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Mullite and mullite-based ceramic composites from kaolinite, sericite clays and wastes from mining

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Mullite (name from Mull Island, Scotland) can be found only as scarce mineral phase in the nature. However, mullite is one of the most common crystalline phases found in traditional and advanced ceramics also for structural material applications in high-temperature engineering, besides electronics and optical applications. This material and their composites depict excellent properties: Low thermal expansion coefficient, high-temperature strength, creep resistance, very high transmittance in the mid-IR range, good chemical and thermal stability, with retention of mechanical properties to elevated temperatures, and stability in oxidative atmospheres. The formation of mullite can be reached by thermal decomposition of aluminosilicates (kyanite, andalucite, sillimanite, topaz), hydroxyaluminosilicates (kaolinite, pyrophyllite, sericite, etc.), as well as by thermal reaction of pure silica, alumina and even feldspar mixtures. A very high temperatures (~1700ºC) and long periods of firing are required for obtaining dense sintered mullite materials because the high activation energy for Al and Si bulk diffusion in the mullite lattice. Though, the fabrication of mullite powders has been extensively described in the bibliography. The high-cost of some raw materials and chemicals, besides some limitations such as the use of organic precursors and solvents, inert atmosphere for reaction, etc., are not appropriate for a large-scale production. Aluminosilicates are expensive and they are found in countries in way of development, being not as common as compared to hydroxyaluminosilicates. Then, the use of kaolinite and sericite clays containing Si and Al, wastes with high Al content and by-products of mining with high-kaolinite content, is an attractive way for mullite preparation and processing at relatively low cost. The present communication is a part of a wide investigation on processing of mullite and mullite-based ceramic composites from these precursors. Pure kaolinite and alumina mixtures in stoichiometric molar ratio of mullite ($3Al_2O_3$. $2SiO_2$) have been also studied to compare the results. The basic features of mullite fabrication of own investigations from all these precursors are presented, compared and overviewed. The methods have implications for the recovery and recycling of Al wastes and use of waste by-products of mining as valuable raw materials. After wet processing of the mullite precursors at the laboratory, thermal treatments using pressed cylindrical samples at 500 MPa from 1200-1600 ºC were, that the thermal behavior of some mullite precursors was influenced by the presence of impurities in the raw materials, in particular using wastes. However, the presence of these impurities originates a progressive and enhanced sintering because some amounts of liquid phase are produced. For instance, porous mullite-based composites, with values of 52-45 vol. % can be obtained by firing some precursors at 1500-1600 ºC for 30 minutes. Microstructures revealed by SEM show the evolution of primary and secondary mullite crystals produced by increased thermal treatments of the precursors. In particular, the use of sericite clays as raw material was very interesting according to the present and precedent results at laboratory level. The possibility of mullite production at a higher scale is discussed. The resultant mullite composites have interesting potential applications as ceramic substrates, refractories, thermal filters and materials used at high-temperatures as thermal barriers.

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