Manufacturing Ceramic Tubes Using the Plasma Melting Process

For 25 years, QSIL GmbH Quarzschmelze Ilmenau/DE has been producing tubes and hollow cylinders from quartz glass in various geometrical dimensions with a crucible-free, direct melting method, which uses plasma arc as an energy source; this method is unique worldwide.

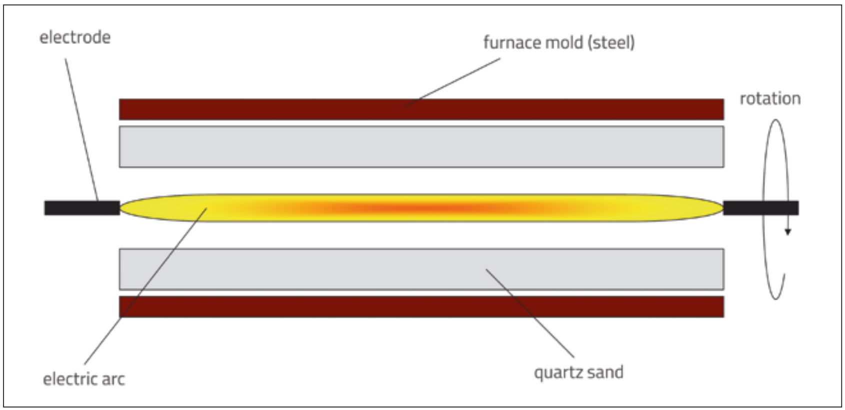

Fig. 1
Scheme of the plasma melting process for quartz glass

Keywords
plasma melting process, crucible-free melting

Introduction

The technology is based on the raw material (quartz) being filled into a steel cylinder, which turns on its longitudinal axis as shown in Fig. 1. After filling, a plasma arc, which can deliver a power of several 100 kW, is ignited in the cylinder's axis. In the ensuing melting process, the sand is melted from the inside to the outside. After cooling, a hollow cylinder of quartz glass is obtained.

Ceramic tubes using the plasma arc process

The melting process for quartz glass described above offers some interesting aspects and opens new possibilities for the manufacturing of ceramic materials:

- The temperatures which can be reached with the plasma arc on the surface of the fill are above 2000 °C and therefore suitable for materials with high melting points.

Fig. 2
Examples of quartz glass tubes

- The melting is crucible-free; there is no deposition of impurities during the process.
- As the melting process takes place in the well-isolated fill, energy consumption is low compared to other methods.

Based on these considerations, QSIL performed laboratory melting processes using different materials, including:

- corundum (Al_2O_3)
- spinel ($MgO–Al_2O_3$)
- AZS material ($Al_2O_3–ZrO_2–SiO_2$)
- mullite ($Al_2O_3–SiO_2$)
- zirconium silicate (Zirkon, $ZrO_2–SiO_2$)
- wollastonite ($CaO–SiO_2$).

In laboratory-scale production, all these materials can be melted, producing crack-free, hollow ceramic cylinders in the final crystallization and cooling processes. We consider the materials to be ceramic due to their polycrystalline structure. In principle, this is an analogy to the known fused cast materials.

Corundum (Al_2O_3) was the first material selected for application in an industrial manufacturing process. In manufacturing crack-free, hollow cylinders using the plasma melting process, the material-compliant management of the cooling process and controlled crystallization during the melt are of key importance. Currently, this technology enables us to manufacture reproducible, crack-free corundum tubes in easy-to-handle sizes of up to 2200 mm in length and up to 300 mm in diameter. Fig. 2 shows examples of these tubes: in the middle, a tube after having been removed from the mould; left and right, cut and ground to different wall thickness. QSIL is working on expanding the range of geometric shapes available.

Material and properties

The characteristics of the plasma melting method, especially the temperature gradient between the inner and outer sides of the tube, give the material thus produced its special properties and structures. A typical sandwich material results, consisting of three well-defined layers:

- The first layer on the inner side of the tube, results through crystallization from the melt. The layer is up to 6 mm thick and non-porous.
- The subsequent layer also results through crystallization from the melt. It has a columnar structure, which can contain individual bubbles.
- On the outer side, a sintered layer of varying density forms.

Some specific material properties result from this sandwich structure:

- The bending strength, determined in accordance with DIN EN 993-6, lies between 20–80 MPa, which is in the range of plasma-sprayed Al_2O_3 ceramics, but lower than that of sintered Al_2O_3 ceramics.
- Thanks to the compactness of the inner layer, the tubes are gas tight even at high temperatures.
- In accordance with DIN EN 993-11, resistance to changes in temperature (loss of strength in comparison to the initial strength for a variety of temperature gradients) was determined and compared to that of plasma-sprayed material and sintered material. Even at very high temperature gradients ($\Delta T > 600$ K), the material exhibited only low loss of strength, comparable to that of plasma-sprayed material, which should indicate good resistance to temperature changes in the application.

Thus, at sufficient basic strength, the material combines the good resistance to changes in temperature characteristic of plasma sprayed ceramics with the gas tightness and hardness of sintered Al_2O_3.

Dr Frank-Peter Ludwig
QSIL GmbH Quarzschmelze Ilmenau
98704 Langewiesen, Germany

E-mail: f.ludwig@qsil.de
www.qsil.de