A SEMI-ANALYTICAL EOS FOR SOCK-COMPRESSED GEOL O GIC MATERIALS. S. Sugita^1, K. Kurosawa^2, T. Kadono^3 and T. Sano^4, ^1Univ. of Tokyo, Kashiwa, Chiba, JAPAN (sugita@k.u-tokyo.ac.jp), ^2JAXA/ISAS, Sagamihara, Kanagawa, JAPAN, Osaka Univ., Suita, Osaka, JAPAN.

Introduction: Accurate equation of state (EOS) is essential for understanding a variety of geologic processes associated with shock compression of materials. A number of highly sophisticated EOS's have been proposed (e.g., M-ANEOS and SESAME), covering a wide range of P-T conditions. However, they are complex and require many model parameters. Also, there are many occasions when only terminal thermodynamic variables after adiabatic decompression are needed. For example, when the terminal molecular composition of an impact-induced vapor is necessary, only the initial entropy gain and chemical reaction processes under low-P-T conditions need to be calculated. Then, only an on-Hugoniot EOS and a low-P-T EOS are necessary. To meet such demands, we derive a new semi-analytical on-Hugoniot EOS, which requires only the Hugoniot shock velocity parameters and specific heat, Grüneisen parameter, and its power-law exponent. Comparison with experimental data indicates that this EOS can reproduce on-Hugoniot entropy and temperature of ice and quartz very well, despite of its small number of model parameters.

Analytical Formulation: Most condensed matter under shock compression is known to follow the linear velocity relation between particle velocity \( U_p \) and shock velocity \( U_s \): \( U_s = C_o + s U_p \), where \( C_o \) and \( s \) are bulk sound velocity and a constant, respectively. This relation holds for a variety of materials over a wide range of impact velocity [1]. Despite the wide applicability of this relation, most EOS's do not take advantage of this relation. Besides the \( U_p-U_s \) relation, we use only general thermodynamic relations, the differential form of Rankine-Hugoniot relations, and Grüneisen EOS. From these relations, we obtain ordinary differential equations for temperature \( T \) and entropy \( S \):

\[
\frac{dT}{dU_p} = C_o \Gamma_o \left( \frac{U_s - U_p}{U_s^\Gamma_o} \right) + \frac{s U_p^2}{C_s U_s} \tag{2}
\]

\[
\frac{dS}{dU_p} = \frac{s U_p^2}{T U_s} \tag{3}
\]

Density and pressure can be obtained with frequently used analytical solutions for Hugoniot curves. Then, all the basic thermodynamic variables can be calculated for Hugoniot without having knowledge of an off-Hugoniot EOS. This EOS needs only six model parameters \( \rho_o, C_o, s, C_s, T_o \), and \( q \).

Experimental Validation: We compared the results of our calculations and literature values in order to examine the validity of the new on-Hugoniot EOS.

Our semi-analytical EOS are compared with shock data of both diopside and quartz obtained by 2-stage light-gas gun [3,4] (Fig. 1). The shock temperatures measured around 150 GPa are well reproduced by our EOS with Dulong-Petit assumption. These good reproductions of well-established shock temperature data and entropy estimates support the validity of our new EOS for Hugoniot conditions.

Planetary Applications: Perhaps, the most important thermodynamic variable that an on-Hugoniot EOS is expected to provide is entropy. Once shock-induced entropy gain is known, its final thermodynamic state after adiabatic decompression can be accurately calculated. There are a number of applications of such entropy calculations in Earth and planetary science. For example, the degrees of melting and vaporization, post-decompression temperature of impact-induced vapor can be calculated relatively easily once entropy gain is given. Furthermore, this EOS is useful for matching thermodynamic conditions between laser-induced and impact-induced vapor plumes [5].