广东摩德娜科技股份有限公司
MODENA TECHNOLOGY LIMITED

Tel:+86-757-8663 1888
Fax:+86-757-8663 1777
E-mail:info@modena.com.cn
www.modena.com.cn

V.TC202510TLXT

MODENA 摩德娜®

INTEGRATED LITHIUM EXTRACTION SOLUTION
提锂系统解决方案

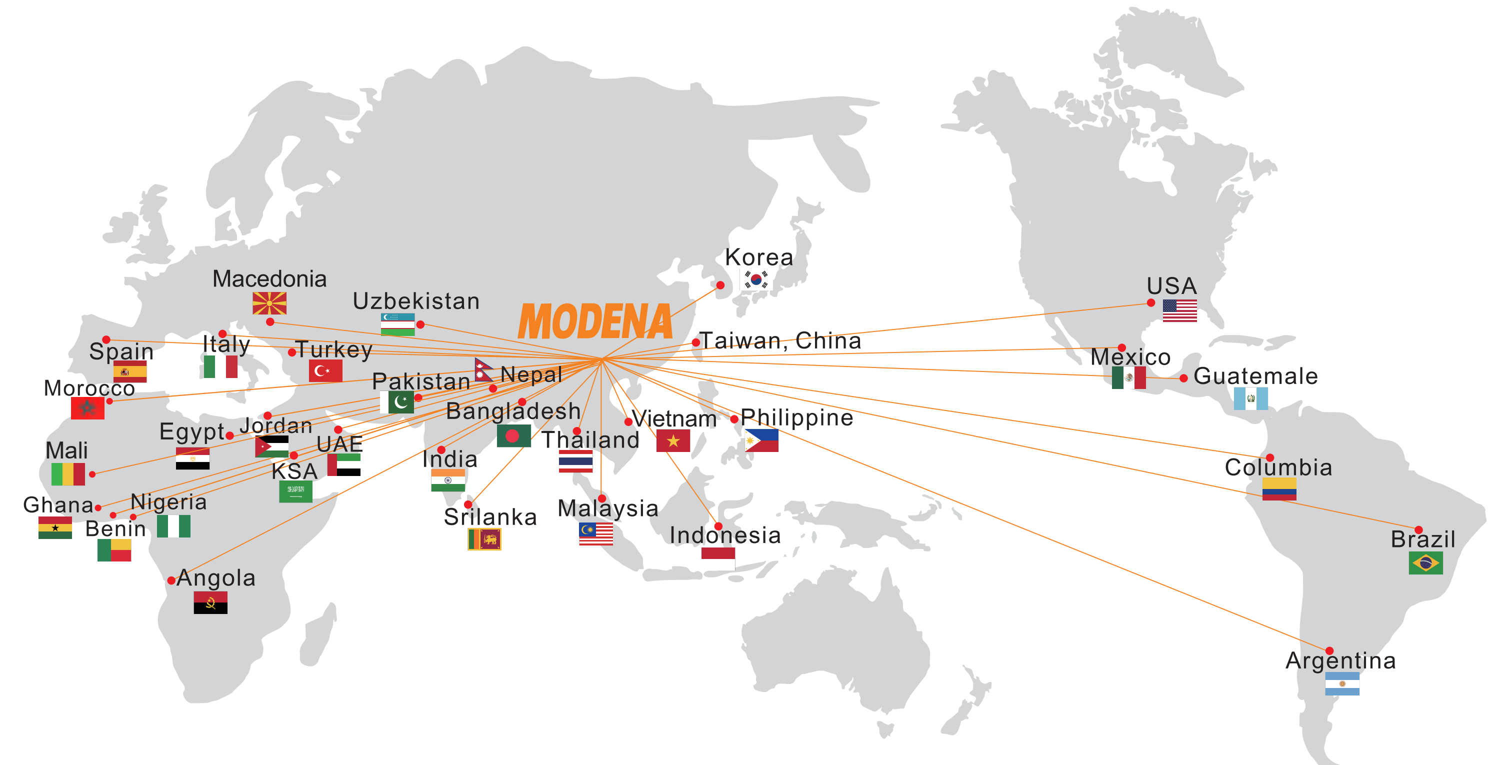
国家高新技术企业
欧盟CE安全认证
中国窑炉协会理事长单位

National High-Tech Enterprise
CE Safety Certificate of European Union
Presidential Unit of China Kiln Association

广东摩德娜科技股份有限公司
MODENA TECHNOLOGY LIMITED

来自世界各地的肯定

APPROVAL FROM ALL OVER THE WORLD



炉火纯青 Mastered Fire Engineered Excellence

自成立以来，摩德娜已为海内外市场客户提供了过千条陶瓷生产线，均得到了客户的认可。数字还在继续增加中......

More than 1,000 production lines have been successfully supplied by Modena in both domestic and overseas market and approved by the customers. And the counting still goes on ... ...

2003

佛山市摩德娜机械有限公司（广东摩德娜科技股份有限公司前身）注册成立。

Foshan City Modena Machinery Co.,Ltd.(predecessor of Modena Technology ltd.) was established.

2008

3000平方米的新办公大楼投入使用。

New office building of 3,000 m2 put into operation.

