Notice

DESCRIPTION CN120519716A

A method for recovering rare earth elements from spent FCC catalysts by Joule thermal flash decomposition and glycine leaching

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一种焦耳热闪速解构协同甘氨酸浸出回收废FCC催化剂中稀土的方法

[0001]

Technical Field

技术领域

[n0001]

This invention relates to the field of valuable metal recycling technology in solid waste, and more specifically, to a method for recovering rare earth elements from waste FCC catalysts by Joule thermal flash decomposition and glycine leaching.

本发明涉及固体废物中有价金属回收利用技术领域，具体地说，涉及一种焦耳热闪速解构协同甘氨酸浸出回收废FCC催化剂中稀土的方法。

[0003]

Background Technology

背景技术

[n0002]

Fluidized catalytic cracking catalysts (FCCs) are widely used in modern petroleum refining industries due to their excellent activity, resistance to heavy metals, activity stability, residue cracking performance, gasoline selectivity, and low cost.

流化催化裂化催化剂(FCC)因具有优异的活性、抗重金属性、活性稳定性、渣油裂化性能、汽油选择性能及成本低廉，被广泛应用于现代石油炼制工业中。

In the petroleum refining catalysis process, FCC catalysts can become ineffective due to the combined effects of sintering, heavy metal contamination such as Ni/V/Fe, pulverization /hydrothermal processes, etc.

FCC催化剂在石油炼制催化过程中，会因为烧结、Ni/V/Fe等重金属污染、粉化/水热等联合作用下致使其失效。

Waste FCC catalysts contain 4%-6% rare earth oxides (mainly La₂O₃ and CeO₂). Recycling and utilizing rare earths from waste FCC catalysts can not only bring huge economic benefits, but also save the mining of primary rare earth mineral resources.

废FCC催化剂中含4%-6%的稀土氧化物(主要是La₂O₃和CeO₂)，开展废FCC催化剂中稀土的回收利用，不仅可以带来巨大的经济利益，同时也能节约原生稀土矿产资源的开采。

However, existing recycling technologies for spent FCC catalysts suffer from bottlenecks such as low rare earth recovery rates (less than 15%) and severe secondary environmental pollution (due to the use of highly toxic acids such as HF).

但废FCC催化剂现有回收技术存在稀土回收率低(不足15%)、环境二次污染重(HF等剧毒强酸使用)等瓶颈问题。

[n0003]

Chinese patent CN202010211919.0 discloses a method for comprehensively recovering valuable metals such as rare earth and aluminum from waste FCC catalysts using a combined process of hydrochloric acid leaching, hydrogen peroxide oxidation, extractant extraction, oxalic acid precipitation, and sodium sulfide precipitation.

中国专利CN202010211919.0公开了一种利用盐酸浸出-双氧水氧化-萃取剂萃取-草酸沉淀-硫化钠沉淀等联合工艺综合回收废FCC催化剂中稀土、铝等有价金属的方法。

However, the recovery efficiency of valuable metals such as rare earths and aluminum is low in this method, and the recovery process uses a large amount of corrosive and polluting chemical reagents such as strong acids/alkalis, resulting in a high environmental risk.

但该方法中稀土和铝等有价金属的回收效率偏低，而且回收过程使用大量的强酸/强碱等腐蚀污染性化学试剂，导致其环境风险偏大。

[n0004]

Chinese patent CN202011393727.2 discloses a method for extracting rare earth elements from waste FCC catalysts by acid leaching coupled with photoreduction. The method is characterized by using strong acids such as nitric acid or hydrochloric acid coupled with photoreduction to efficiently separate and extract rare earth elements La and Ce from waste FCC catalysts.

