continuously, e.g. by withdrawing the polyolefin particles from a part of a circulation loop of a fluidized-bed reactor in which a continuous pneumatic recycle of polymer from the fluidization grid to an upper region of the fluidized-bed reactor is operated. Such a continuous discharging process is
25 for example described in WO 2007/071527 A1. It is however also possible to operate a lateral discharge continuously.

The polyolefin particles are discharged into a gas/solid separation chamber, in which the reaction gas mixture, which is concomitantly discharged with the polyolefin particles from the first gas-phase polymerization reactor, is removed. According to the present invention, the separation chamber is operated at a lower pressure than the pressure in the first gas-phase polymerization reactor. The pressure difference between the first gas-phase polymerization reactor and the gas/solid separation chamber is preferably at least 0.2 MPa and more preferably at least 10 MPa. Preferably the pressure in the separation chamber is in a range of from 0.12 to 0.4 MPa, preferably
35 40 of from 0.15 to 0.3 MPa. The pressure in the separation chamber is controlled by withdrawing

gas from the separation chamber, preferably from the top. It is possible to discharge the gas withdrawn from the separation chamber as off-gas, however preferably the gas is pressurized and recycled to the first gas-phase polymerization reactor.

- 5 After being brought into the separation chamber, the polyolefin particles are transferred into a lower part of the separation chamber in which the polyolefin particles form a densified bed. This transfer usually occurs by gravity. At the lower end of this lower part of the separation chamber, polyolefin particles are withdrawn and transferred to one of the lock hoppers. Consequently, the polyolefin particles within this lower part of the separation chamber move downwards from top to bottom of this lower part driven by gravity. Preferably, the polyolefin particles move as plug flow from top to bottom of lower part of the separation chamber.

15 In a preferred embodiment of the present invention, the lower part of the separation chamber is designed as a conduit of a diameter smaller than the diameter of an upper part of the separation chamber. Preferably this conduit is arranged substantially vertically, where substantially vertically means that the angle between the longitudinal direction of the conduit and the vertical is not more than 40° and preferably not more than 10°. It is also preferred that the lower end of the conduit tapers conically to prevent a dead zone where polymer particles could get stuck.

- 20 At its lower end, the lower part of the separation chamber is provided with at least one discharge valve through which the polyolefins particles are withdrawn from the separation chamber. Suitable discharge valves are, for example, segmental ball or ball valves or rotary plug valves. Preferably the discharge valve is a segmental ball valve. By regulating this valve, the discharge flow is controlled which allows keeping the bed level inside the separation chamber constant. The polyolefin particles are preferably continuously withdrawn from the lower end of the lower part of the separation chamber.

A fluid is fed into the lower part of the separation chamber in an amount that an upward stream of the fluid is induced in the bed of polyolefin particles above the fluid introduction point. Preferably the fluid is introduced at a position near the lower end of the lower part of the separation chamber. It is also possible to feed the fluid at more than one position into the lower part of the separation chamber. Preferably the fluid is fed in a way that it is distributed over the whole cross-section of the lower part of the separation chamber in a region above the fluid introduction point. It is possible to achieve such a distribution with simple means for adding a fluid; it is however also possible to utilize a gas distributor. The fed fluid can be a gas or can be a liquid, which evaporates under the conditions in the settling pipe, or can be a mixture of a gas and such a liquid. Preferably the fluid fed into the settling pipe is a gas. Accordingly, the introduced fluid replaces the reaction gas of the first gas-phase polymerization reactor and acts as barrier, which prevents the reaction gas of the first gas-phase polymerization reactor from being transferred to the second polymerization reactor. The introduced fluid is preferably a component of the reaction gas mixtures of both the

first and the second gas-phase polymerization reactor. It is preferably an inert component such as an inert gas and especially preferred a saturated hydrocarbon such as propane. Preferably the amount of fed fluid is regulated in a way that an effective upward stream of the fluid in the bed of polyolefin particles above the fluid introduction point is induced and reliably sustained. It is however further preferred that a not too high amount of fluid is introduced since on the one hand an expansion of the bed in the settling pipe should be avoided and, on the other hand, the higher the amount of added inert is the higher is either the dilution of the reaction gas with the fluid or the need for purging a part of reaction gas.

