Overview of recent dissertations in the field in Finland

Utilization of mineral side streams in high temperature ceramic materials

Mineral raw materials are solid chemical compounds used in a wide range of industrial processes and end-uses being fundamental to our modern society. Mineral materials, such as oxides, silicates and carbonates, are present in nature, and many of these compounds are also industrially synthesized. Typically, mineral materials are imported in Europe and transported for long distances, resulting in high greenhouse gas emissions. Additionally, in some cases, suitable primary raw material reserves are dwindling and concentrated in certain countries which causes supply problems and price fluctuations. Simultaneously, European industry produces huge and ever-increasing amounts of mineral materials as side streams, which in many cases end up as waste. Side streams from mining processes present the highest proportion of solid mineral residues produced by industry worldwide, with tens of thousands million tons produced annually. Utilization of mineral side streams as secondary raw materials complements the circular economy by closing the material loops, which enables the replacement of imported feedstock and reduces the environmental impact of processes and products.

In recent years, scattered reports on the utilization of mine tailings have indicated their application in civil engineering purposes and as sources of critical metals. In general, the mining industry side streams are still largely viewed as a waste rather than as a resource. This thesis concentrates on the utilization of mineral side streams as raw materials for structures in less studied application field: high temperature ceramic materials. The main objective of this thesis was to increase understanding of the potential and limiting factors for the utilization of mineral side streams in added value ceramic materials with high thermal resistance. To reach this goal, the study focused on investigating, how the variation in mineral side stream composition due to natural impurities influences the formation of ceramic material microstructure and achieved properties in comparison to pure raw material counterparts. Additionally, it was of interest whether it is possible to tailor the mineral side stream composition by mixing different secondary raw material streams. Ceramic structures based on two typical high temperature compounds, mullite ($3Al_2O_3{\cdot}2SiO_2$) and magnesium aluminate spinel ($MgAl_2O_4$), were targeted in synthesis experiments.

As a conclusion, it was observed that in the case of side stream based ceramic materials, the achieved properties rather than chemical composition dictated their usability. The properties' characterization proved that utilization of mineral side streams in ceramic materials show properties comparable with and in some cases even better as compared to pure raw material counterparts. For example, magnesite rich mine tailings together with aluminum anodizing process side stream resulted in glass-bonded magnesium aluminate spinel ceramic coatings with electrical insulation capability at the same level compared to pure magnesium aluminate spinel coatings. Additionally, abrasive wear test results revealed considerably lower wear rate for these glass-bonded coatings than for the pure raw material coatings. Thus, formation of amorphous phase compensated the inferior effect of impurities but also limited the maximum operating temperatures. As an overall conclusion, investigated mineral side streams could potentially substitute pure raw materials in ceramic materials taking into account their maximum operating temperatures due to the softening point of the amorphous phase. The properties of mineral side stream based ceramic materials presented in this thesis set a basis for material property databank creation. This kind of databank, including materials composition and volume information about the side streams, can be used as a starting point for the designing new side stream based materials.

The doctoral dissertation of M.Sc. **Marjaana Karhu** in the field of materials science "Utilization of mineral side streams in high temperature ceramic materials" is available online at http://urn.fi/URN:ISBN:978-952-03-1737-9