中国专利CN202011393727.2公开了一种酸浸耦合光还原提取废FCC催化剂中稀土的方法，该方法的特征是利用硝酸或盐酸等强酸耦合光还原来高效分离提取废FCC催化剂中稀土La和Ce。

This method can achieve a rare earth leaching efficiency of over 95%, but its leaching process requires the consumption of large amounts of strong acids such as nitric acid or hydrochloric acid, and the use of ultraviolet lamps as a strong light source leads to problems such as a large amount of acidic wastewater generated, a high risk of secondary environmental pollution, and poor practical application scenarios in engineering.

该方法能获得95%以上的稀土浸出效率，但其浸出过程需要消耗大量的硝酸或盐酸等强酸，且使用紫外灯作为强光光源，导致含酸废水产生量大、环境二次污染风险高、工程实际应用情景差等问题。

[n0005]

Waste FCC catalysts come from a wide range of sources, have complex compositions, and are often coated with organic carbon, which ultimately makes it difficult to leach and separate high-value metals such as rare earth elements.

废FCC催化剂来源广泛、成分复杂，且呈现有机碳包覆情况，最终会导致其稀土等高价值金属的浸出和分离纯化困难。

Therefore, based on the inherent characteristics of spent FCC catalysts, there is an urgent need to develop rapid, efficient, and low-carbon methods for the recycling of valuable metals such as rare earth elements from spent FCC catalysts.

因此，基于废FCC催化剂的禀赋特性，亟需开发废FCC催化剂中稀土等有价金属的快速、高效、低碳的回收利用方法。

[0008]

Summary of the Invention

发明内容

[n0006]

To address the existing technical challenges in recycling rare earth and other valuable metals from spent FCC catalysts, the present invention aims to develop a Joule heating-enhanced deconstruction synergistic glycine leaching technology to achieve rapid, green, low-carbon, and efficient recycling of rare earth elements La and Ce from spent FCC catalysts.

为了解决上述废FCC催化剂中稀土等有价金属的现有回收利用技术问题，本发明的目的是开发一种焦耳热强化解构协同甘氨酸浸出技术，以实现废FCC催化剂中稀土La和Ce的闪速、绿色、低碳和高效的回收利用。

[n0007]

A method for recovering rare earth elements from spent FCC catalysts by Joule thermal flash decomposition and glycine leaching includes the following steps:

一种焦耳热闪速解构协同甘氨酸浸出回收废FCC催化剂中稀土的方法，包括如下步骤：

[n0008]

(1) Joule heat flash decomposition of waste FCC catalyst: Waste FCC catalyst is pulverized to below 200 mesh using a ball mill and uniformly mixed with conductive medium powder to obtain a mixture. The mixture is then filled into an electrode reactor and treated with Joule heat technology under an inert atmosphere. The resistance heat generated by the current

passing through the mixture generates a high temperature instantaneously, realizing the flash-enhanced decomposition of waste FCC catalyst and obtaining Joule heat decomposition product. The mass ratio of waste FCC catalyst to conductive medium powder is 2:1 to 5:1, the energizing time is 1 to 10 seconds, and the Joule heat temperature is 2500 to 3000°C.

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(1)焦耳热闪速解构废FCC催化剂：使用球磨机将废FCC催化剂粉碎至200目以下，并与导电介质粉末均匀混合获得混合物料，然后将混合物料填充于电极反应器中，在惰性气氛下采用焦耳热技术处理，利用电流通过混合物料产生电阻热，瞬间产生高温，实现废FCC催化剂的闪速强化解构，获得焦耳热解构产物，其中：废FCC催化剂与导电介质粉末的质量比为2:1～5:1，通电时间为1～10秒，焦耳热温度为2500～3000°C。

[n0009]

(2) Glycine leaching of Joule thermal decomposition product: The Joule thermal decomposition product obtained in step (1) is mixed with glycine solution and leaching reaction is carried out under heating and stirring. The leaching solution loaded with La and Ce is obtained by filtration, wherein: the glycine concentration is 0.1 to 0.5 mol/L, the leaching time is 1 to 2 hours, the leaching temperature is 60 to 80°C, the solid-liquid ratio is 0.2:1 to 0.5:1 kg/L, and the stirring speed is 200 to 400 rpm.

