Size reduction with Planetary Ball Mills
RETSCH’s innovative Planetary Ball Mills meet and exceed all requirements for fast and reproducible grinding down to the nano range. They are used for the most demanding tasks, from routine sample processing to colloidal grinding and advanced materials development.
Planetary Ball Mills

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RETSCH Planetary Ball Mills are used for the pulverization of soft, fibrous, hard and brittle materials. They achieve a very high final fineness down to the submicron range. The feed size depends on the mill and can be as large as 10 mm. If the sample feed size is larger than this then the sample must first undergo preliminary size reduction.

Fine size reduction with impact and friction can also be carried out with RETSCH Mixer Mills. They are used for small sample volumes and cryogenic grinding.

For the coarse and preliminary size reduction of hard, brittle or even tough materials, RETSCH Jaw Crushers are the instruments of choice. In contrast, bulky, soft, fibrous or elastic materials are best prepared in RETSCH Cutting Mills.

For the subsequent pulverization a representative part-sample must first be obtained, e.g. with RETSCH's Sample Divider PT 100. For preparing solid samples for XRF analyses RETSCH offers two models of hydraulic Pellet Presses.
Applications

RETSCH Planetary Ball Mills pulverize and mix soft, medium-hard to extremely hard, brittle and fibrous materials. They are suitable for both dry and wet grinding. These versatile mills are used successfully in virtually all industry and research sectors, where the quality control process places the highest demands on purity, speed, fineness and reproducibility.

Free test grinding

As part of RETSCH’s professional customer support we offer our customers the individual advice required to find the optimum solution for their sample preparation task. To achieve this our application laboratories process and measure samples free-of-charge and provide a recommendation for the most suitable method and instrument.

For more information please visit our website www.retsch.com/testgrinding.

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<tr>
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<td></td>
<td>250 ml ZrO₂</td>
<td>15 x 20 mm ZrO₂</td>
<td>1 - 20 mm</td>
<td>130 ml</td>
<td>2 min</td>
<td>450 rpm</td>
<td>63 µm</td>
</tr>
<tr>
<td>Cement clinker</td>
<td>5 - 10 drops of methanol</td>
<td>125 ml ZrO₂</td>
<td>6 x 20 mm ZrO₂</td>
<td>2 - 5 mm</td>
<td>50 g</td>
<td>5 min</td>
<td>450 rpm</td>
<td>100 µm</td>
</tr>
<tr>
<td>Coal</td>
<td></td>
<td>500 ml ZrO₂</td>
<td>25 x 20 mm ZrO₂</td>
<td>10 mm</td>
<td>150 g</td>
<td>4 min</td>
<td>400 rpm</td>
<td>200 µm</td>
</tr>
<tr>
<td>Glass</td>
<td>pre-grinding with 15 x 20 mm balls</td>
<td>250 ml ZrO₂</td>
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<td>5 - 10 mm</td>
<td>120 g</td>
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</tr>
<tr>
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<td>250 ml ZrO₂</td>
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<td>100 g + 50 ml IPA</td>
<td>1 - 2 h</td>
<td>450 rpm</td>
<td>&lt; 1 µm</td>
</tr>
<tr>
<td>Sand</td>
<td></td>
<td>500 ml ZrO₂</td>
<td>25 x 20 mm ZrO₂</td>
<td>1 - 3 mm</td>
<td>200 g</td>
<td>6 min</td>
<td>500 rpm</td>
<td>63 µm</td>
</tr>
<tr>
<td>Sewage sludge</td>
<td>pre-grinding with 7 x 20 mm balls</td>
<td>125 ml ZrO₂</td>
<td>50 x 10 mm ZrO₂</td>
<td>10 - 20 mm</td>
<td>20 g</td>
<td>30 min</td>
<td>400 rpm</td>
<td>63 µm</td>
</tr>
<tr>
<td>Soil</td>
<td></td>
<td>250 ml Stainless steel</td>
<td>15 x 20 mm Stainless steel</td>
<td>10 mm (agglomerates)</td>
<td>120 g</td>
<td>10 min</td>
<td>400 rpm</td>
<td>100 µm</td>
</tr>
<tr>
<td>Straw</td>
<td></td>
<td>125 ml ZrO₂</td>
<td>8 x 20 mm ZrO₂</td>
<td>0 - 2 mm</td>
<td>10 g</td>
<td>30 min</td>
<td>400 rpm</td>
<td>160 µm</td>
</tr>
</tbody>
</table>

This chart serves only for orientation purposes.