- 10 The polyolefin particles withdrawn from the lower end of the lower part of the separation chamber are transferred to one of at least two lock hoppers working intermittently in parallel. For each of the lock hoppers, the following steps are conducted subsequently in a recurring way:
- loading with polyolefin particles coming from the lower part of the separation chamber while the lock hopper is isolated from the second gas-phase polymerization reactor; and
 - 15 - pressurizing by means of a gas comprising reaction gas coming from the second gas-phase polymerization reactor and discharging the polyolefin particles and transferring them to the second gas-phase polymerization reactor while the lock hopper is isolated from the separation chamber, preferably continuing with the pressurizing of the lock hopper by means of the gas comprising reaction gas coming from the second gas-phase polymerization reactor when
 - 20 the polyolefin particles are transferred to the second gas-phase polymerization reactor.

To prevent that reaction gas coming from the second gas-phase polymerization reactor is transferred to the first gas-phase polymerization reactor, the lock hoppers are preferably depressurized before they are filled again with polyolefin particles coming from the lower part of the separation chamber. For depressurizing the lock hoppers, it is possible to discharge the gas remaining in the lock hoppers after the polyolefin particles are transferred into the second gas-phase polymerization reactor as off-gas. It is however also possible to return this gas to the second gas-phase polymerization reactor by feeding it back to the second gas-phase polymerization reactor, e.g. to a gas recycle line at the suction side of the compressor.

30 Since the lock hoppers operate intermittently in parallel, the step of transferring polyolefin particles from the separation chamber to one of the lock hoppers and so loading the lock hopper and the step of pressurizing another lock hopper by means of a gas comprising reaction gas coming from the second gas-phase polymerization reactor occur simultaneously.

35 The process of the present invention requires at least two lock hoppers downstream of the separation chamber. The number of lock hoppers is theoretically discretionary, however usually the process is operated with from 2 to 4 lock hoppers, preferably with 2 or 3 lock hoppers and more preferably with a pair of two lock hoppers. When operating with two lock hoppers, one lock hopper

40 is involved with the step of loading while the other one is involved with the steps of pressurizing

and transferring to the second gas-phase polymerization reactor step or the situation is vice versa.

5 The lock hoppers preferably have a conical lower portion with walls inclined of an angle greater than the repose angle of the polyolefin particles. In a preferred embodiment of the present invention, each lock hopper is connected to the separation chamber by a separate discharge valve.

10 The working in parallel of at least two lock hoppers maximizes the discharge flow rate from the first gas-phase polymerization reactor to a second gas-phase polymerization reactor and results in a substantially continuous transfer of polyolefin particles. Furthermore, the combination of depressurizing and applying a countercurrent stream of a fluid, which acts as barrier, ensures that that no or nearly no reaction gas of the first gas-phase polymerization reactor is introduced into the second gas-phase polymerization reactor.

15 The present invention is further illustrated by Figure 1, which shows schematically the set-up of two serially connected fluidized-bed reactors for carrying out the process of the present invention, i.e. both the first and the second gas-phase polymerization reactor are fluidized-bed reactors.