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(2)焦耳热解构产物的甘氨酸浸出：将步骤(1)所得到的焦耳热解构产物与甘氨酸溶液混合，在加热搅拌下进行浸出反应，过滤获得负载La、Ce浸出液，其中：甘氨酸浓度为0.1～0.5摩尔/升，浸出时间为1～2小时，浸出温度为60～80°C、固液比为0.2:1～0.5:1千克/升，搅拌速度为200～400转/分钟。

[n0010]

(3) Oxalic acid precipitation to separate rare earth La and Ce: Oxalic acid solution was added to the loaded La/Ce leachate obtained in step (2), and precipitation reaction was carried out under heating and stirring. After the precipitation reaction was completed, solid-liquid separation was carried out, and oxalate precipitate and filtrate were obtained by filtration.

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(3)草酸沉淀分离稀土La和Ce：将步骤(2)所得到的负载La/Ce浸出液中加入草酸溶液，在加热搅拌下进行沉淀反应，沉淀反应结束后进行固液分离，过滤得到草酸盐沉淀和滤液。

The oxalic acid concentration was 2–4 mol/L, the precipitation temperature was 80–90°C, the pH value was 1.5–2.0, the precipitation time was 1–2 hours, and the stirring speed was 300–500 rpm.

其中：草酸浓度为2～4摩尔/升，沉淀温度为80～90°C，pH值为1.5～2.0，沉淀时间为1～2小时，搅拌速度为300～500转/分钟。

[n0011]

(4) Rare earth oxide recovery: Oxalate precipitate is placed in a muffle furnace for calcination to finally obtain rare earth oxide products, wherein the calcination temperature is 900-950°C and the time is 1-2 hours.

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(4)稀土氧化物回收：将草酸盐沉淀置于马弗炉中煅烧，最终获得稀土氧化物产品，其中：煅烧温度为900～950°C，时间为1～2小时。

[n0012]

The method for recovering rare earth elements from waste FCC catalyst by Joule thermal flash decomposition and glycine leaching as described in claim 1 is characterized in that the inert atmosphere in step (1) is nitrogen with a purity greater than or equal to 99.9%.

如权利要求1所述一种焦耳热闪速解构协同甘氨酸浸出回收废FCC催化剂中稀土的方法，其特征在于，所述的步骤(1)中惰性气氛为：氮气，纯度大于等于99.9%。

[n0013]

The method for recovering rare earth elements from waste FCC catalyst by Joule thermal flash decomposition and glycine leaching as described in claim 1 is characterized in that the conductive medium in step (1) is one of carbon black, coke, biomass carbon or graphite.

如权利要求1所述一种焦耳热闪速解构协同甘氨酸浸出回收废FCC催化剂中稀土的方法，其特征在于，所述的步骤(1)中导电介质为：炭黑、焦炭、生物质碳或石墨中的一种。

[0017]

Attached Figure Description

附图说明

[n0014]

Figure 1 shows a flowchart of a method for recovering rare earth elements from waste FCC catalysts by Joule thermal flash decomposition and glycine leaching.

图1表示一种焦耳热闪速解构协同甘氨酸浸出回收废FCC催化剂中稀土的方法的流程图。

[0019]

Detailed Implementation

具体实施方式

[n0015]

The solid-liquid ratios mentioned in each step of the following examples are all solid-liquid ratios for the current step.

