











30.48 to 6.41kJ/mol, which is extremely low depolymerized energy. This can be caused by the presence of  $\text{TiO}_2$  content with high concentrations. Previous paper by researchers suggested the low temperature dependency of  $\text{TiO}_2$  dominant slag system. However, the activation energy trend isn't unclear in Fig. 12 (a) because the error bars with large range are existed. Thus, it can't be defined as whether the activation energy decreased with higher  $\text{TiO}_2/\text{SiO}_2$  ratio or stable with extremely low energy. The activation variation in Fig. 12 (b) seems to be correlated well with viscosity trend, which was explained in viscosity and structure analysis parts. The existence of Ti-O-Al simple structure makes the activation energy higher below  $\text{SiO}_2/\text{Al}_2\text{O}_3$  ratio of 1.67. The activation energy, which was calculated from 128.03 to 30.48kJ/mol, also rose above  $\text{SiO}_2/\text{Al}_2\text{O}_3$  ratio of 1.67 with complex silicate network structure increase.

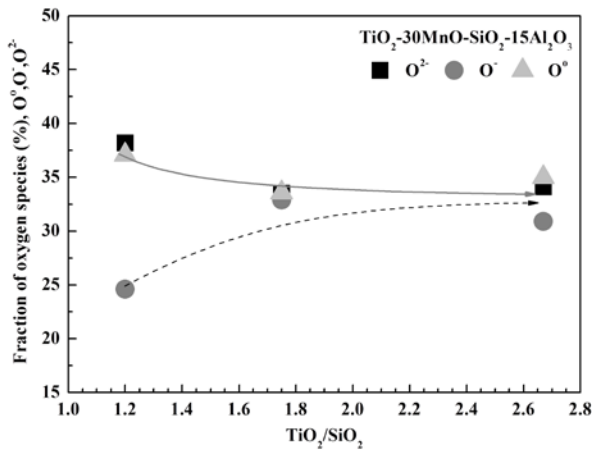


Fig. 10. Influence of  $\text{TiO}_2/\text{SiO}_2$  on the network structure at fixed MnO,  $\text{Al}_2\text{O}_3$  contents by XPS of as-quenched slag at 1773K

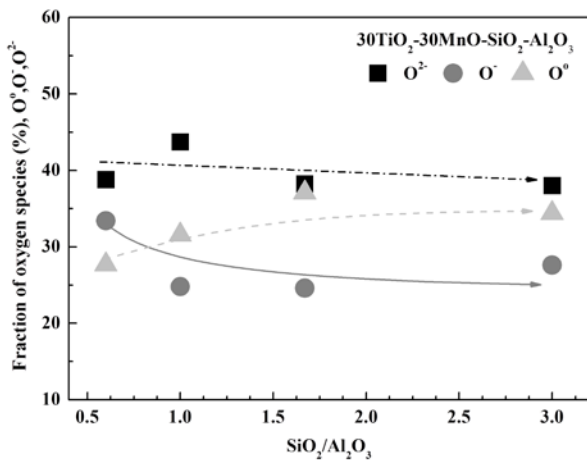


Fig. 11. Influence of  $\text{SiO}_2/\text{Al}_2\text{O}_3$  on the network structure at fixed  $\text{TiO}_2$ , MnO contents by XPS of as-quenched slag at 1773K .

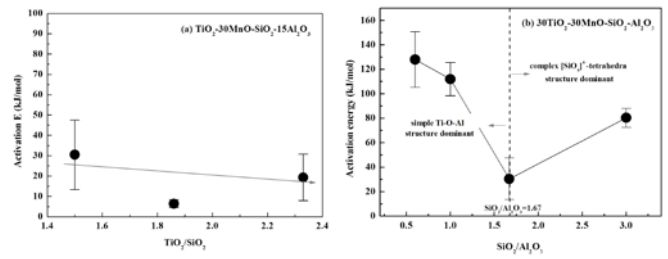


Fig. 12. The activation energy by using Arrhenius type relationship calculation in  $\text{TiO}_2$ -MnO- $\text{SiO}_2$ - $\text{Al}_2\text{O}_3$  slag system.

The influence of  $\text{TiO}_2/\text{SiO}_2$  and  $\text{SiO}_2/\text{Al}_2\text{O}_3$  ratios was identified with  $\text{TiO}_2$ -MnO- $\text{SiO}_2$ - $\text{Al}_2\text{O}_3$  slag system. The viscous behavior was affected by the primary phases at high temperature region. The simple structure of  $\text{TiO}_2$  was substitutes the complex networks structure of  $[\text{SiO}_4]^{4-}$ -tetrahedron, which caused decrease of viscosity at  $\text{TiO}_2$ -30MnO- $\text{SiO}_2$ -15 $\text{Al}_2\text{O}_3$  slag system. When  $\text{Al}_2\text{O}_3$  content substituted with  $\text{SiO}_2$  content, the viscosity linearly increased until it saturated around 0.1Pa·s. This phenomenon seems to be induced by the primary phase difference and the dominant network structure change, which was divided with standard at  $\text{SiO}_2/\text{Al}_2\text{O}_3$  of 1.67. It is reasonable that the  $[\text{SiO}_4]^{4-}$ -tetrahedral structure was dominant over  $\text{SiO}_2/\text{Al}_2\text{O}_3$  ratio of 1.67 and Ti-O-Al structure was dominant below  $\text{SiO}_2/\text{Al}_2\text{O}_3$  ratio of 1.67. The structure analysis was supported by XPS deconvoluted results. The apparent activation energy was calculated by Arrhenius type relationship equation and the slope of the viscosity values within the fully liquid region as between 19.29 and 128.03 kJ/mol.

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