The revolution in ultrafine grinding:
E_{max} – faster, finer, cooler

The E_{max} is an entirely new type of ball mill which was specifically designed by RETSCH for high energy milling down to the nanometer scale. The impressive speed of 2,000 min^{-1}, so far unrivaled in a ball mill, in combination with the special grinding jar design generates a vast amount of size reduction energy. The unique combination of impact and friction results in ultrafine particle sizes in the shortest amount of time. Thanks to the new liquid cooling system, excess thermal energy is quickly discharged preventing both sample and mill from overheating, even after long grinding times. The application examples in this article show impressively that the E_{max} achieves the desired grind sizes in a fraction of the time that conventional ball mills need.

The High Energy Ball Mill E_{max} features two grinding stations and a maximum speed of 2000 min^{-1}

COOLING AND TEMPERATURE CONTROL

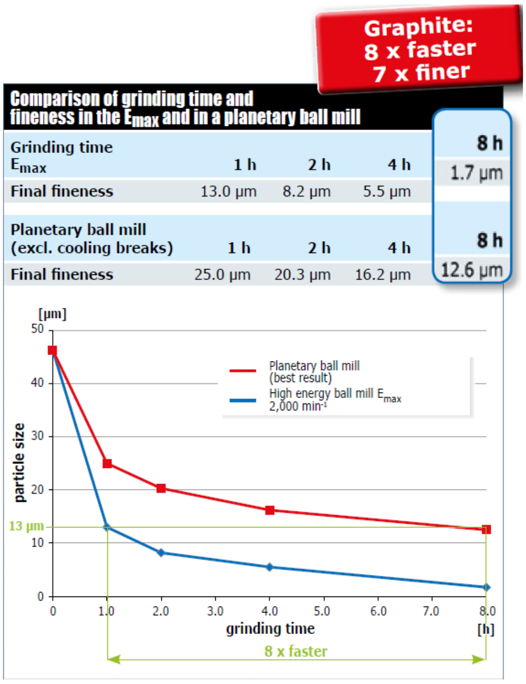
The biggest challenge when developing a high energy ball mill is controlling the temperature. The very high energy produced by ball milling leads to an extreme heat increase inside the grinding jars. RETSCH solved this problem by creating an innovative integrated water-cooling system. Grinding breaks for cooling, which are unavoidable in conventional ball mills even after only 30 minutes grinding at moderate speed, are usually not necessary when using the High Energy Ball Mill E_{max}. To further reduce the temperature, the mill can be connected to a chiller or the tap.

The E_{max} allows the user to carry out the grinding process within a defined temperature range by setting a minimum and a maximum temperature. When the maximum temperature is exceeded, the mill automatically stops and starts again upon reaching the minimum temperature. Cooling can be an essential advantage, especially if heat-sensitive samples are processed or if an alcohol like isopropanol has been added to the sample. Isopropanol evaporates at 82 °C which makes the pressure inside the jar rise considerably. If the temperature remains below this value, the pressure inside the jar and the stress on the sealing are reduced. Moreover, the grinding jar can be opened shortly after the grinding is finished.

With conventional ball mills the user needs to find out about the required cycles of grinding and cooling by empirical trials. If the cooling breaks are not long enough, the sample will be warmed too much. The E_{max}, however, can be operated with variable grinding times and grinding breaks thanks to the definition of the temperature limits. Thus, the grinding process is always reproducible.

FASTER AND FINER

In addition to the avoidance of cool down breaks the efficient high energy grinding mechanism with up to 2000 min^{-1} further decreases the processing time. To produce particles in the sub-micron range, high energy milling must be carried out for a long period of time based on the friction that is generated by a large number of small grinding balls. This process produces a lot of heat in conventional ball mills, making grinding breaks indispensable. In comparison the E_{max} offers an enormous time saving of several hours and the achieved grind size is often much finer.



When grinding graphite the E_{max} clearly outmatches the conventional ball mill with regards to grinding time and final fineness.

HIGH ENERGY INPUT

The high energy input of the E_{max} not only improves grind sizes in the submicron range, but is also beneficial for processes to produce new materials, such as mechanical alloying. Kinetic energy is produced by large, heavy grinding balls hitting the sample material at high revolution speed, generating chemical reactions of the materials used. In mechanical alloying, e.g. of germanium with silicon, this impact effect can cause the alloy partners to bond. If the substances have to be pulverized first, they can be pre-crushed directly in the E_{max}. Usually the process times for mechanical alloying are several hours; in conventional ball mills additional time for grinding breaks must be added. In the alloying process of germanium with silicon the total process time was reduced drastically from 14.5 h in the conventional ball mill to 9 h in the E_{max}. Producing new material in the High Energy Ball Mill E_{max} not only saves time, there are even more advantages: In the example mentioned above, the produced material was virtually non-amorphous and caking of the material, which is a common problem in conventional ball mills, could be avoided.

APPLICATION EXAMPLES

The following examples (table 1) demonstrate the advantages – faster, finer, cooler – of using the High Energy Ball Mill E_{max} for grinding processes.

Table 1: Application examples and results of grinding different samples in the High Energy Ball Mill E_{max}

Sample	Specific feature	Sample amount	Grinding time	Final fineness
Chitin [(1)]	Successful avoidance of temperature-related color change, E_{max} 40°C cooler than conventional ball mill	10 g	8 h	< 164 µm
Polysaccharide [(1)]	Temperature control, 80°C were not exceeded in the E_{max}	10 g	2 h	< 8.9 µm
Melamine resin [(1,2,3)]	Temperature of 50°C was not exceeded, whereas 55°C in conventional ball mill was reached despite long grinding breaks. 2 x finer and 36 x faster than in conventional ball mill, drastic time saving in E_{max}: 33 h!	35 g	3 h	< 133 µm
Wood [(1)]	Temperature limit of 30°C was not exceeded	3 g	10 min	< 64 µm
Titanium dioxide [(3)]	Nano grinding <100 µm only successful in E_{max} (5 x finer than conventional ball mill)	10 g	30 min	< 80 nm
Barium titanate [(2)]	Nano grinding <100 µm, 2 h time saving compared to conventional ball mill	12 g	2 h	< 95 nm
Graphite [(2,3)]	Extreme time saving (24 x faster than conventional ball mill) and very good result (7 x finer than conventional ball mill)	5 g	8 h	< 1.7 µm
Glass frit [(2)]	Fast grinding, 1 h time saving	15 g	10 min	< 1.4 µm
Silicon & Germanium [(4)]	Mechanical alloying: good result; 4-5 h faster than conventional ball mill, nearly no amorphous parts and no caking in the E_{max}	3.63 g Si 2.36 g Ge	20 min PC + 4 h alloying-process	Not analyzed

PC = Pre-crushing;
1 = Cooling, 2 = Time saving, 3= Better final fineness, 4 = Mechanical alloying with high energy input

MAXIMUM SAFETY

The E_{max} was designed for maximum operational safety. The lids of the grinding jars have to be screwed on the grinding jars, so that these are tightly closed for wet grinding and if pressure increases inside the grinding jars. Sensors control the position of the grinding jar; the mill cannot be started if the position is not correct. Possible imbalances are controlled at all times. If they become too strong the mill automatically stops. The remaining grinding time is displayed and the process can be re-started once balance has been restored.

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