# Response to the 1st anonymous reviewer:

*In this study, the authors report electrical conductivity of anhydrous and hydrous gabbroic melt under high temperature and high pressure: Implications for the high conductivity anomalies in the region of mid–ocean ridge, and I found that it is one interesting work. It is first time that the functional model of the electrical conductivity on gabbroic melt was constructed under conditions of 873–1373 K, 1.0–3.0 GPa and water content ranges of 0–8.32 wt%. Their results indicate that the electrical conductivity of gabbroic melts can be employed to reasonably interpret the high conductivity anomalies in the Mohns ridge of the Arctic Ocean. The paper contains the unique data of the electrical conductivities of anhydrous and hydrous gabbroic melts.*

*As a whole, high-pressure electrical conductivity experimental measurements seem to have been designed and executed very consciously. The manuscript is well written, extremely well organized, is easy to read and well-illustrated. The data support the conclusion of this study. The data can potentially provide a new model to deeply explore the origin of the high conductivity anomalies in the Mohns ridge of the Arctic Ocean. I have two recommendations, listed below, but none of them are severe, thus I would strongly recommend its publication in Solid Earth.*

Thanks for your valuable and constructive comments and advisements, which are greatly helping us to improve and enhance our manuscript. In the revised manuscript, all of these above-mentioned issues from the 1st anonymous reviewers have already been supplemented and modified, accordingly. Each correspondent revised counterpart is detailedly described sentence by sentence, as follows.

*1. The vacuum FT–IR spectroscopy measurements were performed on the five different regions of transparent sample surfaces and made an average value. Please provide the corresponding error bar of each water contents for the initial and recovered gabbroic melt samples in Table 2.*

Thanks for your very conscientious comments. According to your valuable advisement, the corresponding error bar of each water content for the initial and recovered gabbroic melt samples have been listed in Table 2.

*2. The low frequency signals in the impedance spectra of gabbroic melts are not completely represent the sole electric conduction response for the polarization process at sample–electrode interface. Please clarify it clearly for the audiences.*

Thanks for your valuable and professional comments and suggestions. Just as pointed out by Tyburczy and Roberts (1990), Dai and Karato (2009a, 2009b) and Dai et al. (2012, 2013), in case of single crystal minerals, the impedance spectra of sample within the high-frequency range from ~$10^2$–$10^3$ Hz to $10^6$ Hz can be interpreted as the bulk conduction mechanism (i.e. grain interior), and whereas, the impedance spectra of sample within the low-frequency range from $10^0$ Hz to ~$10^2$–$10^3$ Hz can be attributed to the sample–electrode interface polarization. As detailedly illustrated by Dai et al. (2008, 2014, 2016) and Dai and Karato (2009c, 2020), in case of polycrystalline aggregates or natural rock, the impedance spectra of sample within the high-frequency range from ~$10^2$–$10^3$ Hz to $10^6$ Hz can be interpreted as the bulk conduction mechanism (i.e. grain interior), and whereas, the impedance spectra of sample within the low-frequency range from $10^0$ Hz to ~$10^2$–$10^3$ Hz can be attributed to the grain boundary

conduction mechanism or the polarization process at sample–electrode interface. In the present studies, I absolutely agreed with your viewpoint that the low frequency signals in the impedance spectra of gabbroic melts are not completely represent the sole electric conduction response for the polarization process at sample–electrode interface. In the revised manuscript, we have already supplemented it "The impedance spectra of gabbroic melts within the high-frequency range from $\sim 10^2$–$10^3$ Hz to $10^6$ Hz can be interpreted as the bulk conduction mechanism (i.e. grain interior), and whereas, the impedance spectra of sample within the low-frequency range from $10^0$ Hz to $\sim 10^2$–$10^3$ Hz represent the grain boundary conduction mechanism or the polarization process at sample–electrode interface (Tyburczy and Roberts (1990), Dai et al. (2008, 2012, 2013, 2014, 2016); Dai and Karato (2009a, b, c, 2020)).

In conclusion, we thank the editor of Professor Yang Chu from Institute of Geology and Geophysics, Chinese Academy of Sciences, and two anonymous reviewers for their very constructive and enlightened comments and suggestions in the reviewing process, which helped us greatly in improving the manuscript.