以下实施例各步骤中出现的固液比均为当前步骤的固液比。

[n0016]

Example 1

实例1

[n0017]

Follow these steps to process:

按照如下步骤进行处理：

[n0018]

(1) Joule thermal flash decomposition of spent FCC catalyst: The spent FCC catalyst was pulverized to below 200 mesh using a ball mill and uniformly mixed with carbon black powder to obtain a mixture. The mixture was then filled into an electrode reactor and treated with Joule thermal technology under a nitrogen atmosphere of 99.9% purity. The electric current passing through the mixture generates resistance heat, instantly producing a high temperature to achieve flash-enhanced decomposition of the spent FCC catalyst and obtain the Joule thermal decomposition product. The mass ratio of spent FCC catalyst to carbon black powder was 4:1, the energizing time was 6 seconds, and the Joule thermal temperature was 2500°C.

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(1)焦耳热闪速解构废FCC催化剂：使用球磨机将废FCC催化剂粉碎至200目以下，并与炭黑粉末均匀混合获得混合物料，然后将混合物料填充于电极反应器中，在纯度等于99.9%的氮气气氛下采用焦耳热技术处理，利用电流通过混合物料产生电阻热，瞬间产生高温，实现废FCC催化剂的闪速强化解构，获得焦耳热解构产物，其中：废FCC催化剂与炭黑粉末的质量比为4:1，通电时间为6秒，焦耳热温度为2500°C

[n0019]

(2) Glycine leaching of Joule thermal decomposition product: The Joule thermal decomposition product obtained in step (1) is mixed with glycine solution and leached under

heating and stirring. The leaching solution loaded with La/Ce is obtained by filtration, wherein: the glycine concentration is 0.3 mol/L, the leaching time is 2 hours, the leaching temperature is 60°C, the solid-liquid ratio is 0.2:1 kg/L, and the stirring speed is 200 rpm.

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(2)焦耳热解构产物的甘氨酸浸出：将步骤(1)所得到的焦耳热解构产物与甘氨酸溶液混合，在加热搅拌下进行浸出反应，过滤获得负载La/Ce浸出液，其中：甘氨酸浓度为0.3摩尔/升、浸出时间为2小时、浸出温度为60°C、固液比为0.2:1千克/升，搅拌速度为200转/分钟。

[n0020]

(3) Oxalic acid precipitation to separate rare earth La and Ce: Oxalic acid solution was added to the La/Ce leachate obtained in step (2), and precipitation reaction was carried out under heating and stirring. After the precipitation reaction was completed, solid-liquid separation was carried out, and oxalate precipitate and filtrate were obtained by filtration. The oxalic acid concentration was 2 mol/L, the precipitation temperature was 80°C, the pH value was 1.5, the precipitation time was 1 hour, and the stirring speed was 300 rpm.

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(3)草酸沉淀分离稀土La和Ce：将步骤(2)所得到的负载La/Ce浸出液中加入草酸溶液，在加热搅拌下进行沉淀反应，沉淀反应结束后进行固液分离，过滤得到草酸盐沉淀和滤液，其中：草酸浓度为2摩尔/升，沉淀温度为80°C，pH值为1.5，沉淀时间为1小时，搅拌速度为300转/分钟。

[n0021]

(4) Recovery of mixed rare earth oxides: Oxalate precipitate is placed in a muffle furnace for calcination to finally obtain rare earth oxide products, wherein the calcination temperature is 900°C and the time is 1 hour.

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(4)混合稀土氧化物的回收：将草酸盐沉淀置于马弗炉中煅烧，最终获得稀土氧化物产品，其中：煅烧温度为900°C，时间为1小时。

[n0022]

(5) ICP test results showed that the recovery rate of rare earth La in the waste FCC catalyst was 95.2%, the recovery rate of cerium was 95.5%, and the total recovery rate of rare earth was 94.5%.