*In a Planetary Ball Mill PM 100
ZrO₂: Zirconium oxide

RETSCH’s application database contains more than 1,000 application reports. Please visit www.retsch.com/applicationdatabase.
Planetary Ball Mills
PM 100, PM 200 and PM 400

Planetary Ball Mill technology

The grinding jars are arranged eccentrically on the sun wheel of the Planetary Ball Mill. The direction of movement of the sun wheel is opposite to that of the grinding jars in the ratio 1:-2 (or 1:-2.5 or 1:-3). The grinding balls in the grinding jars are subjected to superimposed rotational movements, which cause the so-called Coriolis forces. The difference in speeds between the balls and grinding jars produces an interaction between frictional and impact forces, which releases high dynamic energies. The interplay between these forces produces the high and very effective degree of size reduction of the Planetary Ball Mill.

The PM 100 CM operates with a speed ratio of 1:-1 (centrifugal mode). The centrifugal forces produced by the rotation movement the sample and the grinding balls against the inner wall of the grinding jar, where size reduction takes place primarily by pressure and friction.

Powerful and fast grinding down to the nano range

RETSCH Planetary Ball Mills are used wherever the highest degree of fineness is required. Apart from the classical mixing and size reduction processes, the mills also meet all the technical requirements for colloidal grinding and have the energy input necessary for mechanical alloying processes. The extremely high centrifugal forces of the Planetary Ball Mills result in very high pulverization energy and therefore short grinding times.

The Planetary Ball Mills are available in versions with 1, 2 and 4 grinding stations. The freely selectable machine settings, comprehensive range of grinding jars made from top-quality materials as well as the numerous possible ball charge combinations (number and ball size) allow individual adaptation of the grinding parameters to the particular size reduction task.

Together with the “comfort” grinding jars these Planetary Ball Mills offer the highest possible degree of performance, safety and reliability.
Benchtop models
PM 100, PM 100 CM and PM 200

RETSCH Planetary Ball Mills are available in different versions.
Please refer to page 9 for a complete overview of the different performance features.

Type PM 100
The convenient benchtop model with 1 grinding station for grinding jars with a nominal volume of 12 to 500 ml.
Both PM 100 models feature Free-Force-Compensation-Sockets (FFCS) which ensure a safe low-vibration run and minimal oscillation transfers to the laboratory bench.

Type PM 100 CM
The PM 100 CM operates in centrifugal mode, i.e. the speed ratio of sun wheel to grinding jar is 1:-1 (PM 100: 1:-2). This results in a different ball movement which leads to a more gentle size reduction process with less abrasion.

Type PM 200
The benchtop model PM 200 with 2 grinding stations for grinding jars with a nominal volume of 12 to 125 ml.
The larger sun wheel diameter results in a higher energy input when compared to the PM 100.

Maximum operating comfort
The Planetary Ball Mills feature a very convenient operator guidance. All the relevant data can be entered or called up via a graphics display with 1-button operation:
- speed
- grinding time
- energy input
- grinding direction reversal with selection of running and pause times
- starting time
- remaining running time
- display of drive load factor
- operating hours
- clear text error messages
- service intervals

10 combinations of speed, grinding time and interval settings can be stored for repetitive grinding tasks.
With multi-language graphical menu guidance.
Floor models
PM 400 and PM 400 MA

Type PM 400
The robust floor model PM 400 with 4 grinding stations for grinding jars with a nominal volume of 12 to 500 ml. It can grind up to 8 samples simultaneously down to the submicron range thus generating a high sample throughput. The PM 400 is also available with 2 grinding stations. The freely selectable speed from 30 to 400 min\(^{-1}\) in combination with an effective sun wheel diameter of 300 mm allow for a particularly high energy input. Thus, the PM 400 produces samples with analytical fineness in no time.

