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## Density of state anisotropy study in $\eta$ Mo<sub>4</sub>O<sub>11</sub> below Peierls' transition by tunneling effect

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**ABSTRACT:** We study here the evolution with temperature of the  $\eta$  Mo<sub>4</sub>O<sub>11</sub> density of state in different crystallographic directions by tunneling effect. We have pointed out that the evolution of the condensation rate and the width of the pseudo-gap is anisotropic.

### INTRODUCTION :

$\eta$  Mo<sub>4</sub>O<sub>11</sub> is with  $\gamma$  Mo<sub>4</sub>O<sub>11</sub> and Mo<sub>8</sub>O<sub>23</sub> a molybdenum oxyde compound of the MonO<sub>3n-1</sub> family. Its crystalline structure may be represented like an infinite stacks of MoO<sub>6</sub> octhaedra separated by planes of MoO<sub>4</sub> tetrahedra (ref. 1).

Transport properties have been studied for the first time in 80's. This compound presents a charge density wave transition towards 100 K and a second metal-semiconducting along b axis transition around 30 K. (ref 2). The type of this second transition is not well defined to our knowledge. The charge density wave transition (CDW) opens in a one dimensionnal crystal a semiconducting gap in a particular crystallographic direction, also called the nesting direction, and is always accompanied by a periodic lattice distortion (PLD).

The monoclinic molybdenum oxyde is a quasi bidimensionnal crystal, (b c) plane is the highly conducting plane, transport properties are very anisotropic along its crystallographic axis. The CDW transition appears at 98 K  $\pm$  2 K. The wave vector value of the PLD is 0,23 b\*.

Tunneling experiments seems all indicated here to study the evolution with temperature of the density of states in the Fermi level neighbouring for different

crystallographic orientation.

#### EXPERIMENTAL TECHNIQUE :

Tunneling junctions are prepared by using a classical technique. After having washed crystals in ammonia solution, dots of lead are evaporated in vacuum ( $10^{-6}$  Torr) on different natural faces. An insulating barrier of few Å is naturally made at the interface separating the materials. The junction quality has always been verified by observing the classical superconductive lead gap at 4.2 K and 1 K, as shown in left insert in figure 1. The superconductivity is then suppressed by applying a 2 kG magnetic field.

The crystallographic directions have been characterized under an optical microscope and by comparison of conductivity measurements along an axis which contain ohmic contacts and the lead dots, with results published in literature (ref 1). The typical evolution for different temperatures of  $dV/dI$  versus bias voltage is represented in figure 1.

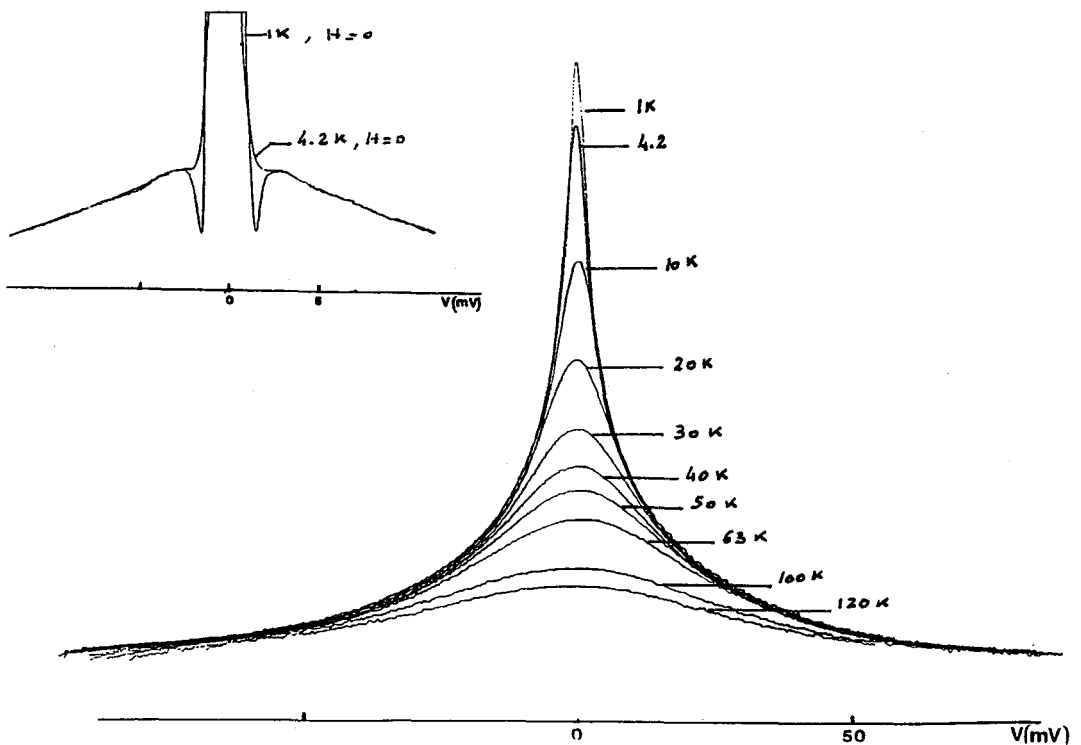


figure 1 : evolution of  $dV/dI$  for various temperature. (left insert : superconductive gap of lead at 4.2 K and 1 K .