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(5)ICP测试结果表明：废FCC催化剂中稀土La的回收率为95.2%，铈的回收率为95.5%，稀土总回收率为94.5%。

[n0023]

Example 2

实例2

[n0024]

Follow these steps to process:

按照如下步骤进行处理：

[n0025]

(1) Joule thermal flash decomposition of waste FCC catalyst: The waste FCC catalyst was crushed to below 200 mesh using a ball mill and uniformly mixed with coke powder to obtain a mixture. The mixture was then filled into an electrode reactor and treated with Joule thermal technology under a nitrogen atmosphere with a purity of 99.9%. The resistance heat generated by the current passing through the mixture was used to generate a high temperature instantaneously, thereby realizing the flash-enhanced decomposition of the waste FCC catalyst and obtaining the Joule thermal decomposition product. The mass ratio of waste FCC catalyst to coke powder was 2:1, the energizing time was 1 second, and the Joule thermal temperature was 2600°C.

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(1)焦耳热闪速解构废FCC催化剂：使用球磨机将废FCC催化剂粉碎至200目以下，并与焦炭粉末均匀混合获得混合物料，然后将混合物料填充于电极反应器中，在纯度等于99.9%的氮气气氛下采用焦耳

热技术处理，利用电流通过混合物料产生电阻热，瞬间产生高温，实现废FCC催化剂的闪速强化解构，获得焦耳热解构产物，其中：废FCC催化剂与焦炭粉末的质量比为2:1，通电时间为1秒，焦耳热温度为2600°C。

[n0026]

(2) Glycine leaching of Joule thermal decomposition product: The Joule thermal decomposition product obtained in step (1) is mixed with glycine solution and leached under heating and stirring. The leaching solution loaded with La/Ce is obtained by filtration, wherein: the glycine concentration is 0.3 mol/L, the leaching time is 1.5 hours, the leaching temperature is 70°C, the solid-liquid ratio is 0.3:1 kg/L, and the stirring speed is 300 rpm.

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(2)焦耳热解构产物的甘氨酸浸出：将步骤(1)所得到的焦耳热解构产物与甘氨酸溶液混合，在加热搅拌下进行浸出反应，过滤获得负载La/Ce浸出液，其中：甘氨酸浓度为0.3摩尔/升、浸出时间为1.5小时、浸出温度为70°C、固液比为0.3:1千克/升，搅拌速度为300转/分钟。

[n0027]

(3) Oxalic acid precipitation to separate rare earth La and Ce: Oxalic acid solution was added to the La/Ce leachate obtained in step (2), and precipitation reaction was carried out under heating and stirring. After the precipitation reaction was completed, solid-liquid separation was carried out, and oxalate precipitate and filtrate were obtained by filtration. The oxalic

acid concentration was 3 mol/L, the precipitation temperature was 85℃, the pH value was 1.7, the time was 1.5 hours, and the stirring speed was 400 rpm.

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(3)草酸沉淀分离稀土La和Ce：将步骤(2)所得到的负载La/Ce浸出液中加入草酸溶液，在加热搅拌下进行沉淀反应，沉淀反应结束后进行固液分离，过滤得到草酸盐沉淀和滤液，其中：草酸浓度为3摩尔/升，沉淀温度为85℃，pH值为1.7，时间为1.5小时,搅拌速度为400转/分钟。

[n0028]

(4) Rare earth oxide recovery: Oxalate precipitate is placed in a muffle furnace for calcination to finally obtain rare earth oxide products, wherein the calcination temperature is 920℃ and the time is 2 hours.

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(4)稀土氧化物回收：将草酸盐沉淀置于马弗炉中煅烧，最终获得稀土氧化物产品，其中：煅烧温度为920℃，时间为2小时。

[n0029]

(5) ICP test results showed that the recovery rate of rare earth La in the waste FCC catalyst was 95.8%, the recovery rate of cerium was 95.6%, and the total recovery rate of rare earth was 94.3%.