Type PM 400 MA
To generate the high energy input which is required for mechanical alloying of hard-brittle materials, the PM 400 is available as "MA" type with a speed ratio of 1:-2.5 or 1:-3.

Mechanical alloying with RETSCH Planetary Ball Mills
The mechanical alloying of materials in a grinding process to form new materials with new properties is no problem for RETSCH Planetary Ball Mills. For ductile metals the speed ratio of the jar to the sun wheel of 1:-2 is fully adequate in most cases, as the impact energy produced by the ball charge is large enough to form an alloy. However, greater energy is required for hard-brittle materials such as covalently bound semiconductors.

The PM 400 MA with an increased speed ratio of 1:-2.5 or 1:-3.0 is available for such applications. The best speed ratio and all other grinding parameters must be determined experimentally for the specific product.
Innovative technology for increased safety

A well thought-out operating concept and, above all, the optimized safety aspects set new standards in this product segment and offer the user the possibility of carrying out size reduction tasks optimally and safely. The powerful and maintenance-free mill drive guarantees a constant controlled speed even for continuous use in long-term trials and under maximum load.

The Planetary Ball Mills offer a high degree of operating convenience, safety and versatility. Thanks to the programmable starting time grinding jobs can be started at night. If a power cut should occur during operation, the mills save all parameters including the remaining grinding time at that point of time. When the power supply is restored the grinding process can be resumed.

A built-in fan with standstill monitoring cools the grinding jars during operation. The extraction volume per hour is greater than the 20-fold grinding chamber volume.

A powerful and maintenance-free mill drive guarantees a constant controlled speed even for continuous use in long-term trials and under maximum load.

The Planetary Ball Mills are particularly safe. They feature a Safety Slider which ensures that the mill can only be started after all grinding jars have been securely fixed with a clamping device. The self-acting lock ensures that the grinding jars are seated correctly and securely. Thanks to the automatic cover closure, the machine only starts when the cover is properly closed. After the grinding process is finished, the cover unlocks automatically. It can only be opened when the mill is at a complete standstill.

The patented quick-action clamping device is used in all RETSCH Planetary Ball Mills. It allows the grinding jars to be inserted in the mills safely, yet conveniently.

Particularly safe

Controlled forces in single-station Planetary Ball Mills

Planetary mills with a single grinding station require a counterweight for balancing purposes. In the Ball Mill PM 100 this counterweight can be adjusted on an inclined guide rail. In this way the different heights of the centers of gravity of differently-sized grinding jars can be compensated in order to avoid disturbing oscillations of the machine.

Any remaining vibrations are compensated by feet with some free movement (Free-Force Compensation Sockets). This innovative FFCS technology is based on the d’Alembert principle and allows very small circular movements of the machine housing that result in an automatic mass compensation. The laboratory bench is only subjected to minimal frictional forces generated in the feet.

In this way the PM 100 ensures a quiet and safe operation with maximum compensation of vibrations even with the largest pulverization forces inside the grinding jars and therefore can be left on the bench unsupervised.
The working principle of the Planetary Ball Mills is based on the relative rotational movement between the grinding jar and the sun wheel. In addition to the sun wheel diameter and speed of rotation this speed ratio is decisive for the energy input and therefore for the results of the size reduction process. The higher the speed ratio, the more energy is generated.

There are Planetary Ball Mills with different speed ratio settings. For example, a ratio of 1:-1 means that each time that the sun wheel rotates the grinding jar also rotates exactly once in the opposite direction (indicated by the minus sign). With a speed ratio of 1:-2 the grinding jar rotates twice for each sun wheel rotation. In order to follow the rotational movement of the grinding jar you have to imagine that you are standing at the center of the sun wheel. During the sun wheel rotation you will see the red reference point exactly twice, i.e. the grinding jar has rotated twice (see illustration).
In addition to the instrument settings, the filling level of the jar is also of crucial importance for a successful grinding process in Planetary Ball Mills. For grinding bulk materials a jar filling should consist of about 1/3 sample and 1/3 ball charge. The remaining third is the free jar volume that is necessary for the free movement of the balls. The table provides guidelines.