20 The first gas-phase polymerization reactor, fluidized-bed reactor (1), comprises a fluidized bed (2) of polyolefin particles, a gas distribution grid (3) and a velocity reduction zone (4). The velocity reduction zone (4) is generally of increased diameter compared to the diameter of the fluidized-bed portion of the reactor. The polyolefin bed is kept in a fluidization state by an upwardly flow of gas fed through the gas distribution grid (3) placed at the bottom portion of the reactor (1). The gaseous stream of the reaction gas leaving the top of the velocity reduction zone (4) via recycle
25 line (5) is compressed by compressor (6), transferred to a heat exchanger (7), in which it is cooled, and then recycled to the bottom of the fluidized-bed reactor (1) at a point below the gas distribution grid (3) at position (8). The recycle gas can, if appropriate, be cooled to below the dew point of one or more of the recycle gas components in the heat exchanger so as to operate the reactor with condensed material, i.e. in the condensing mode. The recycle gas can comprise,
30 besides unreacted monomers, also inert condensable gases, such as alkanes, as well as inert non-condensable gases, such as nitrogen. Make-up monomers, molecular weight regulators, and optional inert gases or process additives can be fed into the reactor (1) at various positions, for example via line (9) upstream of the compressor (6); this non-limiting the scope of the invention. Generally, the catalyst is fed into the reactor (1) via a line (10) that is preferably placed in the lower
35 part of the fluidized bed (2).

The polyolefin particles obtained in fluidized-bed reactor (1) are continuously discharged via line (11) and fed to a solid/gas separator (12), which is operated at a pressure lower than the pressure within fluidized-bed reactor (1), preferably at a pressure of from 0.12 to 0.3 MPa. The pressure
40 within solid/gas separator (12) is controlled by withdrawing gas from the solid/gas separator (12)

via line (13), transferring it to compressor (14), and returning it after compression to fluidized-bed reactor (1) via line (15).

Within the solid/gas separator (12), the polyolefin particles fall by gravity into a lower part (16),
5 which is designed in the form of a conduit having a much smaller diameter than the upper part of the solid/gas separator (12) and which is preferably arranged substantially vertical. The conduit (16) may be made of a uniform diameter, or may comprise more sections having decreasing diameters in the downward direction. The conduit (16) contains a bed of polyolefin particles which moves from top to bottom of the conduit. The lower end of conduit (16) is connected to two discharge valves (17) and (17'), which serve to transfer the polyolefin particles via lines (18) and (18')
10 into two lock hoppers (19) and (19'). Discharge valves (17) and (17') are preferably segmental ball valves. Preferably, the level of polyolefin particles in solid/gas separator (12) is kept almost constant by controlling the rates of transferring polyolefin particles into solid/gas separator (12) and discharging polyolefin particles from the lower end of conduit (16).

15 A fluid is fed via line (20) into conduit (16), preferably at a position near the lower end of the conduit in an amount that an upward stream of the fluid is induced in the bed of polyolefin particles. The introduced fluid is preferably an inert component and especially preferred a saturated hydrocarbon such as propane. The propane is preferably taken from a gas recovery unit (not shown) in
20 which purified propane is obtained by distillation or separation from off-gas of the polymerization reactors.

The polyolefin particles are discharged from the lower end of conduit (16) via discharge valves (17) and (17') and lines (18) and (18') into lock hoppers (19) and (19'). This transfer occurs essentially by gravity.
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Lock hoppers (19) and (19') are further equipped with venting lines (21) and (21') comprising valves (22) and (22') for transferring gas from the lock hoppers (19) or (19') back to the solid/gas separator (12). Lock hoppers (19) and (19') are provided, respectively, with bottom discharge
30 valves (23) and (23') for transferring the polyolefin particles via transfer pipes (24) and (24') to the second fluidized-bed reactor (25). Discharge valves (23) and (23') are preferably segmental ball valves. Transfer pipes (24) and (24') are usually inclined with respect to the vertical. Preferably the angle between the transfer pipes and the vertical is not greater than 45°, more preferably it is in the range of from 15° to 30°. Lock hoppers (19) and (19') are moreover equipped with lines (26)
35 and (26') for pressurizing the lock hopper with reaction gas coming from the second fluidized-bed reactor (25) via line (27) through valves (28) and (28').

