HANSER

Special reprint

Martin Sutter

Micro-injection molding puts ceramics in top form

SPT Roth Ltd.
3250 Lyss, Switzerland
T +41 32 387 80 80
cim@sptroth.com

Small Precision Tools Inc.
Petaluma, CA 94954, USA
T +1 707 765 4545
cim@sptca.com

SPT Asia Pte Ltd.
Singapore 318992
T +65 6253 5577
info@sptasia.com

Small Precision Tools Co. Ltd.
Wuxi, Jiangsu, P.R. China 214072
T +86 510 8516 1968
cim@sptchina.com

Micro-injection molding puts ceramics in top form

Ceramic injection molding permits the economical production of ultra-precise small components while affording the maximum **DESIGN FREEDOM** in terms of geometric and material properties. As a result, the advantages of the high-performance material benefit a wide range of industries.

Fig. 1. Micro-components made of oxide ceramics - the illustration depicts the innovative use of the material by a wide range of industries.

MARTIN SUTTER

In recent years, fine industrial ceramics have become established as a forward looking material in almost every industry. Ceramic injection molding (CIM) offers an outstanding opportunity to make the optimum use of the advantages of this new material. In order to exploit the potential offered by this modern ceramic forming process to the fullest, however, comprehensive know-how is needed throughout the entire processing sequence; to include the production of the raw material, the design and manufacture of the molding dies, trough the CIM process itself, to the finishing of the component and its quality control. Only in this way can product quality and consistency be guaranteed across different batches **(Fig. 1)**.

Applications for CIM components

The use of ceramics in existing or new products can be recommended to meet the following requirements in particular:

- Bio-compatibility
- Corrosion resistance
- Electrical insulation properties
- Wear resistance
- Quality of finish (polished, Netshape N2)
- Thermal stability
- A high modulus of elasticity with low weight.

In medical technology and the dental industry, particular value is placed on bio-compatibility, transparency, coloration, quality of finish and consistency. These place exacting demands on the purity of the materials, process reliability and quality assurance. There is no shortage of applications for ceramics in these fields, given the widespread need for e.g. dental tooth implants, abutments, orthodontic brackets, medical endoscopic devices and nozzles for analytical requirements.

In the field of machine manufacture, on the other hand, characteristics such as extreme hardness and resistance to wear, corrosion and chemicals count for a great deal, together with exceptional strength and low weight relative to volume. Examples worth a mention in this category would be nozzles, guides, gearwheels and parts with screw threads.

Photos: SPT Roth

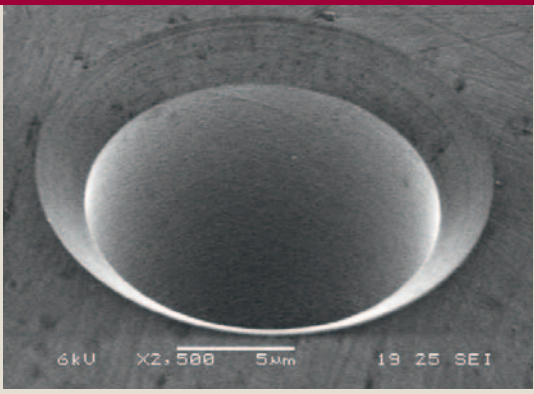

Fig. 2. The utmost precision for tiny component shapes - tapped drill-holes in Al_2O_3 with a diameter of 15 µm and a tolerance of ± 1 µm.

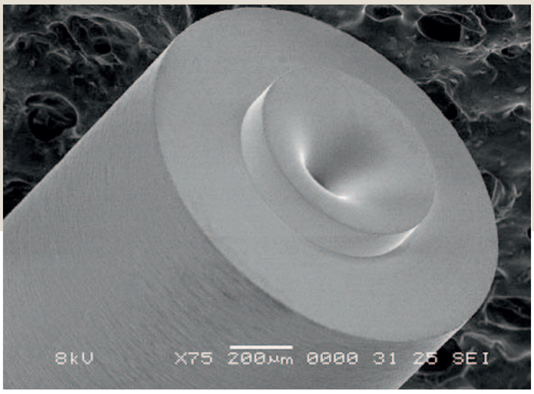

Fig. 3. Exceptional freedom of design for component shapes in ZrO_2 - sintered drill-hole geometry with outlet in final form.