**Grinding jars for excellent grinding results**

The performance and the result of sample preparation are also determined by the choice of the grinding jar and its ball charge. The choice depends on the amount of sample and the final fineness and purity of the ground sample that are necessary for the subsequent analysis.

The "comfort" range of grinding jars has been specially designed for extreme working conditions such as long-term trials, wet grinding, high mechanical loads and maximum speeds as well as for mechanical alloying.

Each grinding station in Retsch planetary ball mills can accommodate 2 directly stacked 12 or 25 ml "comfort" grinding jars. Grinding stations in the PM 100 and PM 400 also allow the stacking of two 50 ml grinding jars by using an additional adapter.

**The unique advantages of “comfort” grinding jars**

- Unusually simple and safe handling
- Safe, non-slip seating with built-in anti-rotation device and conical base centering
- O-ring for gas-tight and dust-proof seal
- User-friendly gripping flanges on jar and lid
- Gap between jar and edge of lid for easy opening
- Stainless steel protective jacket (for agate, sintered aluminum oxide, zirconium oxide and tungsten carbide grinding jars)
- Grinding jar identification (item number, material and volume)
- Labeling field (e.g. for sample information)

In addition to the instrument settings, the filling level of the jar is also of crucial importance for a successful grinding process in Planetary Ball Mills. For grinding bulk materials a jar filling should consist of about 1/3 sample and 1/3 ball charge. The remaining third is the free jar volume that is necessary for the free movement of the balls. The table provides guidelines.

**Grinding jar filling levels – guidelines for sample volume and ball charge**

<table>
<thead>
<tr>
<th>grinding jar</th>
<th>Sample volume</th>
<th>Max. feed size</th>
<th>PM 100</th>
<th>PM 200</th>
<th>PM 400</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 ml</td>
<td>up to 5 ml</td>
<td>&lt;1 mm</td>
<td>50 pcs.</td>
<td>5 pcs.</td>
<td>–</td>
</tr>
<tr>
<td>25 ml</td>
<td>up to 10 ml</td>
<td>&lt;1 mm</td>
<td>100 pcs.</td>
<td>8 pcs.</td>
<td>–</td>
</tr>
</tbody>
</table>
| 50 ml        | 5 - 20 ml     | <3 mm         | 200 pcs.| 10 pcs.| 7 pcs. | 3 pcs. | –
| 80 ml        | 10 - 35 ml    | <4 mm         | 250 pcs.| 25 pcs.| 10 pcs.| 5 pcs. | –
| 125 ml       | 15 - 50 ml    | <4 mm         | 500 pcs.| 30 pcs.| 18 pcs.| 7 pcs. | –
| 250 ml       | 25 - 120 ml   | <6 mm         | 1200 pcs.| 50 pcs.| 45 pcs.| 15 pcs.| 6 pcs. | –
| 500 ml       | 75 - 220 ml   | <10 mm        | 2000 pcs.| 100 pcs.| 70 pcs.| 25 pcs.| 8 pcs. | 4 pcs. |

**Material composition guidelines**

<table>
<thead>
<tr>
<th>Grinding jar</th>
<th>Material no.</th>
<th>approx. hardness</th>
<th>Material analysis (in %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardened steel</td>
<td>1.2080</td>
<td>62-63 HRC</td>
<td>Fe (84.89), Cr (12), C (2.2), Mn (0.45), Si (0.4), P (0.03), S (0.03)</td>
</tr>
<tr>
<td>Stainless steel</td>
<td>1.4034</td>
<td>48-52 HRC</td>
<td>Fe (82.925), Cr (14.5), Mn (1), Si (1), C (0.5), P (0.045), S (0.03)</td>
</tr>
<tr>
<td>Tungsten carbide</td>
<td>1180-1280 HV 30</td>
<td></td>
<td>WC (94), C (6)</td>
</tr>
<tr>
<td>Agate</td>
<td>6.5-7 Mohs</td>
<td></td>
<td>SiO₂ (99.91), Al₂O₃ (0.02), Na₂O (0.02), Fe₂O₃ (0.01), K₂O (0.01), MnO (0.01), MgO (0.01), CaO (0.01)</td>
</tr>
<tr>
<td>Sintered aluminum oxide</td>
<td>1750 HV</td>
<td></td>
<td>Al₂O₃ (99.7), MgO (0.075), SiO₂ (0.075), CaO (0.07), Fe₂O₃ (0.01), Na₂O (0.01)</td>
</tr>
<tr>
<td>Zirconium oxide*</td>
<td>1200 HV</td>
<td></td>
<td>ZrO₂ (94.5), Y₂O₃ (5.2), SiO₂/ MgO/ CaO/ Fe₂O₃/ Na₂O/ K₂O (&lt; 0.3)</td>
</tr>
</tbody>
</table>

