Ionic current in molybdenum disulfide thin films

K.H. Norian

Electrical and Computer Engineering Department, 19 Memorial Drive West, Lehigh University Bethlehem, PA, USA 18015, Fax (610) 758-6279, Tel (610) 758-4082, E-mail **khn0@lehigh.edu**

Abstract

The present work is a study of ion transport in MoS_2 polycrystalline thin films. Under the action of an electric field ionic currents may flow in compound semiconductors due to ions in potential energy wells surmounting a barrier and jumping into a neighboring well. Starting from the electrical current versus voltage characteristics of the molybdenum disulfide films the jump distance for S^{2-} ions was determined to be 5.3±2 nm.

1. Introduction

This paper concerns a study of ionic electrical conduction through polycrystalline molybdenum disulfide thin films. An ionic current results in ionic semiconductors when, under the action of an applied electric field, an ion in a potential energy well surmounts an energy barrier to jump into a neighboring well. The jump distance between energy wells in MoS_2 thin films was calculated.

2. Theory

Fig 1 shows the potential energy variation as a function of distance into the ionic conductor. An ion at the bottom of an energy well has to surmount an energy barrier of U electron volts to jump into the adjacent well. Without an applied electric field, the material is at equilibrium, and the number of ions moving in any net direction, and the current, are zero. The application of an electric field E lowers the potential energy between two wells, a distance a apart, by eEa where e is the ionic charge. This lowers the barrier height for ions tending to move to the right by $0.5eEa$ electron volts and increases the barrier by the same amount for ions moving to the left[1]. The net electrical current in an ionic conductor with a potential difference V applied across its thickness d is

$$I=I_0\sinh(eaE/2kT) \qquad (1)$$

where a is the jump distance between neighboring potential wells, $E=V/d$ the electric field, and the rest of the symbols have their usual meaning.

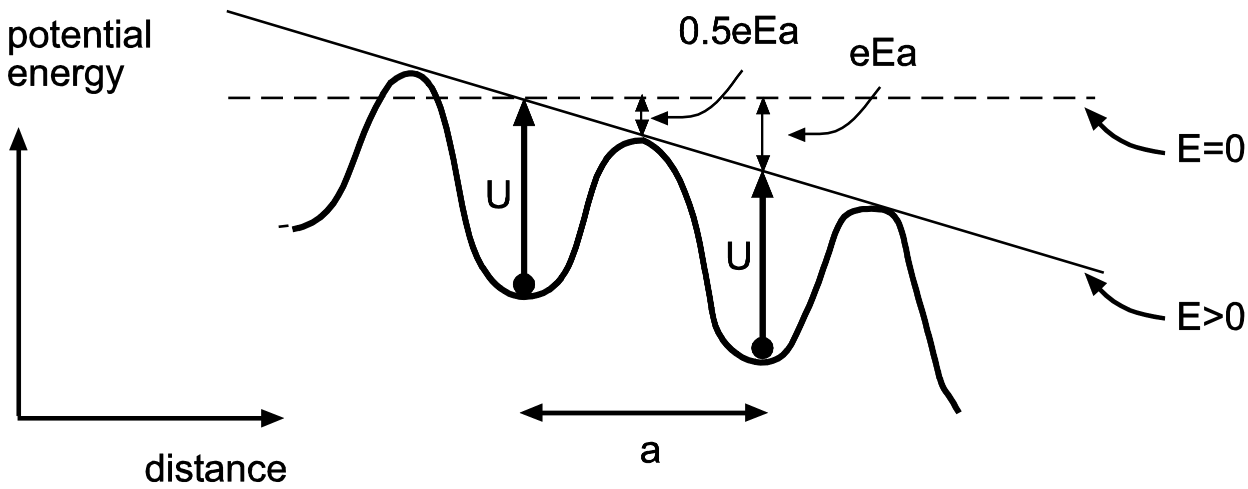

Fig 1 *Potential energy versus distance along ionic crystal showing ions in potential wells. U is the potential barrier when the applied field is zero. The application of the electric field E alters the barrier height.*

When $eaE \gg kT$ the barrier for ions tending to move to the left is large enough to make this component of current negligible, compared to the forward current, and the net current is now given by

$$I=0.5I_0\exp(eaE/2kT) \quad (2)$$

Linear and semi-log plots of current versus applied voltage V for Equs 1 and 2 appear in Figs 2 and 3. They show that at high electric fields the current voltage relationship can be represented by Equ 2. Also, taking the logarithm of both sides of Equ 2 gives a linear relationship between $\ln I$ and and V for large E. Plotting $\ln I$ versus V gives a straight line with slope

$$\Delta(\ln I)/\Delta V=ea/2dkT \quad (3)$$

The jump distance a is then determined from Equ 3.