Filling of lock hopper (19) is performed by closing discharge valve (23) and opening valves (17) and (22). As a result, polyolefin particles move from solid/gas separator (12) into lock hopper (19).
40 Pressure compensation occurs via venting line (21) through valve (22). Once lock hopper (19) is

completely filled, valves (17) and (22) are closed while valves (23) and (28) are opened. Opening of valve (28) causes a pressurization of lock hopper (19) by a portion of the reaction gas coming from the second fluidized-bed reactor (25) through the line (27). The simultaneous opening of the discharge valve (23) allows transferring the polyolefin particles by combined effect of pressure and gravity through transfer pipes (24) into fluidized-bed reactor (25). When all polyolefin particles are discharged from lock hopper (19), valves (23) and (28) are closed. To prevent reaction gas coming from the second fluidized-bed reactor being transferred to the first fluidized-bed reactor, lock hopper (19) is depressurized and the reaction gas coming from the second fluidized-bed reactor is discharged as off-gas via line (21) and valve (29) before being filled again with polyolefin particles.

The same sequence of operations, but out of phase, is performed by the lock hopper (19'). While polyolefin particles are transferred from lock hopper (19) to fluidized-bed reactor (25), filling of lock hopper (19') is performed by closing discharge valve (23') and opening valves (17') and (22'). As a result, polyolefin particles move from solid/gas separator (12) into lock hopper (19'). Pressure compensation occurs via venting line (21') through valve (22'). When filling of lock hopper (19') is completed and lock hopper (19) is fully discharged, valves (17') and (22') are closed while valves (23') and (28') are opened. Opening of valve (28') causes a pressurization of lock hopper (19') by a portion of the reaction gas coming from the second fluidized-bed reactor (25) through the line (27). The simultaneous opening of the discharge valve (23') allows transferring the polyolefin particles by combined effect of pressure and gravity through transfer pipes (24') into fluidized-bed reactor (25). When all polyolefin particles are discharged from lock hopper (19') and lock hopper (19) is filled again, valves (23') and (28') are closed and lock hopper (19') is depressurized via line (21') and valve (29').

The second gas-phase polymerization reactor, fluidized-bed reactor (25) is operated like the fluidized-bed reactor (1). It comprises a fluidized bed (30) of polyolefin particles, a gas distribution grid (31) and a velocity reduction zone (32). The polyolefin bed is kept in a fluidization state by an upwardly flow of gas fed through the gas distribution grid (31). The gaseous stream of the reaction gas leaving the top of the velocity reduction zone (32) via recycle line (33) is compressed by compressor (34), transferred to a heat exchanger (35), in which it is cooled, and then recycled to the bottom of the fluidized-bed reactor (25) at a point below the gas distribution grid (31) at position (36). Make-up monomers, molecular weight regulators, and optional inert gases can be fed into the reactor (25) for example via line (37) upstream of the compressor (33). The polyolefin particles discharged from lock hoppers (19) and (19') via transfer pipes (24) and (24') enter the fluidized-bed reactor (25) at one or more points (38). Discharge of polyolefin particles from fluidized-bed reactor (25) and transfer to a successive polymerization reactor or to a finishing treatment stage, as it is known to a person skilled in the art, is carried out through one or more lines (39).

In another aspect, the present invention relates to an apparatus for the multistage polymerization of olefins, comprising at least two serially connected gas-phase polymerization reactors and a device for transferring polyolefin particles from an upstream gas-phase polymerization reactor to a downstream gas-phase polymerization reactor, the transferring device comprising

- 5 - a gas/solid separation chamber placed downstream of the upstream gas-phase polymerization which gas/solid separation chamber is equipped at a lower part with an inlet for introducing a fluid, and
- connected to the gas/solid separation chamber at least two lock hoppers, placed in a parallel arrangement, directly connected to the downstream gas-phase polymerization reactor.