# Response to the 2<sup>nd</sup> anonymous reviewer:

*This study performed experimental measurements on the electrical conductivities of gabbroic melt with various water contents at high temperature and pressure. The results show the gradual increase of electrical conductivity of gabbroic melt with increasing water content and decreasing pressure. This work has a potential implication for the conductivity anomalies in the Mohns ridge of the Arctic ocean. I would recommend publication after some improvements.*

Thanks for your valuable and constructive comments and advisements, which are greatly helping us to improve and enhance our manuscript. In the revised manuscript, all of these above-mentioned issues from the 2<sup>nd</sup> anonymous reviewers have already been supplemented and modified, accordingly. Each correspondent revised counterpart is detailedly described sentence by sentence, as follows.

*1. Can the authors show some micrographs of the products?*

Thanks for your precious and valuable comments and suggestions. To observe the macroscopic and microscopic structure of the products after electrical conductivity measurements, we perform the optical microscope observation and the back-scattered electron images acquired with a scanning electron microscope for the recovered anhydrous gabbroic melt and hydrous gabbroic melt with a water content of 2.59 wt%.
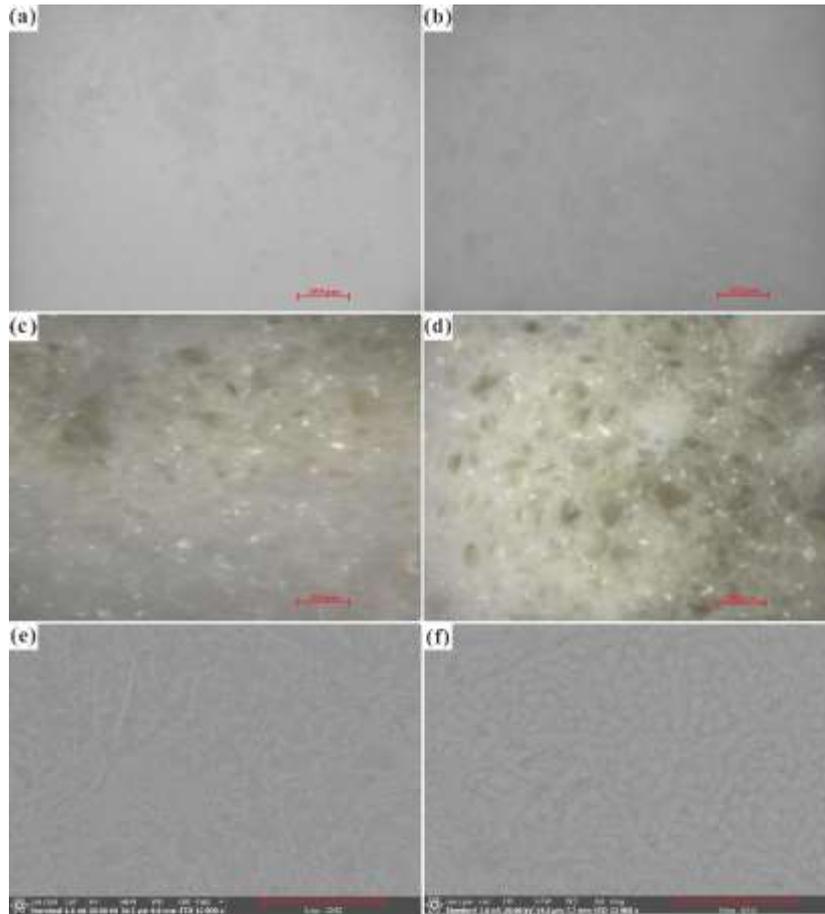
**Figure 1.** Representative microstructural observations of recovered anhydrous and hydrous gabbroic melts after the electrical conductivity measurements. In here, (a) and (c) are standing for the plane-polarized and cross-polarized reflected microscopy images for the recovered anhydrous sample, respectively; (b) and (d) are standing for the plane-polarized and cross-polarized reflected microscopy images for the recovered hydrous sample with a water content of 2.59 wt%, respectively. The back-scattered electron images were acquired with a scanning electron microscope for the recovered anhydrous (e) and hydrous (f) gabbroic melts with a water content of 2.59 wt%.