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(5)ICP测试结果表明：废FCC催化剂中稀土La的回收率为95.8%，铈的回收率为95.6%，稀土总回收率为94.3%。

[n0030]

Example 3

实例3

[n0031]

Follow these steps to process:

按照如下步骤进行处理：

[n0032]

(1) Joule thermal flash decomposition of waste FCC catalyst: The waste FCC catalyst was crushed to below 200 mesh using a ball mill and uniformly mixed with biomass carbon powder to obtain a mixture. The mixture was then filled into an electrode reactor and treated with Joule thermal technology under a nitrogen atmosphere with a purity of 99.9%. The electric current passing through the mixture generates resistance heat, instantly generating

high temperature to achieve flash-enhanced decomposition of the waste FCC catalyst and obtain Joule thermal decomposition products. The mass ratio of waste FCC catalyst to biomass carbon powder was 3:1, the electric current time was 8 seconds, and the Joule thermal temperature was 2800°C.

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(1)焦耳热闪速解构废FCC催化剂：使用球磨机将废FCC催化剂粉碎至200目以下，并与生物质碳粉末均匀混合获得混合物料，然后将混合物料填充于电极反应器中，在纯度等于99.9%的氮气气氛下采用焦耳热技术处理，利用电流通过混合物料产生电阻热，瞬间产生高温，实现废FCC催化剂的闪速强化解构，获得焦耳热解构产物，其中：废FCC催化剂与生物质碳粉末的质量比为3:1，通电时间为8秒，焦耳热温度为2800°C。

[n0033]

(2) Glycine leaching of Joule thermal decomposition product: The Joule thermal decomposition product obtained in step (1) is mixed with glycine solution and leached under heating and stirring. The leaching solution loaded with La/Ce is obtained by filtration, wherein: the glycine concentration is 0.4 mol/L, the leaching time is 1.2 hours, the leaching temperature is 75°C, the solid-liquid ratio is 0.4:1 kg/L, and the stirring speed is 350 rpm.

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(2)焦耳热解构产物的甘氨酸浸出：将步骤(1)所得到的焦耳热解构产物与甘氨酸溶液混合，在加热搅拌下进行浸出反应，过滤获得负载La/Ce浸出液，其中：甘氨酸浓度为0.4摩尔/升、浸出时间为1.2小时、浸出温度为75°C、固液比为0.4:1千克/升，搅拌速度为350转/分钟。

[n0034]

(3) Oxalic acid precipitation to separate rare earth La and Ce: Oxalic acid solution was added to the loaded La/Ce leachate obtained in step (2), and precipitation reaction was carried out under heating and stirring. After the precipitation reaction was completed, solid-liquid separation was carried out, and oxalate precipitate and filtrate were obtained by filtration.

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(3)草酸沉淀分离稀土La和Ce：将步骤(2)所得到的负载La/Ce浸出液中加入草酸溶液，在加热搅拌下进行沉淀反应，沉淀反应结束后进行固液分离，过滤得到草酸盐沉淀和滤液。

The oxalic acid concentration was 3.5 mol/L, the precipitation temperature was 80°C, the pH value was 1.8, the precipitation time was 2 hours, and the stirring speed was 450 rpm.

其中：草酸浓度为3.5摩尔/升，沉淀温度为80°C，pH值为1.8，时间为2小时,搅拌速度为450转/分钟。

[n0035]

(4) Rare earth oxide recovery: Oxalate precipitate is placed in a muffle furnace for calcination to finally obtain rare earth oxide products.

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(4)稀土氧化物回收：将草酸盐沉淀置于马弗炉中煅烧，最终获得稀土氧化物产品。

The calcination temperature was 910°C and the time was 1.5 hours.

其中，煅烧温度为910°C，时间为1.5小时。

[n0036]

(5) ICP test results showed that the recovery rate of rare earth La in the waste FCC catalyst was 96.3%, the recovery rate of cerium was 96.4%, and the total recovery rate of rare earth was 95.6%.

