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Electrical conductivity modelling of molten slag based on viscosity data - A mechanistic approach

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The majority of core pyrometallurgical processes rely on redox reactions, i.e. chemical reactions that involve electron transfer. Such reactions occur, for instance, when molten metals are reduced from their oxidic precursors or, in general, when elements transition between the metal and slag phases. To gain a comprehensive understanding of these processes and for exploring potential redesign options, it is essential to investigate conduction phenomena (both ionic and electronic) in slag melts, since electrical conduction offers valuable insights into slag composition and fundamental reaction mechanisms. Moreover, the understanding of the electrochemical properties of slags is imperative to ensure effective operation of any electrometallurgical process (EAF, Smelter, Molten Oxide Electrolysis, etc.).
In this study, the electrical conductivity of molten calcium silicate slags is investigated through the utilisation of a four-electrode setup, also referred to as extended Van der Pauw measurement configuration. This configuration involves measuring the complex impedance of a melt over a frequency range of 0.1 to 100 kHz at varying immersion depths. The electrical conductivity of molten slags of varying compositions is studied and temperature-dependent findings on conductivity and viscosity are correlated by the Arrhenius and the Vogel-Fulcher-Tammann approach. In addition to the semi-empirical correlation, a mechanistic model is employed, motivated by the diffusive transport analogy of momentum and mass. Thereby, ionic conduction in the molten slag is related to viscosity data. This approach considers electrical conductivity as a cumulated contribution of ion-specific mobility, charge and ion concentrations, providing a fundamental perspective on ionic transport in molten slags. Subsequently, the model calculations are compared with the measured electrical conductivity data.

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