2010

佛山市摩德娜机械有限公司通过CE认证，同年获评定为“广东省高新技术企业”。

Modena qualified for CE certification and ranked as “Provincial new hi-tech enterprise”.

2011

摩德娜全资子公司新兴县摩德娜机械有限公司（占地150亩）在广东省云浮市新兴县新城工业园奠基。

Wholly-owned subsidiary of Modena, Xinxing Modena Machinery Limited, laid its foundation in Xincheng Industrial Park in Xinxing Town, Yunfu City, Guang-dong Province, covers 100,000sqm area.

2012

摩德娜MFS-305型大规格抛光砖用高效节能宽体窑获国家科学技术部评定为“国家重点新产品”。

Modena’s MFS-305 high-efficiency wide-body kiln for polished tiles was awarded as “National Key and New Product” by the Ministry of Science and Technology.

2015

摩德娜自主研发辊道窑新型节能系统RCH获得国家技术专利（ZL201510927025.0）。

Modena’s self-developed new type of energy-saving system RCH obtained National Patent (No. ZL201510927025.0).

2017

摩德娜成功研发并推出新型电子空燃比（ADC）系统并获得国家专利（ZL201711461351.2）。极大程度地赋予辊道窑以更大的生产弹性和更高程度的自动化水平，并在能耗上达到了390kal/kg（瓷质砖），为国际先进水平。

Modena researched and developed its all-new Air/Gas Smart Control system (ADC) and obtained National Patent (No. ZL201711461351.2). The ADC system empowers the roller kiln with more productivity and higher level of automation, gas consumption reaches 390kcal/kg (for vitrified products) which is at the international leading level.

2018

亚洲首条双层大规格岩板窑炉生产线在印度LIOLI工厂一次性投产成功，整线热工设备由摩德娜提供。

The very first Double-decker kiln for large-format sintered slab production line in Asia, supplied by Modena to LIOLI, was put into production successfully.

2020

在中国岩板爆发的元年，摩德娜得到多家国内陶瓷头部企业（蒙娜丽莎，东鹏和金牌等）的青睐，供应多条INFINITY系列双层岩板窑炉和多层干燥器。截止2020年9月，亚洲区域的所有双层岩板窑炉（超过9条）均为摩德娜制造。

The year of 2020 is the year of Sintered Slab in China, Modena’s INFINITY series thermal equipment (the Double-decker kilns and multilayer dryers) enjoyed the most popularity from the top brands (Monalisa, Dongpeng, Goldmedal etc.). Till September 2020, all the Double-decker kilns for sintered slab in Asia are provided by Modena (more than 9 lines).

2021

在后疫情时代，摩德娜整体营业收入创下历史记录。在出口市场尤为突出，3352个货柜的年度出货量冠绝行业，覆盖全球各大陶瓷产区，且以”全窑型“的全面数据回答了新时代的问卷。

In the post epidemic era, Modena set a historical record of annual turnover. It is particularly prominent in the overseas market. The annual shipment of 3,352 containers is the largest in the industry, covering all major ceramic zones in the world, and has answered the questionnaire of the new era with the a Full Slam of kiln models.

2022

摩德娜与霍尼韦尔达成氢能应用战略合作，共同开发陶瓷行业低碳燃烧技术。此举不仅响应国家“双碳”目标，更推动窑炉清洁能源结构的革命性突破，为全球陶瓷产业低碳发展提供了创新解决方案。

Modena and Honeywell established a strategic partnership in hydrogen energy applications to jointly develop low-carbon combustion technologies for the ceramic industry. This initiative not only aligns with China's "Dual Carbon" goals but also drives a revolutionary breakthrough in the clean energy structure of kilns, providing innovative solutions for the global ceramic industry's low-carbon development.

2023

摩德娜与新玻尔合作的10万m²/天超大产量中板窑炉生产线成功实现规模化量产，通过创新的生产架构和优化的热工系统，提供了更高效率、更稳定的生产解决方案，创下全球窑炉单线产能新纪录！

Modena and XinBoer successfully achieved mass production with their groundbreaking 100,000 m²/day porcelain tile kiln production line. Featuring an innovative production architecture and optimized thermal system, this project delivers unprecedented efficiency and production stability, setting a new world record for single-line kiln capacity in the ceramic industry.

2024

摩德娜与赣锋锂业合作的碳酸锂项目成功启动，通过独特的连续煅烧方式实现矿物中锂元素的释放与转化，展现了摩德娜技术的跨界应用，标志着摩德娜向多元化热工装备服务商的转型迈出关键一步。

Modena and Ganfeng Lithium successfully launched their lithium carbonate project. The innovative continuous calcination technology enables efficient lithium extraction and conversion, demonstrating Modena's cross-industry technological capabilities. This milestone marks a crucial step in Modena's transformation into a diversified thermal equipment solutions provider.