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(5)ICP测试结果表明：废FCC催化剂中稀土La的回收率为96.3%，铈的回收率为96.4%，稀土总回收率为95.6%。

[n0037]

Example 4

实例4

[n0038]

Follow these steps to process:

按照如下步骤进行处理：

[n0039]

(1) Joule thermal flash decomposition of waste FCC catalyst: The waste FCC catalyst was crushed to below 200 mesh using a ball mill and uniformly mixed with graphite powder to obtain a mixture. The mixture was then filled into an electrode reactor and treated with Joule thermal technology under a nitrogen atmosphere with a purity of 99.9%. The resistance heat generated by the current passing through the mixture was used to generate a high temperature instantaneously, thereby realizing the flash-enhanced decomposition of the waste FCC catalyst and obtaining the Joule thermal decomposition product. The mass ratio of waste FCC catalyst to graphite powder was 5:1, the energizing time was 10 seconds, and the Joule thermal temperature was 3000°C.

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(1)焦耳热闪速解构废FCC催化剂：使用球磨机将废FCC催化剂粉碎至200目以下，并与石墨粉末均匀混合获得混合物料，然后将混合物料填充于电极反应器中，在纯度等于99.9%的氮气气氛下采用焦耳

热技术处理，利用电流通过混合物料产生电阻热，瞬间产生高温，实现废FCC催化剂的闪速强化解构，获得焦耳热解构产物，其中：废FCC催化剂与石墨粉末的质量比为5:1，通电时间为10秒，焦耳热温度为3000℃。

[n0040]

(2) Glycine leaching of Joule thermal decomposition product: The Joule thermal decomposition product obtained in step (1) is mixed with glycine solution and leached under heating and stirring. The leaching solution loaded with La/Ce is obtained by filtration, wherein: the glycine concentration is 0.5 mol/L, the leaching time is 1 hour, the leaching temperature is 80°C, the solid-liquid ratio is 0.5:1 kg/L, and the stirring speed is 400 rpm.

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(2)焦耳热解构产物的甘氨酸浸出：将步骤(1)所得到的焦耳热解构产物与甘氨酸溶液混合，在加热搅拌下进行浸出反应，过滤获得负载La/Ce浸出液，其中：甘氨酸浓度为0.5摩尔/升、浸出时间为1小时、浸出温度为80℃、固液比为0.5:1千克/升，搅拌速度为400转/分钟。

[n0041]

(3) Oxalic acid precipitation to separate rare earth La and Ce: Oxalic acid solution was added to the La/Ce leachate obtained in step (2), and precipitation reaction was carried out under heating and stirring. After the precipitation reaction was completed, solid-liquid separation was carried out, and oxalate precipitate and filtrate were obtained by filtration. The oxalic

acid concentration was 4 mol/L, the precipitation temperature was 90°C, the pH value was 2, the time was 2 hours, and the stirring speed was 500 rpm.

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(3)草酸沉淀分离稀土La和Ce：将步骤(2)所得到的负载La/Ce浸出液中加入草酸溶液，在加热搅拌下进行沉淀反应，沉淀反应结束后进行固液分离，过滤得到草酸盐沉淀和滤液，其中：草酸浓度为4摩尔/升，沉淀温度为90°C，pH值为2，时间为2小时，搅拌速度为500转/分钟。

[n0042]

(4) Rare earth oxide recovery: Oxalate precipitate is placed in a muffle furnace for calcination to finally obtain rare earth oxide products, wherein the calcination temperature is 950°C and the time is 2 hours.

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(4)稀土氧化物回收：将草酸盐沉淀置于马弗炉中煅烧，最终获得稀土氧化物产品，其中：煅烧温度为950°C，时间为2小时。

[n0043]

(5) ICP test results showed that the recovery rate of rare earth La in the waste FCC catalyst was 97.2%, the recovery rate of cerium was 96.8%, and the total recovery rate of rare earth was 95.8%.