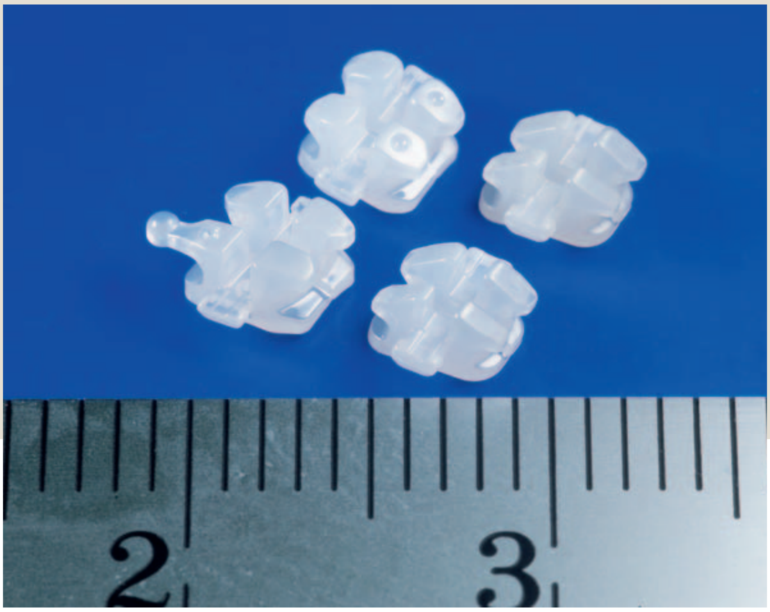

Fig. 4. Transparent tooth brackets - injection molded parts of complex shapes.

Fig. 5. Internal and external threads - no reworking is necessary.

The electronics sector calls for effective electrical and thermal insulation, ESD properties and geometrically precise dimensions for particularly small components. Among others, uses occur in bonding capillaries, receptacle guides and grippers.

In general, it can be said that ceramic injection molding offers itself as a distinctly economical and reliable production technique, particularly for medium-sized unit quantities and upwards, involving complex shapes, stringent tolerance standards, thin walls and tiny holes **(Figs. 2 and 3)**.

Material characteristics

Apart from a variety of specific, application-related mixtures, two basic materials, in particular, have become established in the field of oxide ceramics. Aluminum Oxide (Al_2O_3) is currently the most important oxide ceramic material. It stands out by virtue of its:

- High strength and hardness
- High wear resistance
- Corrosion resistance
- High thermal conductivity for a ceramic
- Outstanding electrical insulation properties
- High-temperature resistance

Zirconium Oxide (ZrO_2) is principally selected for the following reasons and characteristics:

- Exceptional bending strength
- High modulus of elasticity (comparable with steel)
- Low thermal conductivity
- High-temperature resistance, and
- good tribological characteristics.

The possibility of individually adapting and producing the material required for the injection process, otherwise known as the feed stock and relating to the mixture ratio, grain size and binding agent, fulfils the requirements for matching the properties of the material to the requirements of the finished part to the optimum extent.

The CIM process

Of all the shaping methods, the ceramic injection molding process offers the greatest design freedom. With it, arbitrary shapes such as internal and external threads, undercuts, inclined drill-holes and freely formed faces can be directly produced without incurring any reworking costs.

The oxide powder or powders are mixed in varying proportions with a binding agent. The resulting feed stock must be suitable for injection molding at a high

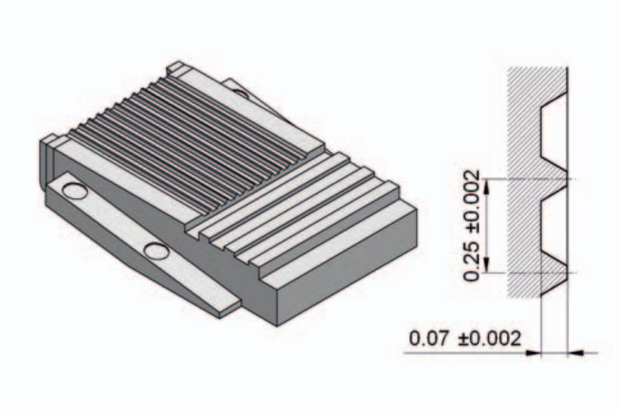

Fig. 6. Original component.