公司简介

COMPANY PROFILE

广东摩德娜科技股份有限公司（原佛山市摩德娜机械有限公司，以下简称“公司”）成立于2003年，是一家专业从事热工装备及成套生产线研发、生产、销售和售后服务的高新技术企业。公司以陶瓷机械为起点，长期专注于干燥与烧成技术的创新与应用，逐步形成以节能、智能和环保为核心的技术体系，产品远销印度、越南、美国、泰国、印尼、马来西亚、孟加拉国、巴基斯坦、土耳其、沙特阿拉伯、阿联酋、埃及、墨西哥、哥伦比亚等国家和地区，连续多年成为中国窑炉与陶瓷整线装备出口领先企业。

在持续深耕传统热工领域的同时，摩德娜积极布局新能源材料装备，基于二十多年在高温热工装备方面的技术积累，开发出适用于锂云母、锂辉石等资源的提锂系统解决方案（Lithium Extraction Solution）。该系统覆盖从物料预处理、煅烧反应、破碎、酸浸至后处理的关键工序，具备能效高、稳定性好、系统集成度高等优势，为新能源材料行业提供高效、绿色的装备支持。

凭借国际化的专业团队、先进的核心技术、完善的运作管理及高性价比的产品，摩德娜在国际市场上具备强大的竞争力。公司始终不忘企业的社会责任，坚持以节能减排、绿色制造为发展方向，通过技术创新推动产业升级，致力于让中国热工装备走向世界，成为全球领先的节能环保型材料装备供应商。

Modena Technology Limited (formerly Foshan City Modena Machinery Co., Ltd.) was founded in 2003 as a high-tech enterprise specializing in the R&D, manufacturing, sales, and service of thermal equipment and complete production lines. Originating from the ceramic machinery sector, Modena has focused for over two decades on innovations in drying and firing technologies, developing an energy-efficient, intelligent, and environmentally friendly system portfolio. Our products are widely exported to India, Vietnam, the U.S., Thailand, Indonesia, Malaysia, Bangladesh, Pakistan, Turkey, Saudi Arabia, the U.A.E., Egypt, Mexico, and Colombia, making Modena one of the leading Chinese exporters of kilns and complete ceramic production plants.

While continuing to strengthen its core business in thermal engineering, Modena is now expanding into the new energy materials field, leveraging its rich experience in high-temperature technology to develop Integrated Lithium Extraction Solutions for resources such as lepidolite and spodumene. The system covers key processes from material feeding, calcination, crushing, and acid leaching to post-treatment, featuring high energy efficiency, system stability, and strong process integration—providing reliable and sustainable equipment for the lithium extraction industry.

With its international professional team, advanced core technologies, excellent management, and highly cost-effective products, Modena has become a highly competitive player in the global market. The company upholds its social responsibility and adheres to the principle of energy conservation and environmental protection, driving industrial development through innovation. Modena is committed to becoming a world-class supplier of energy-saving and environmentally friendly material processing equipment.

目录 CONTENTS

提锂系统解决方案

INTEGRATED LITHIUM EXTRACTION SOLUTION(Lepidolite as source)