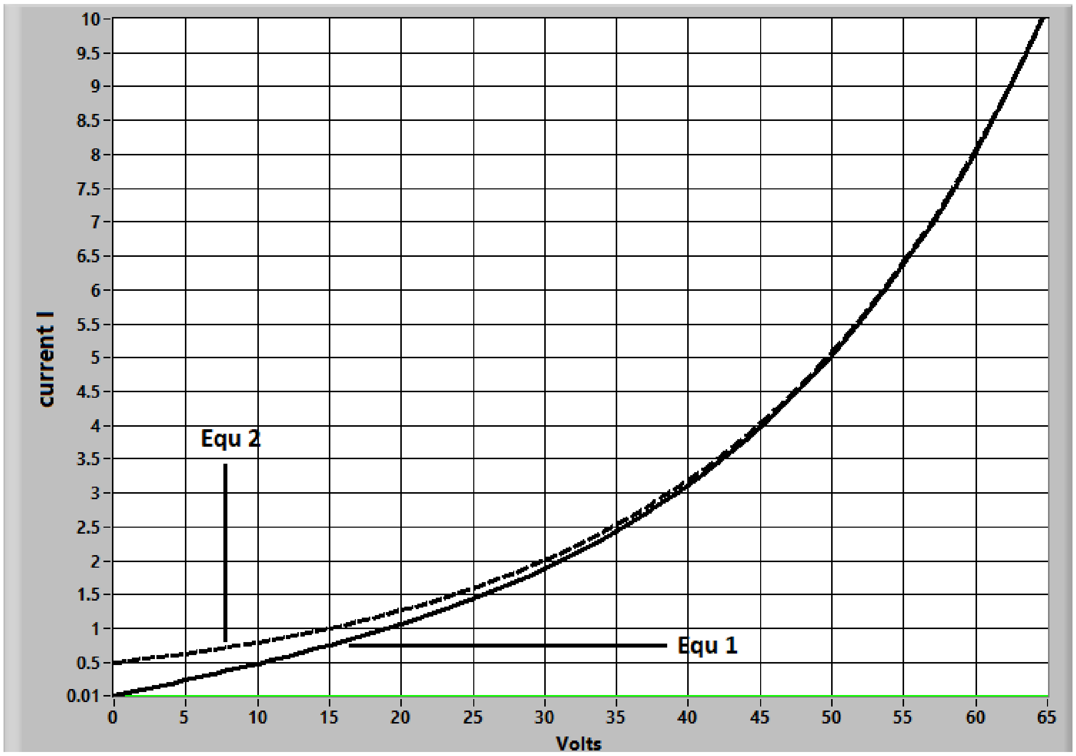

Fig 2 *Linear plot of current vs voltage*

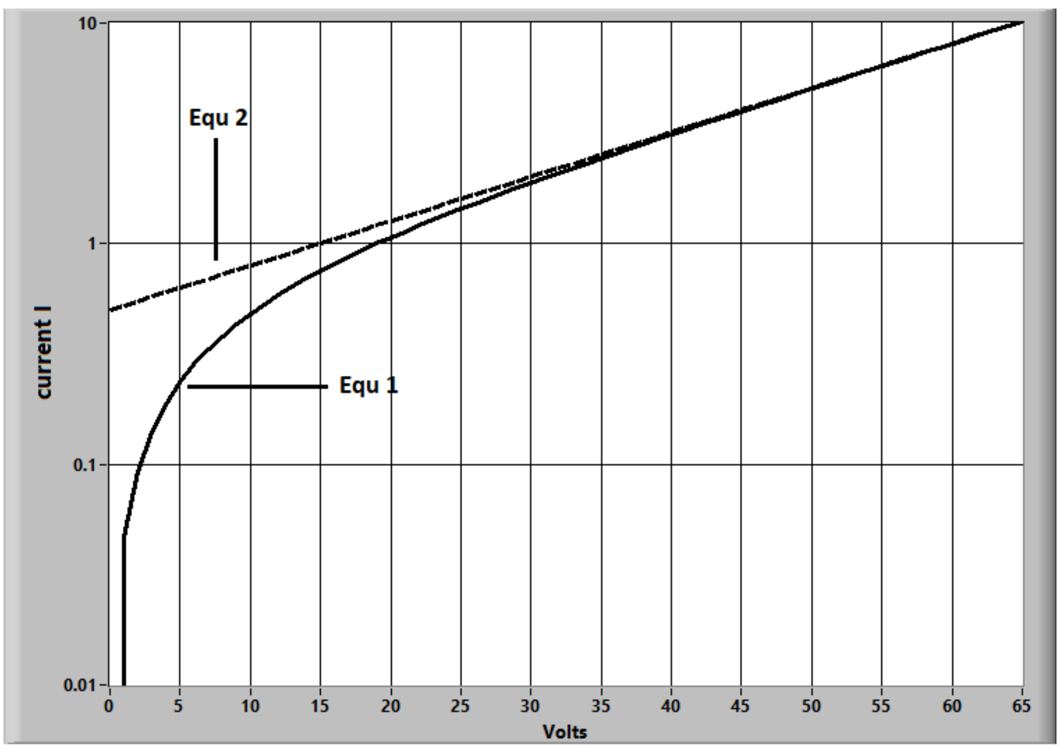

Fig 3 *Log-linear plot of current vs voltage*

3. Experimental

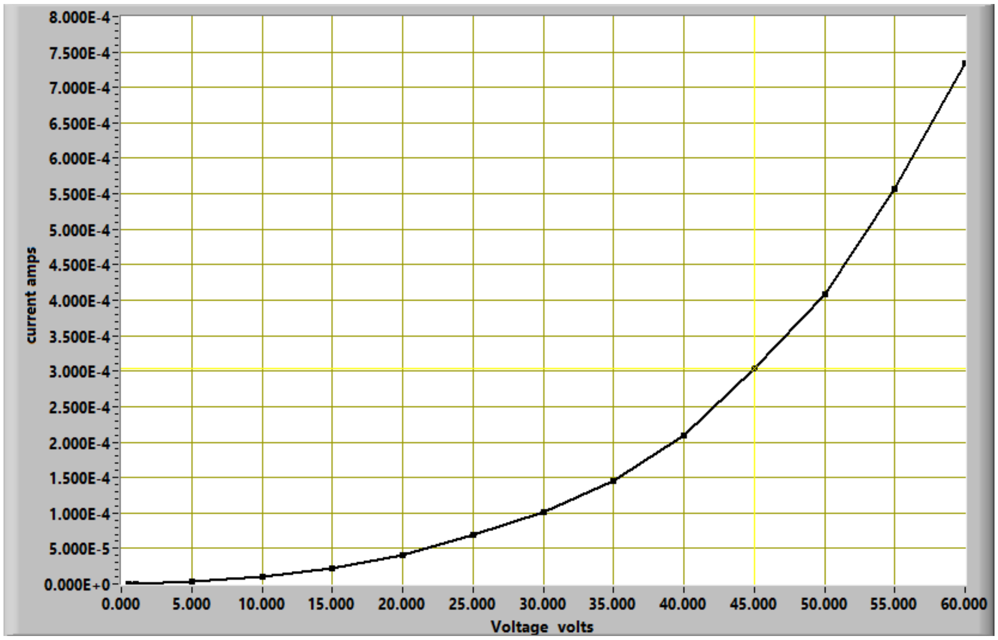

Fig 4 *Linear plot of current vs voltage for* MoS_2 *films*

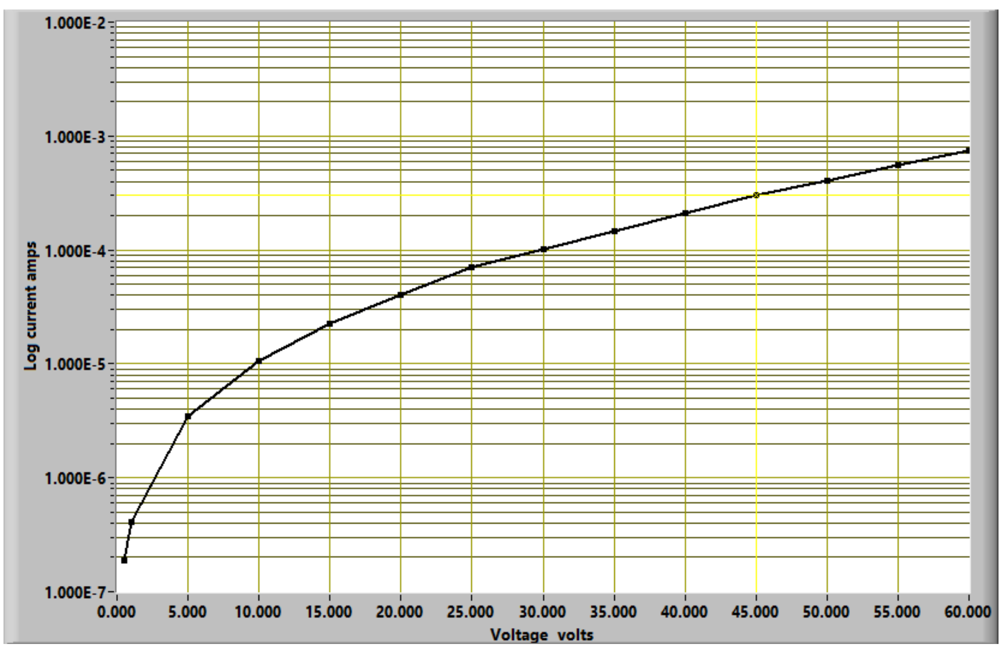

Fig 5 *Semi-log plot of current vs voltage for* MoS_2 *films*

Figs 4 and 5 show the linear and semi-log plots of the experimentally determined current-voltage values for polycrystalline MoS_2 films at room temperature. Equ 1 fits the plots of Figs 4 and 5. The curve in Fig 5 shows a linear relationship between ln*I* and and *V* for voltages higher than 25 volts. The average jump distance *a* for S^{2-} ions, determined using Equ 3, for the films examined, was 5.3±2 nm.

4. Reference

1. N. F. Mott and R. W. Gurney, Electronic processes in ionic crystals, 2nd Edition, Oxford University Press, Oxford, 1957.