## RESULTS AND DISCUSSION :

It's well known that the density of states  $N(E)$  can be obtained by first derivative of tunneling current versus applied voltage (ref 2 ). For an experimental reason we plot the inverse  $dV/dI$ . We have choosed the  $dV/dI$  curve at 100 K in figure 1 as ground base. If we compute the inverse of difference between different curves and ground base , we obtain the density of state evolution for different temperatures. The condensation rate is described in figure 2 .The condensation at Fermi level is the most important when the junction plane is perpendicular to a axis and ohmic contacts are along b axis or in other hand that tunneling current is contained in ab plane (curve 1) . In this case the width at half height of the tunneling density of state at 1 K ( $2\Delta$ ) is less important and is typically equal to 15 mV  $\pm$  2 mV.

At the opposite, when tunneling current is contained in bc plane (curve 3) the condensation at Fermi level is the slowliest and the value of  $2\Delta$  is the largest (typically 30 mV  $\pm$  2 mV). The curve n°2 represents the case where junction plane is perpendicular to a axis and ohmic contacts being along c axis (tunneling current is along ac plane), the value of  $2\Delta$  is also 30 mV  $\pm$  2mV.If we compare the evolution of condensation rate in orthorombic molybdenum bronze, as shown ,in figure 2 ,we remarks that the tunneling characteristics are quasily independent of crystalline orientation.This result is coherent with conductivity curves obtained with this material

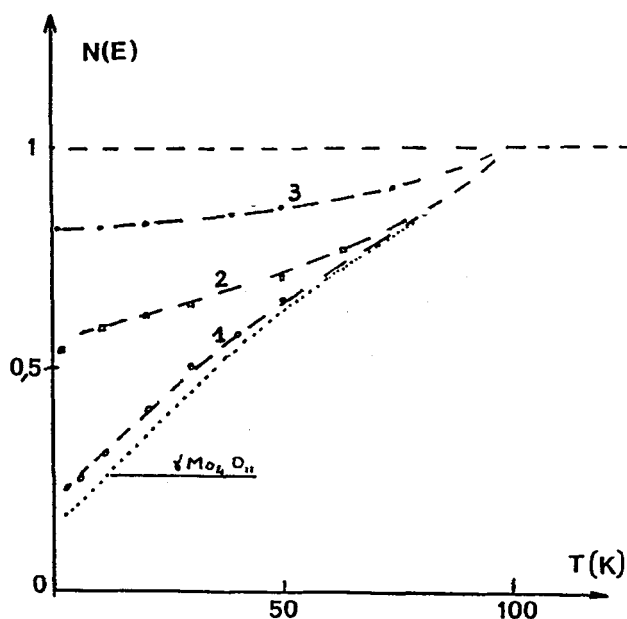


Figure 2: Evolution of condensation rates along different directions in  $\eta$  Mo<sub>4</sub>O<sub>11</sub> and in  $\gamma$  Mo<sub>4</sub>O<sub>11</sub> .

In the aim to verify that the "gap" or "condensation at Fermi level" follow a BCS comportment with temperature we have supposed firstly that the shape of condensation have a lorentzian form given by the following expression :

$$N(E) = (1 - k_c \Delta^2 / (\Delta^2 + E^2)) \quad \text{formula in which } k_c \text{ is the condensation rate at}$$

lowest temperature . Secondly we have supposed that  $2\Delta$  followed a BCS law

$$\text{versus temperature as: } \Delta(T) = \Delta(0) (1 - (T / T_P))^{1/2} . \text{ We have introduced this}$$

expression in the classical formula giving the first derivative of tunneling current

versus bias voltage (ref 2 ). We have plotted in figure 3 the results of simulation. The

surprise is a good similitude between experimental results and computation. If we

use a gaussian gap with the same parameter  $k_c$  the simulation give a bad result. We

are not able to explain this fact , and we hope that this analytic form of density of states could be a way for a theoretical work.

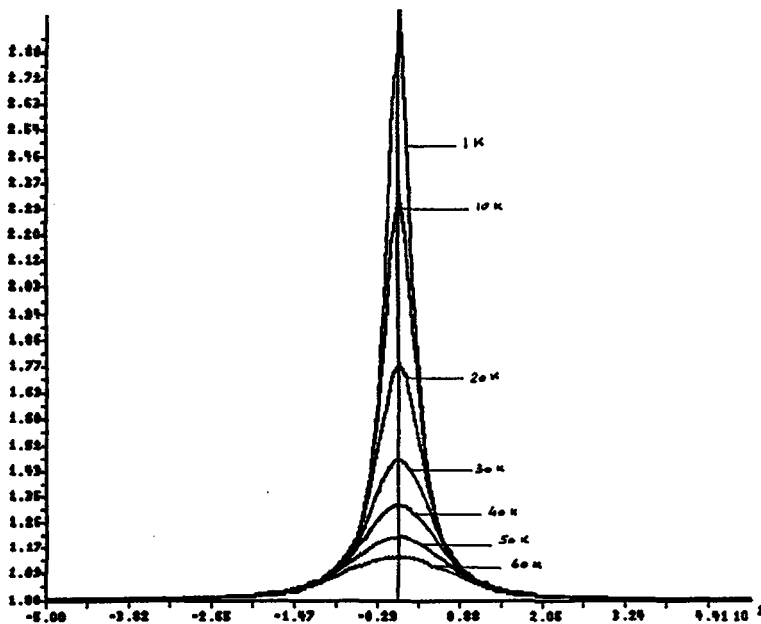


Figure 3: Simulation of  $dV/dI$  versus applied voltage with a lorentzian condensation

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