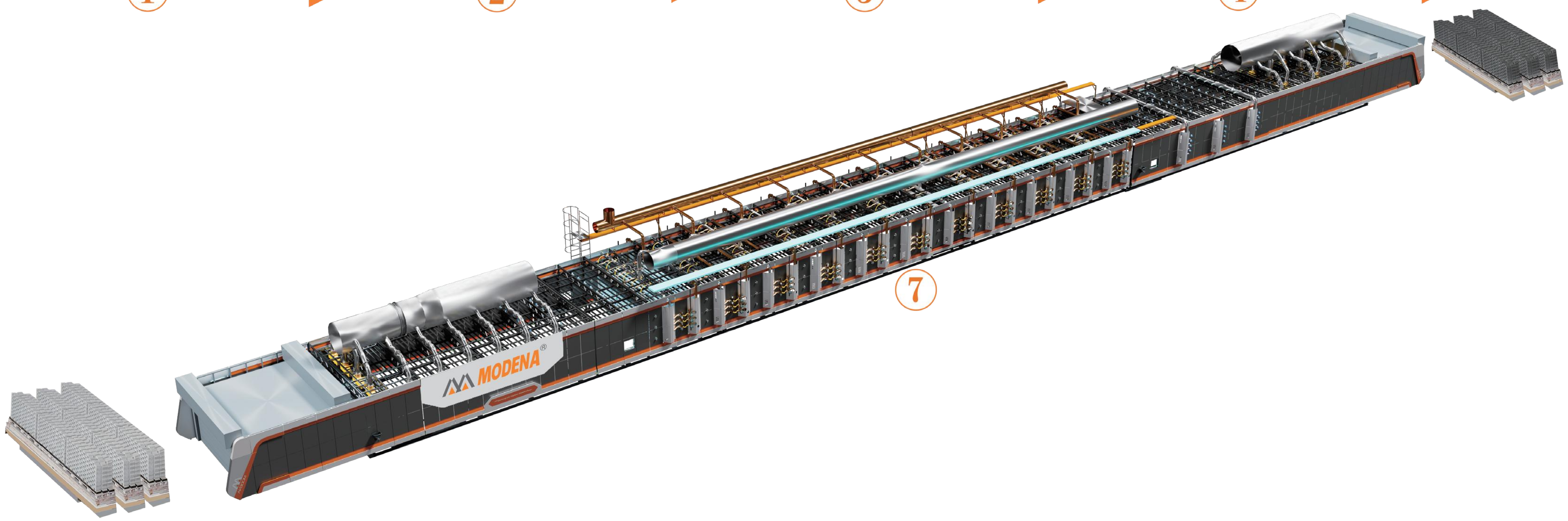
原料上料
RAW MATERIAL FEEDING
①

辅料存储
ADDITIVE STORAGE
②

混料和输送
BATCHING & CONVEYING
③

加湿搅拌
MOISTENING & MIXING
④

压制
COMPACTION
⑤



⑥
干燥
DRYING

⑦
煅烧
CALCINATION

⑧
卸车
UNLOADING

⑨
破碎
CRUSHING

⑩
浸出
LEACHING

提锂解决方案

LITHIUM EXTRACTION SOLUTION

随着新能源汽车行业的快速发展，对锂离子电池关键原材料碳酸锂的需求急剧增长，提锂行业传统锂辉石资源分布少、资源逐渐消耗、价格持续上涨，而锂云母分布广泛，储量大，成本低，因此锂云母提锂技术成为当前研究热点。在众多锂云母提锂工艺中，隧道窑焙烧技术因其能耗低、污染小、操作稳定等优势脱颖而出。以上流程图显示了隧道窑焙烧锂云母制备新能源电池材料的技术原理、工艺流程、设备创新及发展前景，为相关领域的研究与产业化提供参考。

With the rapid development of the new energy vehicle industry, the demand for lithium carbonate, a key raw material for lithium-ion batteries, has sharply increased. The traditional spodumene resources in the lithium extraction industry are scarce, gradually consumed, and prices continue to rise. However, lepidolite is widely distributed, has large reserves, and low costs. Therefore, lithium extraction technology from lithium mica has become a current research hotspot. Among numerous lithium extraction processes using lepidolite, tunnel kiln calcination technology stands out due to its advantages of low energy consumption, minimal pollution, and stable operation. The above flowchart shows the technical principles, process flow, equipment innovation, and development prospects of tunnel kiln calcination lepidolite to prepare new energy battery materials, providing reference for research and industrialization in related fields.

传统焙烧工艺多采用回转窑设备，虽然技术成熟，但存在能耗高（天然气消耗通常超过 $100Nm^3/T$）、废气排放量大、易结窑等问题。
隧道窑焙烧锂云母与传统回转窑相比有以下优势：

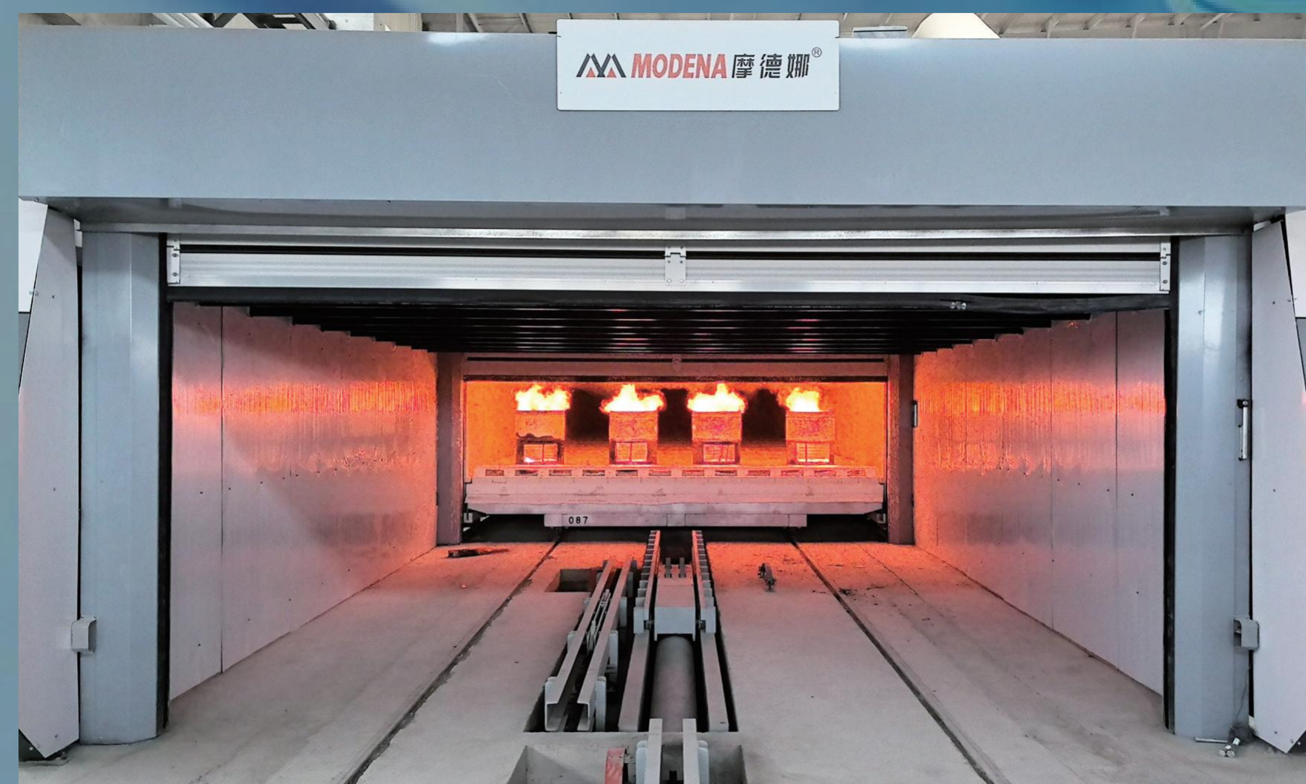
- 能耗显著降低：通过优化窑炉结构和热工制度，天然气消耗可降至 $60Nm^3/T$ 以下
- 温度控制精确：分区控温使物料受热更均匀，锂转化率可达 93% 以上
- 环保性能优越：封闭式设计减少废气排放，余热回收系统提高能源利用率
- 设备投资较少：相比回转窑，隧道窑建设成本降低约 30%