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Preferably the lower part of the gas/solid separation chamber, which is equipped with the inlet for introducing the fluid, is a conduit of a diameter smaller than the diameter of an upper part of the gas/solid separation chamber. It is preferred that this conduit is arranged substantially vertically, where substantially vertically means that the angle between the longitudinal direction of the conduit and the vertical is not more than 40° and preferably not more than 10°. It is also preferred that

15 the lower end of the conduit tapers conically.

It is further preferred that each lock hopper of the apparatus is connected to the lower part of the separation chamber through a separate discharge valve. It is also preferred that each lock hopper is connected to the second gas-phase polymerization reactor via a separated transfer pipe, wherein each of the transfer pipes comprises a discharge valve.

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Examples

25 The melt flow rate $MFR_{2.16}$ was determined according to DIN EN ISO 1133:2005, condition D at a temperature of 190°C under a load of 2.16 kg.

The density was determined according to DIN EN ISO 1183-1:2004, Method A (Immersion) with compression molded plaques of 2 mm thickness. The compression molded plaques were prepared with a defined thermal history: Pressed at 180°C, 20MPa for 8 min with subsequent crystallization in boiling water for 30 min.

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The particle size distribution was determined through the use of a Tyler Testing Sieve Shaker RX-29 Model B available from Combustion Engineering Endecott provided with a set of twelve sieves, according to ASTM E-11-87, of 106, 125, 180, 300, 500, 710, 1000, 1400, 2000, 2800, 3350, and 4000 µm.

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The bulk density was determined according to DIN EN ISO 60:2000-01.

The hydrogen concentration in the second fluidized-bed reactor (25) was determined by gas chromatography.

A homopolymerization of ethylene was carried out in the presence of hydrogen as molecular weight regulator and propane as inert diluent in the first fluidized-bed reactor (1) of a series of two connected fluidized-bed reactors as shown in Figure 1. The cylindrical reaction part of the fluidized bed reactor (1) had an inner diameter of 1000 mm and a height of 3500 mm. The upper level of the fluidized bed was adjusted in a way that the mean residence time of the polyolefin particles in the first fluidized-bed reactor was always 2.0 h. Discharging of the polyolefin particles from the first fluidized-bed reactor (1) was carried out discontinuously with the utilized discharge valve intermittently opening with an opening time of each times 1 s.

The discharged polyolefin particles were transferred into a separation chamber (12) for separating the polyolefin particles from entrained reaction gas of the first fluidized-bed reactor (1). The separation chamber had an upper cylindrical part of an inner diameter of 600 mm and a height of 1000 mm. The lower part of the separation chamber was a vertically arranged conduit (16) comprising a cylindrical part with an inner diameter of 200 mm and a length 1250 mm. Below the cylindrical part, the conduit (16) was conically tapering over a length of 300 mm to the inner diameter of the discharge line of 40 mm. The middle part of the separation chamber connecting the upper cylindrical part of the separation chamber and the conduit part of the separation chamber had a height of 800 mm.

Propane was fed as fluid into the conduit (16) at a position near the lower end of the conduit in order to prevent that the gas composition of the first fluidized-bed reactor, which was still contained in the interspace between the polyolefin particles, was carried over to the second fluidized-bed reactors.

The second fluidized-bed reactor was not operated as polymerization reactor but only as take-up device for the transferred polyethylene particles and accordingly the gas-phase of the second fluidized-bed reactor was pure propane. To keep the level of the fluidized bed in the second reactor constant, the same amount of polymer was discharged from the second reactor as was transferred from the first reactor. The pressure in the second reactor was kept constant by feeding fresh propane to compensate for gas losses in connection with discharging polymer particles from the second reactor.

For carrying out the polymerization, a Ziegler catalyst was used which was prepared as described in Examples 1-6 of WO 2009/027266. The pre-polymerized solid catalyst component was then contacted with triisobutylaluminum (TIBAL) in liquid propane at 25°C and a pressure of 2.5 MPa in a pre-contacting vessel in a weight ratio of 2 g TIBAL / g catalyst. The mean residence time of the catalyst in the pre-contacting vessel was 60 min.

