Phase transition of KCl under shock compression

2002 J. Phys.: Condens. Matter 14 10783

(http://iopscience.iop.org/0953-8984/14/44/377)

INSTITUTE OF PHYSICS PUBLISHING JOURNAL OF PHYSICS: CONDENSED MATTER

J. Phys.: Condens. Matter **14** (2002) 10783–10785 PII: S0953-8984(02)38100-1

Phase transition of KCl under shock compression

T Mashimo[1], **K Nakamura**[1], **K Tsumoto**[1], **Y Zhang**[1], **S Ando**[2] **and H Tonda**[2]

[1] Shock Wave and Condensed Matter Research Center, Kumamoto University, Kumamoto 860-8555, Japan
[2] Faculty of Engineering, Kumamoto University, Kumamoto 860-8555, Japan

Received 13 June 2002
Published 25 October 2002
Online at stacks.iop.org/JPhysCM/14/10783

Abstract

It had been reported that for potassium chloride (KCl) the B1–B2 phase transition (PT) occurs under shock and static compressions, but the measured transition points showed large scatter. In this study, Hugoniot measurement experiments were performed on KCl single crystals by the inclined-mirror method combined with use of a powder gun. The anisotropic Hugoniot elastic limits and PT points were observed. The PT points along the $\langle 100\rangle$, $\langle 110\rangle$ and $\langle 111\rangle$ axis directions were determined as 2.5, 2.2 and 2.1 GPa, respectively. The anisotropic transition was reasonably explained in terms of the displacement mechanism along the $\langle 111\rangle$ axis direction.

1. Introduction

Potassium chloride (KCl) is a typical ionic crystal with the NaCl (B1) type of structure. It was reported that this material transformed to a CsCl (B2) type of structure under static compression [1–3]. In shock-compression research, Hugoniot measurements have been performed by the pin-contact method in the pressure region up to 200 GPa [4, 5]. The shock-wave profiles were observed by the quartz gauge method and the electromagnetic gauge method in the low-pressure region [6, 7]. However, the measured transition points under shock and static compressions showed large scatter. In this study, Hugoniot measurement experiments are performed on KCl single crystals parallel to the (100), (110) and (111) planes by the inclined-mirror method combined with use of a propellant gun to study the B1–B2 phase transition (PT).

2. Experimental procedure

The plate-shaped specimens, with thickness of about 3–4 mm and width of about 19 × 16 mm, were cut from single crystal. Some single crystals were grown by the Bridgman method under an air atmosphere, and some were provided by the Nihon Kessho Kogaku Co., Ltd. The purity of the starting material was higher than 4N. The mean bulk density was measured to be 1.989 g cm^{-3} by the Archimedean method.

0953-8984/02/4410783+03$30.00

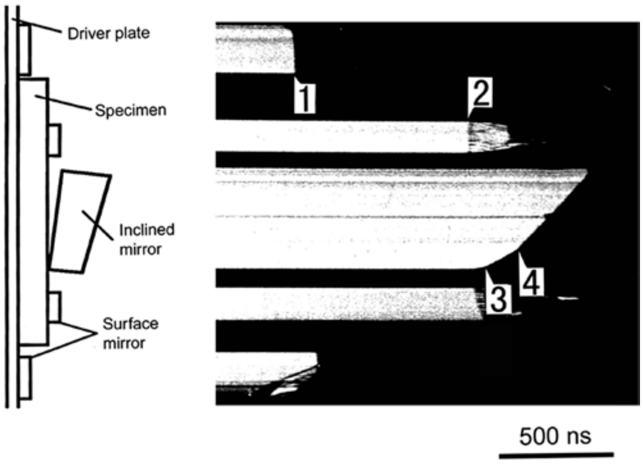

Figure 1. A streak photograph obtained by the inclined-mirror method for a single crystal shocked along the ⟨111⟩ axis at an impact velocity of 1.426 km s^{-1}.

The Hugoniot parameters were measured by means of the inclined-mirror method using rotating-mirror-type streak camera which provided a maximum writing rate on the film greater than 10 mm μs^{-1} [8]. In particular, we used a long-pulsed dye laser as light source, which meant we could use a thinner slit (2 μm) to increase the time resolution to higher than 1 ns [9]. The setting angles of the inclined mirror were 2°–5° in this study. The plane shock wave was generated by the high-velocity impact method using a keyed-powder gun 27 mm in bore diameter (impact velocity <2 km s^{-1}) [10]. Tungsten, copper or aluminium alloy (2024Al) plates were used as the impact and driver plates. These specimens and plates were finished parallel to an accuracy of 2–3 μm. The impact velocities were measured by the electromagnetic method within an accuracy of 0.2%. The particle velocities of the elastic wave and the plastic wave were analysed using the free-surface approximation, and the final shock-wave analysis was done by the impedance-matching method. The Hugoniot data for the impact and driver plates from [11] were used.