正是基于这些优势，近年来隧道窑焙烧技术在国内锂云母提锂领域得到快速推广。

Traditional calcination processes often use rotary kiln equipment. Although the technology is mature, it has problems such as high energy consumption (natural gas consumption usually exceeds $100Nm^3/T$), large exhaust emissions, and easy kiln formation.
Compared with traditional rotary kilns, tunnel kiln calcination of lepidolite has the following advantages:

- Significant reduction in energy consumption: By optimizing the kiln structure and thermal system, natural gas consumption can be reduced to below $60Nm^3/T$
- Accurate temperature control: zone temperature control makes the material heated more evenly, and the lithium conversion rate can reach over 93%
- Superior environmental performance: Closed design reduces exhaust emissions, waste heat recovery system improves energy utilization efficiency
- Less equipment investment: Compared to rotary kilns, the construction cost of tunnel kilns is reduced by about 30%

It is precisely based on these advantages that tunnel kiln calcination technology has been rapidly promoted in the field of lithium extraction from lepidolite in China in recent years.



原料上料
RAW MATERIAL FEEDING

锂云母属于层状硅酸盐矿物，其晶体结构由[SiO]^{2}四面体层和[AlO]八面体层交替排列组成，锂离子被牢固地束缚在八面体空隙中。当温度升至 500-600℃时，锂云母开始脱除结构水和羟基；温度继续升高至 700-900℃时，晶体结构发生坍塌重组，锂从晶格中释放出来。此时若存在适当的添加剂（如钙盐、硫酸盐等），游离的锂离子将与添加剂反应生成可溶性锂盐（主要为硫酸锂），为后续浸出工序创造条件。

Lepidolite belongs to layered silicate minerals, and its crystal structure consists of alternating [SiO] ^{2} tetrahedral layers and [AlO] octahedral layers. Lithium ions are firmly bound in the octahedral voids. When the temperature rises to 500-600 ℃, lepidolite begins to remove structural water and hydroxyl groups; When the temperature continues to rise to 700-900 ℃, the crystal structure collapses and reorganizes, and lithium is released from the lattice. If appropriate additives (such as calcium salts, sulfates, etc.) are present at this time, free lithium ions will react with the additives to form soluble lithium salts (mainly lithium sulfate), creating conditions for subsequent leaching processes.

辅料存储
ADDITIVE STORAGE

生产过程中所需的各种化学试剂（如浓硫酸）、燃料（如天然气、煤粉）和添加剂等，需要有专门的储罐或仓库进行安全储存。然后根据工艺要求，通过计量泵或输送系统，精确地投加到主工艺流程中。

Various chemical reagents (such as concentrated sulfuric acid), fuels (such as natural gas and pulverized coal), and additives required in the production process need to be stored safely in specialized storage tanks or warehouses. Then, according to process requirements, they are precisely added to the main process flow through metering pumps or conveying systems.

混料和输送
BATCHING & CONVEYING

预处理后的锂云母与添加剂按比例 (通常 100:5 至 100:60) 在混料机中均匀混合。添加剂的选择需考虑矿石特性，常用组合包括：
• 碳酸钙 + 硫酸钠：适用于高硅锂云母，促进硅酸盐分解。
• 氢氧化钙 + 硫酸钙：适合高铁锂云母，抑制铁对锂的包裹。
• 复合添加剂：针对复杂成分矿石，如硫酸钠 + 硫酸钾 + 氧化钙组合。
混合物料的水分含量需控制在 3-8% 之间。水分过低不利于后续压制成型，过高则会增加烘干能耗。
部分工艺采用干法配料，省略烘干环节，直接进入下一工序。

Pre treated lepidolite and additives are uniformly mixed in a mixer in a ratio of 100:5 to 100:60. The selection of additives should consider the characteristics of the ore, and common combinations include:
• Calcium carbonate+sodium sulfate: suitable for high silica lepidolite, promoting silicate decomposition.
• Calcium hydroxide+calcium sulfate: suitable for high-speed iron lepidolite, inhibiting iron encapsulation of lithium.
• Composite additives: targeting complex mineral components such as sodium sulfate+potassium sulfate+calcium oxide combination.
The moisture content of the mixed material should be controlled between 3-8%. Low moisture content is not conducive to subsequent compression molding, while high moisture content will increase drying energy consumption.
Some processes use dry batching, omitting the drying step and directly entering the next process.