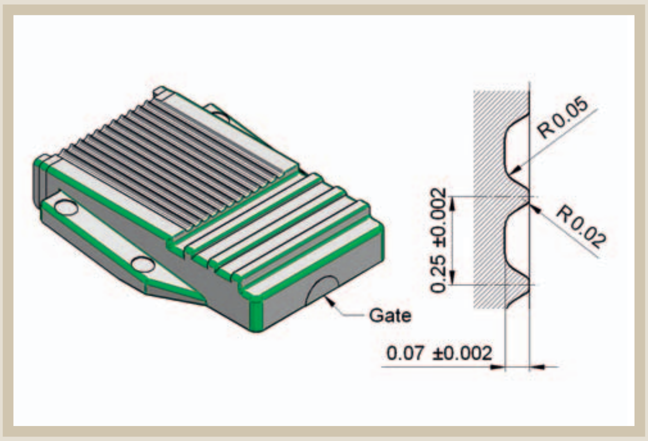

Fig. 7. The same component following redesign in accordance with CIM principles.

green density and the binding agent capable of being removed before the sintering process takes place. Ceramic injection molding is similar to plastic injection molding and is carried out on optimized micro-injection molding machines. An important criterion is that the optimum green density is achieved.

Usually, the binding agent content is carefully removed from the molded blank in accordance with a thermal/time curve. In this process, the binding agents are driven off through thermal decomposition or by means of a combination of extraction and pyrolysis. When freed of these agents, however, the component must retain precisely the shape it acquired in the injection molding process.

With the sintering process, compaction (without pressure) assumes almost the same theoretical density values as the pure material itself. At the same time, provision must be made for a linear contraction of 20-30%. The sintering of oxide ceramics is carried out in air or a vacuum; in this case, sintering contraction is dependent on the material and the green density achieved for the injection molding process. With the aid of hot isostatic presses (HIPs), the microstructure can be retrospectively compacted again under heat and pressure (the last 0.5%) for special applications.

After they have undergone thermal treatment, the component parts possess the properties of the pure material itself, e.g. hardness, density, compression resistance, solidity, resistance to chemicals, freedom from distortion, and thermal and electrical properties.

After the sintering process, CIM blanks essentially correspond to the finished part. If necessary, further work may be carried out to remove e.g. any sprue or to produce a special product feature. All the common processing methods can be used for finishing operations, such as grinding, lapping, honing and polishing.

Designing for CIM

In order to make the optimum use of CIM technology, the following points should be observed at the design stage of the component part:

- Unnecessary and pronounced variations in wall thicknesses, and abrupt changes of cross sections, should be avoided.
- Accumulations of material should be circumvented (incorporate recesses).
- Wherever possible, round off sharp edges.
- Make lengthy, freestanding cores as symmetrical as possible.

Figs. 4 and 5 depict two products of complex shapes which have retained their shape in every detail in the injection molding process without any additional finishing work. **Figs. 6 and 7** depict a component which has been designed for CIM in conjunction with the customer from as early as the design stage.

The shaping possibilities offered by the CIM process are comparable with those of plastic or metal micro-injection molding. Because of their special properties, however, fine ceramics open up entirely new possibilities. Developments in recent years are already indicating that increasing numbers of users from the most wide ranging industries are making use of these possibilities for their products and are substituting fine ceramics for conventional materials. In doing so, manufacturers are pursuing the objective of endowing their products with better usage characteristics and, in turn, reinforcing their competitiveness. ■

> CONTACT

MANUFACTURER
SPT Roth Group
see frontpage or visit
www.smallprecisiontools.com/cim

AUTHOR

MARTIN SUTTER is Product and Sales Manager for Fine Ceramic Products with SPT Roth in Lyss, Switzerland;
martin.sutter@sptroth.com

Photos: SPT Roth