The above percentages are mean values. We reserve the right to make alterations.

*Yttrium-part-stabilized
Accessories for grinding jars “comfort”

Optimum safety during wet grinding and under inert atmosphere

The Planetary Ball Mills are not only suitable for dry grinding but also for wet grinding, e.g. for the production of colloidal systems. The “comfort” grinding jars offer maximum safety. They are gas-tight and dust-proof and can be equipped with special safety closure devices. It permits the gas-tight handling inside and outside of a glovebox and ensures the safe transport of the grinding jar. Furthermore, overpressure which may build up during and after the wet grinding process cannot escape.

The aeration lid is used to create an inert atmosphere in the grinding jar.

Pressure and Temperature Measuring System PM GrindControl

The PM GrindControl is available with a stainless steel grinding jar of 250 ml or 500 ml.

A bidirectional connection between grinding jar and PC ensures the sending and receiving of data. The jar lid is equipped with a sender/receiver module, the corresponding module is connected to the PC via a USB flash drive. Thus, grinding jar and PC communicate via a robust and secure wireless connection.

In order to understand the processes which occur during grinding with ball mills (e.g. chemical reactions, phase changes), it is helpful to record the most important thermodynamic parameters: pressure and temperature.

Planetary Ball Mills are frequently used for the development of new materials by mechanical alloying due to their high energy input. The processes and reactions which take place in the grinding jar during grinding can be monitored and controlled.

The measurement data can be recorded with different sampling rates; the longest interval is 5 seconds, the shortest 5 milliseconds.

The data are exported by mouse click and are available in ASCII format so that they can be easily processed with common software programs such as Excel.

The complete system – including accessories such as the grinding jar and a conversion kit for gassing – is delivered in an aluminum case.

Benefits at a glance

- Measurement ranges
  - gas pressure: up to 500 kPa
  - temperature: 0 - 200 °C
- No modification of the mill required
- Indoor range approx. 15 m
- Max. operating time with fully charged accumulator 80 h
- Simultaneous operation of 4 measurement systems possible
- Multilingual software
- Robust design
Planetary Ball Mills order data

Planetary Ball Mills PM 100, PM 200, PM 400

<table>
<thead>
<tr>
<th>Planetary Ball Mills PM 100, PM 200, PM 400</th>
<th>Item No.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PM 100 (please order grinding jars and grinding balls separately)</strong></td>
<td>speed ratio</td>
</tr>
<tr>
<td>PM 100 for 230 V, 50/60 Hz with 1 grinding station</td>
<td>1 : -2</td>
</tr>
<tr>
<td>PM 100 CM for 230 V, 50/60 Hz with 1 grinding station</td>
<td>1 : -1</td>
</tr>
<tr>
<td><strong>PM 200 (please order grinding jars and grinding balls separately)</strong></td>
<td>speed ratio</td>
</tr>
<tr>
<td>PM 200 for 230 V, 50/60 Hz with 2 grinding stations</td>
<td>1 : -2</td>
</tr>
</tbody>
</table>

PM 400 mounted on casters (2 x lockable) (please order grinding jars and grinding balls separately)

<table>
<thead>
<tr>
<th>Item No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM 400 for 220-230 V, 50-60 Hz with 4 grinding stations</td>
</tr>
<tr>
<td>PM 400/2 for 220-230 V, 50-60 Hz with 2 grinding stations</td>
</tr>
<tr>
<td>PM 400 MA for 220-230 V, 50/60 Hz with 4 grinding stations</td>
</tr>
<tr>
<td>PM 400 MA for 220-230 V, 50/60 Hz with 2 grinding stations</td>
</tr>
</tbody>
</table>