加湿搅拌
MOISTENING & MIXING

加湿搅拌与均化处理
配料完成后，混合物料需进行关键的加湿搅拌与均化处理，此工序是确保后续成型与焙烧反应均匀性的核心环节。该过程通常在双轴搅拌机中完成，该设备集搅拌、加湿、均化功能于一体。
工艺目的：
湿度调节： 通过向搅拌机内喷入雾化工艺水，将混合料的含水量精确控制在3%-8% 的最佳区间。
均匀化：对锂云母与添加剂（如碳酸钙、硫酸钠等）进行高强度剪切、对流和扩散混合，彻底消除因原料比重和粒度差异可能带来的分层和偏析，确保每一部分物料的成分高度一致。
预活化： 在搅拌过程中，水分和添加剂与锂云母颗粒表面充分接触，可起到一定的预活化作用，为后续高温下的化学反应奠定基础。

Humidification stirring and homogenization treatment
After the ingredients are completed, the mixed materials need to undergo key humidification, stirring, and homogenization processes, which are the core steps to ensure the uniformity of subsequent forming and calcination reactions. This process is usually completed in a dual axis mixer, which integrates mixing, humidification, and homogenization functions.
Process objective:
Humidity regulation: By spraying atomized process water into the mixer, the moisture content of the mixture is precisely controlled within the optimal range of 3% -8%.
Homogenization: High strength shear, convection, and diffusion mixing of lepidolite and additives (such as calcium carbonate, sodium sulfate, etc.) is carried out to completely eliminate the possible stratification and segregation caused by differences in raw material density and particle size, ensuring that the composition of each part of the material is highly consistent.
Pre activation: During the stirring process, water and additives come into full contact with the surface of lepidolite particles, which can play a certain pre activation role and lay the foundation for subsequent chemical reactions at high temperatures.

压制
COMPACTION

有两种主要方式：一种是将混合料压制成砖块（尺寸通常 250×120×60mm 左右），每车码放 5-15 层；另一种是将物料装入耐火容器（每车 10-100 个容器，总重 200-5000kg）。前者适合自动化生产线，后者操作更灵活。成型后的生料强度需适中，既要承受码垛压力，又要在焙烧后易于破碎浸出。

There are two main ways: one is to press the mixture into tiles (usually around 250 × 120 × 60mm in size) and stack them in 5-15 layers per vehicle; Another method is to load the materials into fire-resistant containers (10-100 containers per vehicle, with a total weight of 200-5000kg). The former is suitable for automated production lines, while the latter is more flexible in operation. The strength of the formed raw material needs to be moderate, which not only needs to withstand stacking pressure, but also is easy to break and leach after calcinatior.

干燥
DRYING

目前主流的干燥方式是与隧道窑紧密耦合的余热干燥，这是实现节能降耗的关键。利用焙烧冷却段的余热。 隧道窑冷却段需要将约1000℃的熟料冷却至150℃以下出窑，这个过程会产生大量中低温废热（通常200-400℃）。将这些热风引出，作为干燥介质，是最高效的能源利用方式。

Controllable cooling technology: The roasted hot material (about 1000 ℃) cannot directly contact cold air, otherwise it may cause rapid cooling cracking or lithium salt coating of the material. Modern tunnel kilns often use gradient cooling methods:
High temperature slow cooling zone (1000-600 ℃): utilizing the waste heat from the kiln tail to preheat the combustion air and naturally cool down
• Medium temperature controlled cold zone (600-300 ℃): Introduce some external air to control the cooling rate
Low temperature rapid cooling zone (300-150 ℃): Activate the forced air cooling system to quickly cool down to the kiln outlet temperature

控制参数 Control parameters	典型范围/要求 Typical scope/requirements	控制要点和说明 Control points and instructions
干燥介质温度 Dry medium temperature	100 - 250 ℃	入口温度不宜超过250℃，避免料坯表面过烧。温度需根据料坯初始水分和干燥阶段进行分段控制。 The inlet temperature should not exceed 250 ℃ to avoid overburning of the billet surface. The temperature needs to be controlled in sections according to the initial moisture content of the billet and the drying stage.
干燥介质风速 Dry medium wind speed	1 - 3 m/s	风速过小，传热传质效率低；风速过大，可能吹垮料坯或导致干燥不均。 Low wind speed leads to low heat and mass transfer efficiency; Excessive wind speed may blow down the billet or cause uneven drying.
干燥时间 drying time	2 - 8 h	与料坯形状、厚度、初始水分含量密切相关。砖坯较厚，时间需延长。 It is closely related to the shape, thickness, and initial moisture content of the billet. The tiles are thick and the time needs to be extended.
最终水分含量 Final moisture content	< 1.0%	必须使用快速水分测定仪进行抽样检测，确保达标。 A rapid moisture analyzer must be used for sampling and testing to ensure compliance.
环境湿度（排湿控制） Environmental humidity (dehumidification control)	相对湿度 < 30% relative humidity	通过调节排湿风机的频率或风门开度来控制干燥室内的环境湿度。 Control the ambient humidity inside the drying room by adjusting the frequency of the dehumidification fan or the opening of the air door.