Example 1

An ethylene polymerization with a production rate of 80 kg/h was carried out in the fluidized-bed reactor (1) at 80 °C and a pressure of 2.5 MPa. The composition of the reaction gas was 7.0 mol% ethylene, 21 mol% hydrogen and 72 mol% propane. The second fluidized-bed reactor (25) was held at a pressure of 2.4 MPa. The pressure of the separation chamber (12) was kept at 0.15 MPa.

The produced polyethylene had a melt flow rate $MFR_{2.16}$ of 140 g/10 min, a density of 0.968 g/cm³. The average particle diameter of the obtained polyethylene particles was 1050 µm, 0.5% of the polyethylene particles had a particle diameter of less than 180 µm and the bulk density of the obtained polyethylene particles was 0.540 g/cm³.

The discharge of the polyethylene particles was carried out intermittently with 10 openings of the discharge valve per hour, thus discharging in average 8 kg of polyethylene particles per opening.

Propane was fed into the conduit (16) in a quantity of 10 kg/h. After two hours of operating the hydrogen concentration in the second fluidized-bed reactor (25) remained below the detection limit of 0.1 vol%. This proves that the operating conditions were adequate for preventing the reaction gas of the first fluidized-bed reactor (1) from being transferred into the second fluidized-bed reactor (25).

Example 2

An ethylene polymerization similar to the polymerization of Example 1 was carried out; however the production rate was increased to 350 kg/h.

The discharge of the polyethylene particles was carried out intermittently with 44 openings of the discharge valve per hour, thus discharging in average 8 kg of polyethylene particles per opening. Propane was fed into the conduit (16) in a quantity of 44 kg/h.

After two hours of operating the hydrogen concentration in the second fluidized-bed reactor (25) remained below the detection limit of 0.1 vol%, proving that no reaction gas of the first fluidized-bed reactor (1) was transferred into the second fluidized-bed reactor (25).

Example 3

The ethylene polymerization of Example 2 was repeated.

The discharge of the polyethylene particles was carried out intermittently with 44 openings of the discharge valve per hour, thus discharging in average 8 kg of polyethylene particles per opening. Propane was fed into the conduit (16) in a quantity of 30 kg/h.

- 5 After two hours of operating the hydrogen concentration in the second fluidized-bed reactor (25) remained below the detection limit of 0.1 vol%, proving that no reaction gas of the first fluidized-bed reactor (1) was transferred into the second fluidized-bed reactor (25).

Comparative Example A

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The ethylene polymerization of Example 2 was repeated.

The discharge of the polyethylene particles was carried out intermittently with 44 openings of the discharge valve per hour, thus discharging in average 8 kg of polyethylene particles per opening.

- 15 Propane was fed into the conduit (16) in a quantity of 5 kg/h.

- Shortly after starting transferring polyethylene particles from the first to the second fluidized-bed reactor, hydrogen could be detected in the second reactor. After one hour of operating, a hydrogen concentration of 0.5 vol% was reached showing that reaction gas of the first fluidized-bed reactor (1) was transferred into the second fluidized-bed reactor (25). Accordingly a too low amount of propane was fed into the conduit (16) to achieve an upward stream of propane in the bed of polyethylene particles in the conduit (16).
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Claims

