Inorganic polymers as advanced and sustainable materials for sensible heat storage

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The transition from fossil fuels to renewable energy sources (RES) faces many challenges, with the stabilization of power grid being a key concern. Thermal Energy Storage (TES) technologies offer an efficient and adaptable solution to address this issue, by storing surplus energy, particularly produced from intermittent renewables such as solar and wind and harnessing it when demand peaks or supply drops. The different methods developed for TES applications are classified into three groups, namely sensible, latent and thermochemical heat storage techniques [1]. Among them, sensible TES technologies are the most developed due to the low cost, although they have low energy storage capacity (< 60%) [2]. These technologies involve heating a storage medium and storing heat as an increase in its temperature. Heat storage media could be solid or liquid materials, such as concrete, natural rocks, water, oil and molten salts. However, the thermal decomposition of almost all of them at temperatures higher than 500 ºC and issues of durability, evaporation, leakage and chemical and mineralogical composition, limits their application in low temperature processes (<180 ºC), like sterilization, drying, pressing, cooking etc. found in textile, food, beverage and paper industries. This paper investigates the possible utilization of inorganic polymers (or geopolymers) as advanced and sustainable materials for sensible TES systems. The introduction of inorganic polymers in the TES sector is aimed at tackling the thermal stability challenges for solid sensible heat storage materials and improving the durability and storage efficiency of TES systems, without increasing their cost. Inorganic polymers are green, sustainable and advanced synthetic materials produced according to the low energy demand and reduced GHG emissions technology of geopolymerization at low temperature (<100 ºC) and ambient pressure. Their production is based on a polycondensation reaction, which occurs between solid materials of aluminosilicate composition and strong alkaline silicate solutions, yielding amorphous to semi-crystalline solid materials characterized by a three-dimensional polymeric network of Si-O-Al (or -Si) bonds. The formed materials possess excellent physical, mechanical and thermal properties, including micro- to nano-porosity, high mechanical strength, durability, thermal stability and fire resistance [3]. Such properties are significant for their utilization in TES applications. Moreover, the utilization of secondary resources, like CDW reduces their cost production and enhances sustainability.

In order to quantify the potential application of the CDW-based inorganic geopolymers in sensible TES systems, a comparison of these materials with commercial or pilot demonstrating solid sensible heat storage materials, in terms of properties, cost, and efficiency, is performed in this paper. In addition, the possibility of designing the properties of these novel sensible heat storage material and the crucial parameters

affecting their performance are also discussed. According to the available literature and preliminary experimental results, the CDW-based inorganic polymers keep their structural stability at temperatures higher than 450 ºC, in which ordinary Portland cement (OPC) decomposes. Moreover, these materials present similar heat capacity with OPC-based materials and many natural rocks like olivine, anhydrite, quartz and basalt. Based on the results of this work, CDW-based inorganic polymers can be considered as suitable materials for highly efficient sensible TES applications.

Keywords—*geopolymers, sensible heat, thermal energy storage, sustainability, high performance*

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