煅烧
CALCINATION

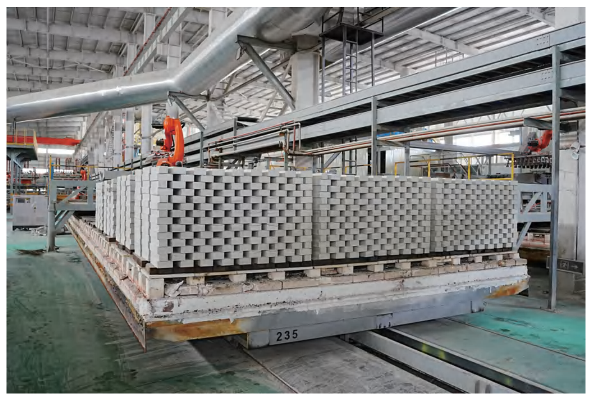
锂云母隧道窑焙烧主要化学反应及温度范围。
Main chemical reactions and temperature range of lepidolite tunnel kiln calcination.

温度范围（°C） Temperature range (° C)	主要物理化学变化 Main physical and chemical changes	反应产物 Reaction product
100~300	脱除吸附水和部分结晶水 Remove adsorbed water and some crystal water	干燥的锂云母 Dry lepidolite
300~600	结构羟基脱除，晶体开始膨胀 Removal of structural hydroxyl groups, crystal begins to expand	无定形锂云母 Amorphous lepidolite
600~800	晶体结构破坏，锂开始释放 Crystal structure destruction, lithium begins to release	游离锂离子 Free lithium ions
800~1000	与添加剂反应生成可溶锂盐 Reacts with additives to generate soluble lithium salts	Li^{+}、SO_4^{-}等 Li^{+}、SO_4^{-} etc
>1000	过度烧结，锂可能被包裹 Excessive sintering may cause lithium to be encapsulated	难溶化合物 Insoluble compound

卸车
UNLOADING

烧成后的砖坯由机械手进行自动卸载到输送线上进入下一个工序。整个卸料过程与窑车运输系统紧密联动。当一台窑车卸料完毕并驶离后，下一台满载的窑车会自动进入卸料工位，形成一个连续的自动化作业循环。

The material after calcination will be unloaded by robotic arm to a conveyor and transport tothe next process. The entire unloading process is closely integrated with the kiln car transportation system. When one kiln car completes unloading and departs, the next fully loaded kiln car will automatically enter the unloading position, forming a continuous automated operation cycle.



破碎
CRUSHING

焙烧料冷却与破碎:

冷却要求：出窑物料需冷却至80℃以下，防止高温物料遇水急骤沸腾;
破碎粒度：采用对辊破碎机将物料破碎至0.5-2mm，增加比表面积;
磁选除铁：通过强磁选去除焙烧过程中混入的铁质杂质;

Cooling and crushing of calcinated materials:

Cooling requirements: The materials exiting the kiln need to be cooled to below 80 ℃ to prevent high-temperature materials from boiling rapidly when encountering water.
Crushing particle size: Use a roller crusher to crush the material to 0.5-2mm, increasing the specific surface area.
Magnetic separation for iron removal: using strong magnetic separation to remove iron impurities mixed in during the calcination process.

浸出

LEACHING

焙烧后的锂云母熟料中，锂主要以可溶性硫酸锂（Li_2SO_4）形式存在，同时含有少量未完全转化的锂化合物及杂质元素。浸出过程基于固液萃取原理，通过水或稀酸溶液将锂离子从固相转移至液相。现代锂云母浸出多采用三级或四级逆流浸出工艺，最大限度提高锂回收率。
典型四级逆流浸出流程：

新焙烧料 → 第四级浸出（贫液） → 第三级浸出 → 第二级浸出 → 第一级浸出（浓液）
第一级浸出：使用最后一次的浸出液（相对富锂）与新焙烧料接触，
末级浸出：使用新鲜水或极贫液，充分回收残余锂，
锂回收率：四级逆流浸出系统总回收率可达97-98%。

In the calcined lepidolite clinker, lithium mainly exists in the form of soluble lithium sulfate (Li_2SO_4), while containing a small amount of incompletely converted lithium compounds and impurity elements. The leaching process is based on the principle of solid-liquid extraction, which transfers lithium ions from the solid phase to the liquid phase through water or dilute acid solution.
Modern lithium mica leaching often adopts a three-stage or four stage countercurrent leaching process to maximize lithium recovery rate.
Typical four stage countercurrent leaching process:

New roasted material → Fourth stage leaching (lean solution) → Third stage leaching → Second stage leaching → First stage leaching (concentrated solution)
First level leaching: Use the last leaching solution (relatively lithium rich) to come into contact with the new roasted material.
Final leaching: Use fresh water or extremely lean solution to fully recover residual lithium.
Lithium recovery rate: The total recovery rate of the four stage countercurrent leaching system can reach 97-98%.