1. A process for polymerizing olefins at temperatures of from 30°C to 140°C and pressures of from 1.0 MPa to 10 MPa in the presence of a polymerization catalyst in a multistage
5 polymerization of olefins in at least two serially connected gas-phase polymerization reactors, the process for transferring polyolefin particles from a first gas-phase polymerization reactor to a second gas-phase polymerization reactor comprising the steps of
- 10 a) discharging polyolefin particles from the first gas-phase polymerization reactor into a separation chamber in which the polyolefin particles are separated from concomitantly discharged reaction gas, the separation chamber being at a lower pressure than the pressure in the first gas-phase polymerization reactor;
- 15 b) transferring the polyolefin particles within the separation chamber into a lower part of the separation chamber which contains a bed of polyolefin particles which moves from top to bottom of this part of the separation chamber and into which a fluid is introduced in an amount that an upward stream of the fluid in the bed of polyolefin particles above the fluid introduction point is induced,
- 20 c) withdrawing polyolefin particles from the lower end of said lower part and transferring them to one of at least two lock hoppers working intermittently in parallel; and
- 25 d) simultaneously pressurizing another of the at least two lock hoppers working intermittently by means of a gas comprising reaction gas coming from the second gas-phase polymerization reactor.
2. A process for polymerizing olefins according to claim 1, wherein the bed of polyolefin particles moves as plug flow from top to bottom of the lower part of the separation chamber.
- 30 3. A process for polymerizing olefins according to claim 1 or 2, wherein the lower part of the separation chamber, which contains the bed of polyolefin particles, is a conduit of a diameter smaller than the diameter of an upper part of the separation chamber.
- 35 4. A process for polymerizing olefins according to claim 3, wherein the conduit is arranged substantially vertically.
5. A process for polymerizing olefins according to claim 3 or 4, wherein the lower end of the conduit tapers conically.

6. A process for polymerizing olefins according to any of claims 1 to 5, wherein the multistage polymerization of olefins is a multistage polymerization of ethylene or ethylene and comonomer and the polymerization in the first polymerization reactor is a polymerization carried out in the presence of hydrogen.
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7. A process for polymerizing olefins according to any of claims 1 to 6, wherein the fluid introduced into the conduit is an inert gas.
8. A process for polymerizing olefins according to any of claims 1 to 7, wherein the pressure in the separation chamber is in a range of from 0.12 to 0.4 MPa.
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9. A process for polymerizing olefins according to any of claims 1 to 8, wherein for each of the lock hoppers, the following steps are conducted subsequently in a recurring way:
- loading with polyolefin particles coming from the lower part of the separation chamber while the lock hopper is isolated from the second gas-phase polymerization reactor; and
 - pressurizing by means of a gas comprising reaction gas coming from the second gas-phase polymerization reactor and discharging the polyolefin particles and transferring them to the second gas-phase polymerization reactor while the lock hopper is isolated from the separation chamber.
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10. An apparatus for the multistage polymerization of olefins, comprising at least two serially connected gas-phase polymerization reactors and a device for transferring polyolefin particles from an upstream gas-phase polymerization reactor to a downstream gas-phase polymerization reactor, the transferring device comprising
- a gas/solid separation chamber placed downstream of the upstream gas-phase polymerization which gas/solid separation chamber is equipped at a lower part with an inlet for introducing a fluid, and
 - connected to the gas/solid separation chamber at least two lock hoppers, placed in a parallel arrangement, each connected to the downstream gas-phase polymerization reactor.
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11. An apparatus for the multistage polymerization of olefins according to claim 10, wherein the lower part of the gas/solid separation chamber, which is equipped with the inlet for introducing the fluid, is a conduit of a diameter smaller than the diameter of an upper part of the gas/solid separation chamber.
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12. An apparatus for the multistage polymerization of olefins according to claim 10 or 11, wherein the conduit is arranged substantially vertically.
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13. An apparatus for the multistage polymerization of olefins according to any of claims 10 to 12, wherein the lower end of the conduit tapers conically.
14. An apparatus for the multistage polymerization of olefins according to any of claims 10 to 13, wherein each lock hopper is connected to the lower part of the separation chamber through a separate discharge valve.
15. An apparatus for the multistage polymerization of olefins according to any of claims 10 to 14, wherein each lock hopper is connected to the second gas-phase polymerization reactor via a separated transfer pipe, each transfer pipe comprising a discharge valve.