*2. In figure 8, there are two small errors. For example, 0.3 in the vertical coordinate should be -0.3; the electrical conductivity value of the anhydrous basaltic melt from Ni et al., 2011 (log δ~0.1) in this figure is much higher than the extrapolation from the reference. Please check the value and correct it.*

Thanks for your valuable and professional comments and suggestions. According

to your valuable advisement, we have already checked and modified these two errors in the Figure 8 of the revised manuscript. I doubly checked the original electrical conductivity results on the anhydrous basaltic melts to be reported by Ni et al. (2011) very conscientiously. This mistake has already been corrected in the revised edition.

*3. In Table 3, the derived value for activation volume is negative, which means that the electrical conductivity increases with increasing pressure. This contrasts to the fact that electrical conductivity of gabbroic melt decreases with increasing pressure (Figure 5). Can the authors explain this?*

Thanks for your precious and professional comments. The influence of pressure on the electrical conductivity of gabbroic melt can be depicted as,

$$\sigma = \sigma_0 \exp(-\Delta H/kT) = A_0(1-BP) \exp[-\frac{\Delta U + P\Delta V}{kT}]$$

In here, $\sigma_0$ stands for the pre–exponential factor (S m$^{-1}$), $k$ stands for the Boltzmann constant (eV K$^{-1}$), $T$ stands for the absolute temperature (K), $\Delta U$ stand for the activation energy (eV), $\Delta V$ stands for the activation volume (cm$^3$ mole$^{-1}$), and $P$ stands for pressure (GPa), respectively. The pre–exponential factor ($\sigma_0$) and activation enthalpy ($\Delta H$) of pressure dependence can be illustrated as the relations of $\sigma_0=A_0(1-BP)$ and $\Delta H=\Delta U+P\Delta V$.

For the derived value for activation volume ($\Delta U$) is negative, the corresponding activation enthalpy ($\Delta H$) reduced slightly from 0.85 eV to 0.81 eV with the rise of pressure from 1.0 GPa to 3.0 GPa, as shown in Table 2. And the exp($-\Delta H/kT$) increased slightly with increasing pressure, correspondingly. Meanwhile, the pre–exponential factor ($\sigma_0$) had significant reductions with increasing pressure. When the pressure raised from 1.0 GPa to 3.0 GPa, the pre–exponential factor ($\sigma_0$) decreased greatly from 3020

S/m to 617 S/m. According to Arrhenius relation, both of the pre–exponential factor ($\sigma_0$) and activation volume ($\Delta V$) made changes and affect the electrical conductivity of gabbroic melt as the experimental pressure increased. And the reduction degree of the pre–exponential factor ($\sigma_0$) was much more significant than the increase of the $\exp(-\Delta H/kT)$. And thus, the activation volume ($\Delta V$) cannot directly indicate the pressure dependence of the electrical conductivity of gabbroic melt, the variations of activation volume ($\Delta V$) and pre-exponential factor ($\sigma_0$) need to be considered comprehensively.

*4. In line 354-356, dacitic melt is from Laumonier et al., 2015, and andesitic melt is from Guo et al., 2017. Please correct it.*

Thanks for your important and precious comments. According to your valuable advisement, we have already modified "dacitic melt reported by Guo et al. (2017), the 20.41 wt% of andesitic melt reported by Laumonier et al. (2015)" to "dacitic melt reported by Laumonier et al. (2015), the 20.41 wt% of andesitic melt reported by Guo et al. (2017)" in the revised manuscript.

*5. Is it appropriate to apply gabbroic melt with ~8 wt% $H_2O$ to the Mohns ridge of the Arctic ocean since the partial melting of mid-ocean ridge is usually water-poor?*

Thanks for your precious and valuable comments and suggestions. For the representative Mohns ridge of the Arctic Ocean, previously available petrological and geochemical results have already revealed that the range of water content for the crustal rock and melt in the Mohns ridge is ~0.25–2.64 wt% (Neumann, E. R. and Schilling, J. G. Petrology of basalts from the Mohns–Knipovich Ridge; the Norwegian–Greenland Sea. *Contrib. Mineral. Petrol.* **1984**, *85*, 209–223; Poreda, R., Schilling, J. G., and Craig, H. Helium and hydrogen isotopes in ocean–ridge basalts north and south of Iceland.

*Earth Planet*. *Sci*. *Lett*. 1986, *78*, 1–17). It is really a little high to apply gabbroic melt with ~8 wt% $H_2O$ to the Mohns ridge of the Arctic ocean. According to your valuable advisement, we have already modified the relative discussions in the revised manuscript.