其他提锂解决方案 OTHER LITHIUM EXTRACTION SOLUTION

锂辉石回转窑煅烧工艺

ROTARY KILN CALCINATION FOR SPODUMENE

锂辉石回转窑煅烧工艺流程包括原料制备、混合、入窑、煅烧、冷却、收尘和产品包装等工序。首先，将锂辉石、石灰石和碳酸钠等原料按照一定比例破碎和粉磨，然后进行计量和混合。混合均匀后的原料经过输送设备送入回转窑的进料端。随着回转窑的转动，原料在高温下进行煅烧和反应。出料端排出的高温物料经过冷却器进行快速冷却，同时回收余热。冷却后的物料进入收尘器进行收尘处理，收集细颗粒物和有害气体。最后，经过包装工序得到碳酸锂产品。

The calcination process of spodumene rotary kiln includes raw material preparation, mixing, kiln feeding, calcination, cooling, dust collection, and product packaging. Firstly, raw materials such as spodumene, limestone, and sodium carbonate are crushed and ground in a certain proportion, and then measured and mixed. The mixed raw materials are sent to the feeding end of the rotary kiln through the conveying equipment. As the rotary kiln rotates, the raw materials undergo calcination and reaction at high temperatures. The high-temperature material discharged from the discharge end is rapidly cooled by a cooler while recovering waste heat. The cooled material enters the dust collector for dust collection treatment, collecting fine particles and harmful gases. Finally, lithium carbonate products are obtained through packaging processes.

1. 原料预处理

（1）破碎与筛分
原矿经颚式破碎机粗碎至≤100mm。
再经圆锥破碎机/反击破中碎至≤30mm。
最后进入球磨机细碎至≤0.074mm（200目），提高煅烧反应效率。

（2）磁选除铁
采用干式磁选机去除Fe_2O_3（要求≤0.5%），避免影响后续浸出。

（3）配矿与均化
混合不同品位锂辉石矿，控制Li_2O含量≥5%。
通过均化库储存，确保成分稳定。

1. Raw material pretreatment

(1) Crushing and screening
The raw ore is roughly crushed to ≤ 100mm by a jaw crusher.
Further crushed by cone crusher/counterattack to ≤ 30mm.
Finally, it enters the ball mill for fine crushing to ≤ 0.074mm (200 mesh) to improve the efficiency of calcination reaction.

(2) Magnetic separation for iron removal
Use a dry magnetic separator to remove Fe_2O3 (with a requirement of ≤ 0.5%) to avoid affecting subsequent leaching.

(3) Mineral blending and homogenization
Mix different grades of spodumene ore and control the Li_2O content to be ≥ 5%.
Ensure ingredient stability through homogenization storage.

2. 预热脱水（200~800℃）

（1）多级旋风预热
物料进入3~4级旋风预热器，与窑尾高温废气（800~1000℃）逆流换热。
温度逐步升至600~800℃，脱除游离水和部分结晶水。

（2）关键控制参数
预热器出口废气温度≤300℃（余热回收）。
物料含水率降至≤1%。

2. Preheating and dehydration (200~800 ℃)

(1) Multi stage cyclone preheating
The material enters the 3-4 stage cyclone preheater and exchanges heat with the high-temperature exhaust gas (800~1000 ℃) at the kiln tail in reverse flow.
Gradually raise the temperature to 600-800 ℃ and remove free water and some crystalline water.

(2) Key control parameters
Preheater outlet exhaust gas temperature ≤ 300 ℃ (waste heat recovery).
The moisture content of the material is reduced to ≤ 1%.

3. 高温煅烧（950~1100℃）

（1）回转窑煅烧
预热带（窑头~25%长度）：800~950℃，进一步脱水。
高温带（中部50%长度）：950~1100℃，完成α→β相变（转化率≥95%）。
冷却带（窑尾25%长度）：降温至800℃以下，稳定β型结构。

（2）关键操作要点
温度控制：严格控制在1050±50℃，避免过烧（>1150℃导致玻璃化）或欠烧（<950℃转化不足）。
窑速调节：0.5~3 rpm，物料停留时间40~60分钟。
火焰形状：采用长焰燃烧，避免局部高温结圈。

4. 成品储存与输送

煅烧后的β-锂辉石经链板输送机送至料仓，供后续酸浸或碱法加工。

3. High temperature calcination (950~1100 ℃)

(1) Rotary kiln calcination
Pre tropical zone (kiln head~25% length): 800~950 ℃, further dehydrated.
High temperature zone (50% length in the middle): 950~1100 ℃, complete the α→β phase transition (conversion rate ≥ 95%).
Cooling zone (25% length of kiln tail): Cool down to below 800 ℃ to stabilize the β - shaped structure.

(2) Key operational points
Temperature control: Strictly control at 1050 ± 50 ℃ to avoid overburning (>1150 ℃ causing vitrification) or undercooking (<950 ℃ insufficient conversion).
Kiln speed adjustment: 0.5~3 rpm, material retention time of 40~60 minutes.
Flame shape: Long flame combustion is used to avoid local high-temperature ring formation.

4. Finished product storage and transportation

The calcined β - lithium pyroxene is transported to the silo by a chain plate conveyor for subsequent acid leaching or alkaline processing.