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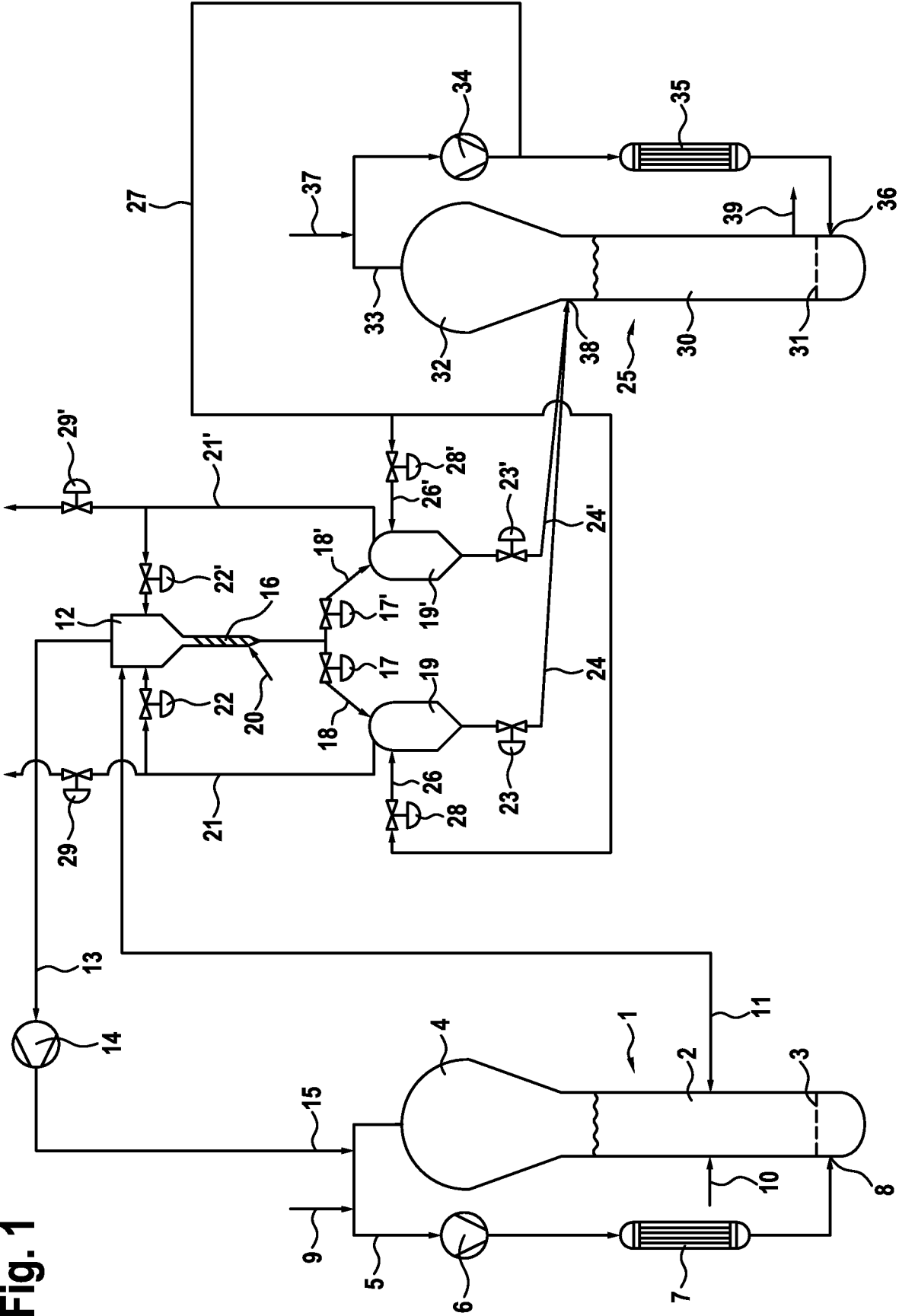


Fig. 1