3. Results and discussion

Figure 1 shows a typical streak photograph obtained by the inclined-mirror method for a single crystal shocked along the ⟨111⟩ axis at an impact velocity of 1.426 km s^{-1}. At points 1 and 2, the elastic shock wave arrived at the rear surfaces of the driver plate and the specimen, respectively. Along the ⟨111⟩ axis direction, the particle velocity of the elastic wave was determined as 0.06 km s^{-1}. But the ones along the ⟨100⟩ and ⟨110⟩ axis directions were negligibly small (<0.01 km s^{-1}). This showed that the strength under uniaxial compression along the ⟨111⟩ axis direction was largest. A further kink due to the B1–B2 transition is observed at point 4, where the particle velocity was determined as 0.311 km s^{-1}. The elastic wave velocities along the ⟨100⟩ and ⟨110⟩ axis directions were consistent with the ultrasonic data [12].

Figure 2 shows the Hugoniot compression curve in the low-pressure region. The Hugoniot elastic limit (HEL) stress along the ⟨111⟩ axis direction was 0.4 GPa, while the ones along the ⟨100⟩ and ⟨110⟩ axis directions were negligibly small. The PT points along the ⟨100⟩, ⟨110⟩ and ⟨111⟩ axis directions were determined as 2.5, 2.2 and 2.1 GPa, respectively, which showed large

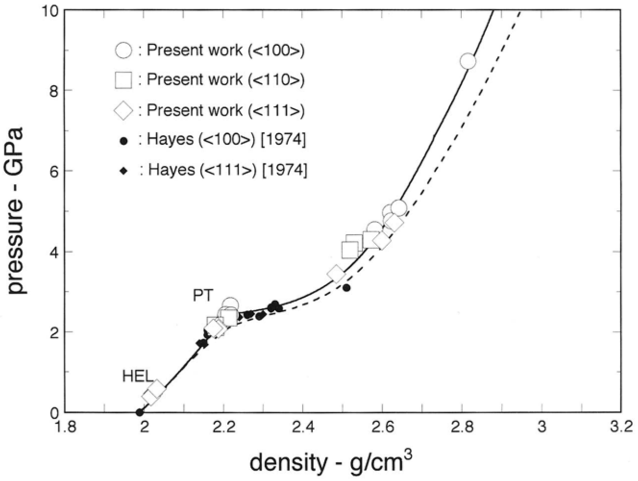

Figure 2. The Hugoniot compression curve in the low-pressure region.

anisotropy in the PT. The transition point along the ⟨111⟩ axis direction was lower than those along the ⟨100⟩ and ⟨110⟩ axis directions. This was reasonably well explained if we assumed that the B1-type structure transforms to the B2-type one with a displacement mechanism along the ⟨111⟩ axis direction. The volume change between the B1- and B2-type phases at zero pressure was estimated to be 13 ± 1%.

References

[1] Nagasaki H and Minomura S 1964 *J. Phys. Soc. Japan* **19** 1496
[2] Bassett W A, Takahashi T and Campbell J K 1969 *Trans. Am. Crystallogr. Assoc.* **5** 93
[3] Yagi T 1977 *J. Phys. Chem. Solids* **39** 563
[4] Heyes D B 1974 *J. Appl. Phys.* **45** 1208
[5] Dremin A N, Pershin S V and Pogorelov V F 1965 *Combust., Explos., Shock Waves* **1** 1
[6] Al'tshuler L V, Pavlovskii M N, Kuleshova L V and Simakov G V 1963 *Sov. Phys.–Solid State* **5** 203
[7] Kormer S B, Sinitsyn M V, Kirillov G A, Urlin V D and Blinov A V 1965 *Sov. Phys.–JETP* **20** 811
[8] Mashimo T, Nakamura A and Hamada S 1993 *Proc. SPIE* **1801** 170
[9] Uchino M, Kaetsu M and Mashimo T 1996 *Proc. SPIE* **2869** 597
[10] Mashimo T, Ozaki S and Nagayama K 1984 *Rev. Sci. Instrum.* **55** 226
[11] McQueen R G, Marsh S P, Taylor J W, Fritz J N and Carter W J 1970 *High-Velocity Impact Phenomena* (New York: Academic) ch 7, pp 293–417
[12] Anderson O L 1965 *Physics of Acoustics* vol 3B (New York: Academic)