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(5)ICP测试结果表明：废FCC催化剂中稀土La的回收率为97.2%、铈的回收率为96.8%，稀土总回收率为95.8%。

[n0044]

Example 5

实例5

[n0045]

Follow these steps to process:

按照如下步骤进行处理：

[n0046]

(1) Joule thermal flash decomposition of waste FCC catalyst: The waste FCC catalyst was crushed to below 200 mesh using a ball mill and uniformly mixed with coke powder to obtain a mixture. The mixture was then filled into an electrode reactor and treated with Joule thermal technology under a nitrogen atmosphere with a purity of 99.9%. The electric current passing through the mixture generates resistance heat, instantly generating high temperature

to achieve flash-enhanced decomposition of the waste FCC catalyst and obtain Joule thermal decomposition products. The mass ratio of waste FCC catalyst to coke powder was 4.5:1, the electric current time was 8 seconds, and the Joule thermal temperature was 2800°C.

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(1)焦耳热闪速解构废FCC催化剂：使用球磨机将废FCC催化剂粉碎至200目以下，并与焦炭粉末均匀混合获得混合物料，然后将混合物料填充于电极反应器中，在纯度等于99.9%的氮气气氛下采用焦耳热技术处理，利用电流通过混合物料产生电阻热，瞬间产生高温，实现废FCC催化剂的闪速强化解构，获得焦耳热解构产物，其中：废FCC催化剂与焦炭粉末的质量比为4.5：1，通电时间为8秒，焦耳热温度为2800°C。

[n0047]

(2) Glycine leaching of Joule thermal decomposition product: The Joule thermal decomposition product obtained in step (1) is mixed with glycine solution and leached under heating and stirring. The leaching solution loaded with La/Ce is obtained by filtration, wherein: the glycine concentration is 0.2 mol/L, the leaching time is 1.5 hours, the leaching temperature is 65°C, the solid-liquid ratio is 0.25:1 kg/L, and the stirring speed is 250 rpm.

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(2)焦耳热解构产物的甘氨酸浸出：将步骤(1)所得到的焦耳热解构产物与甘氨酸溶液混合，在加热搅拌下进行浸出反应，过滤获得负载La/Ce浸出液，其中：甘氨酸浓度为0.2摩尔/升、浸出时间为1.5小时、浸出温度为65°C、固液比为0.25:1千克/升，搅拌速度为250转/分钟。

[n0048]

(3) Oxalic acid precipitation to separate rare earth La and Ce: Oxalic acid solution was added to the La/Ce leachate obtained in step (2), and precipitation reaction was carried out under heating and stirring. After the precipitation reaction was completed, solid-liquid separation was carried out, and oxalate precipitate and filtrate were obtained by filtration. The oxalic acid concentration was 2.5 mol/L, the precipitation temperature was 80°C, the pH value was 1.6, the time was 2 hours, and the stirring speed was 380 rpm.

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(3)草酸沉淀分离稀土La和Ce：将步骤(2)所得到的负载La/Ce浸出液中加入草酸溶液，在加热搅拌下进行沉淀反应，沉淀反应结束后进行固液分离，过滤得到草酸盐沉淀和滤液，其中：草酸浓度为2.5摩尔/升，沉淀温度为80°C，pH值为1.6，时间为2小时,搅拌速度为380转/分钟。

[n0049]

(4) Rare earth oxide recovery: Oxalate precipitate is placed in a muffle furnace for calcination to finally obtain rare earth oxide products, wherein: the calcination temperature is 930°C and the time is 1.5 hours.

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(4)稀土氧化物回收：将草酸盐沉淀置于马弗炉中煅烧，最终获得稀土氧化物产品，其中：煅烧温度为930°C，时间为1.5小时。

[n0050]

(5) ICP test results showed that the recovery rate of rare earth La in the waste FCC catalyst was 95.3%, the recovery rate of cerium was 95.4%, and the total recovery rate of rare earth was 94.9%.

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(5)ICP测试结果表明：废FCC催化剂中稀土La的回收率为95.3%、铈的回收率为95.4%，稀土总回收率为94.9%。