**Accessories**

Add-on weight for PM 100 (if total weight of grinding jar, grinding balls, sample material and accessories is >7.3 kg) 22.221.0002


Other electrical versions available for the same price

**Measuring system PM GrindControl for PM 100 and PM 400**

<table>
<thead>
<tr>
<th>Item No.</th>
</tr>
</thead>
</table>

PM GrindControl with grinding jar “comfort” 250 ml, stainless steel, for PM 100 and PM 400 22.782.0004

PM GrindControl with grinding jar “comfort” 500 ml, stainless steel, for PM 100 and PM 400 22.782.0005

**“comfort” grinding jars for PM 100, PM 200 and PM 400**

| Item No. |

“comfort” grinding jars 12 ml 25 ml 50 ml 80 ml 125 ml 250 ml* 500 ml*

Hardened steel – – 01.462.0145 – 01.462.0144 01.462.0224 01.462.0229

Stainless steel 01.462.0239 01.462.0240 01.462.0149 01.462.0321 01.462.0148 01.462.0223 01.462.0228

Tungsten carbide – – 01.462.0156 01.462.0326 01.462.0155 01.462.0222 –

Agate – – 01.462.0139 01.462.0197 01.462.0136 01.462.0220 01.462.0225

Sintered aluminum oxide – – 01.462.0153 – 01.462.0152 01.462.0221 01.462.0226

Zirconium oxide – – 01.462.0188 – 01.462.0187 01.462.0219 01.462.0227

*not for PM 200

**Accessories for “comfort” grinding jars**

| Item No. |

Adapter for stacking 50 ml “comfort” grinding jars in the PM 100 or PM 400 03.025.0002

for 50 ml “comfort” grinding jars made from hardened steel or stainless steel 03.025.0003

Aerating lids for “comfort” grinding jars 250 ml 500 ml

for grinding jars made from hardened steel – 22.107.0017

for grinding jars made from stainless steel 22.107.0005 22.107.0007

for grinding jars made from tungsten carbide 22.107.0006 –

for grinding jars made from agate – 22.107.0012

for grinding jars made from sintered aluminum oxide – 22.107.0013

for grinding jars made from zirconium oxide 22.107.0014 22.107.0010

Safety closure devices for “comfort” grinding jars 50 ml 80 ml, agate 80 ml, SS/WC 125 ml 250 ml 500 ml

Safety closure device 22.867.0002 22.867.0007 22.867.0003 22.867.0004 22.867.0005

**Grinding balls**

| Item No. |

Grinding balls 2 mm Ø 3 mm Ø 5 mm Ø 10 mm Ø 15 mm Ø 20 mm Ø 30 mm Ø 40 mm Ø

Hardened steel – – 05.368.0029 05.368.0059 05.368.0108 05.368.0033 05.368.0057 05.368.0056

Stainless steel 22.455.00101) 22.455.00111) 22.455.00032) 05.368.0063 05.368.0109 05.368.0062 05.368.0061 05.368.0060

Tungsten carbide – – 05.368.0038 05.368.0071 05.368.0110 05.368.0070 05.368.0069 05.368.0068

Agate, polished – – 05.368.0024 05.368.0067 05.368.0111 05.368.0028 05.368.0065 05.368.0064

Sintered aluminum oxide – 05.368.0019 05.368.0021 05.368.0112 05.368.0054 05.368.0053 05.368.0052

Zirconium oxide3) 05.368.00891) 05.368.0091 05.368.0094 05.368.00903) 05.368.0093 05.368.0092 05.368.0091

1) container = 500 g, 2) container = approx. 200 pcs., 3) beads with 0.1 mm Ø, 0.5 mm Ø and 1 mm Ø are also available

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RETSCH – Your specialist for sample preparation offers you a comprehensive range of equipment. Please request information on our crushers, mills, sieve shakers, sample dividers, feeders as well as cleaning and drying machines.