Electrical conductivity of albite at high temperatures and high pressures

HAIYING HU,1,2 HEPING LI,1,* LIDONG DAI,1 SHUANGMING SHAN,1 AND CHENGMING ZHU1

1Laboratory for Study of the Earth’s Interior and Geoﬂuids, Institute of Geochemistry, Chinese Academy of Sciences, Guiyang, Guizhou 550002, China
2Graduate School of Chinese Academy of Sciences, Beijing 100039, China

ABSTRACT

The electrical conductivity of low albite has been measured using a complex impedance spectroscopic technique at 1.0–3.0 GPa and 773–1073 K in the frequency range of $10^{-1}$ to $10^6$ Hz in a YJ-3000t multi-anvil press. Within this frequency range, the complex impedance plane displays a semi-circular arc that represents a grain interior conduction mechanism. The electrical conductivity of albite increases with increasing temperature, and the relationship between electrical conductivity and temperature fits the Arrhenius formula. Pressure has a weak effect on the electrical conductivity of albite in the experimental pressure-temperature ($P$-$T$) range in the present work. The pre-exponential factors decrease, and the activation enthalpy increases slightly with increasing pressure. The activation energy and activation volume of albite are $0.82 \pm 0.04$ eV and $1.45 \pm 0.28$ cm$^3$/mol, respectively. Comparison with previous results with respect to albite indicates that our data are similar to previous data within the same temperature range. The dominant conduction mechanism in albite is suggested to be ionic conduction, where loosely bonded sodium cations, the dominant charge carriers, migrate into interstitial sites within the feldspar aluminosilicate framework. The Na diffusivity inferred from electrical conductivity of albite in this study using the Nernst-Einstein relation is consistent with that of previous studies on natural albite.

Keywords: Albite, high temperature and high pressure, electrical conductivity, conduction mechanism

INTRODUCTION

Based on the electrical conductivity of minerals measured in the laboratory at high temperatures and high pressures, researchers are eager to establish a conductivity model for complicated structural rocks that exist at various depths in the Earth’s interior. The model can provide important constraints on the results of magnetotelluric (MT) and geomagnetic deep sounding (GDS), material composition, and thermal state distribution. Electrical conductivities of minerals at high temperatures and pressures are an important to explore the microstructures of materials in the Earth’s interior, and are also the significant approach to relate the mineral microstructure with macroscopic properties and processes (Laštovičková 1991; Tyburczy and Fisler 1995; Gaillard 2004; Poe et al. 2008). Consequently, laboratory measurements of minerals at high $T$ and $P$ are the fundamental work of mineralogy, petrology, geochemistry, and geophysics.

Since quartz and feldspars comprise ~85% of the volume of the Earth’s crust (Downs et al. 1996), the electrical conductivity of feldspars largely influences the crust’s physical properties. Most previous studies have focused on the conductivity of quartz, gneiss, granulite, and other high-grade metamorphic rocks (Jain and Nowick 1982; Lee et al. 1983; Kronenberg and Kirby 1987; Glover and Vine 1992; Bagdassarov and Delépine 2004; Fuji-ta et al. 2004, 2007; Wang et al. 2002, 2010), whereas there has been little research on the electrical conductivity of feldspars. Albite is an end-member of the feldspars, and an understanding of the electrical conductivity of albite would be helpful to study the electrical conductivities of the entire feldspar group. Most previous experimental studies on the electrical conductivity of feldspars were carried out under atmospheric pressure and high-$T$ conditions (Khitarov and Slutskii 1965; Maury 1968a, 1968b; Piwinskii and Duba 1974; Piwinskii et al. 1977; Bakhterev 2008). Recently, Ni et al. (2011) measured the electrical conductivity of synthetic anhydrous and hydrous albite glasses and liquids at 473 to 1773 K and 0.9 to 1.8 GPa in a piston-cylinder apparatus. However, the samples used were not natural crystalline feldspar. Therefore, a systemic study of the electrical conductivity of natural albite at high $T$ and $P$ is required.

We measured the electrical conductivity of hot-press sintered albite at temperatures from 773 to 1073 K and pressures from 1.0 to 3.0 GPa using AC impedance spectra at frequencies from $10^{-1}$ to $10^6$ Hz. The effect of $P$ and $T$ on the electrical conductivity of albite was observed, and the results obtained are compared with those of previous studies. We also discuss the conduction mechanism of albite under high $T$ and $P$ in detail.

* E-mail: hepingli_2007@hotmail.com