# Electric Transport Study of Superconducting $MgB_2$ Wire

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**Abstract**

Superconducting $MgB_2$ wires were prepared by exposing boron fiber to magnesium powder in high temperature. Pulse current method has been used to study the $V$-$I$ characteristics systematically in a large current range. Using a scaling function, all the $R$-$T$ curves in different field converge into a single universal curve. From the $V$-$I$ curves, we find a much sharp N-S transition and in high field a reasonable large $J_c$ is found.

*Key words:* $V$-$I$ characteristics; $MgB_2$ wire; Pulse current method

## 1. Introduction

There has been increasing interest in studying the properties of $MgB_2$ since the discovery of its superconductivity with $T_c$~39K [1]. Dense $MgB_2$ wires were also successfully fabricated [2], which showed promising prospect in strong current applications. In this paper we will report recent results of transport study of $MgB_2$ wires by pulse current method.

## 2. Experimental

The $MgB_2$ wire is prepared by sealing 100$\mu$m diameter boron fiber (with 15$\mu$m diameter tungsten core) and magnesium powder with $Ta$ foil, putting them into a quartz tube and placing the tube into an 800°C furnace for about 1.5 hours. After cooling to room temperature naturally, we find that the $MgB_2$ layer on the surface of wire is almost 0.5$\mu$m in thickness and $1.5\times10^{-6}$ $cm^2$ in cross-section area. In order to reduce the contact resistance of current electrodes, gold films are deposited on the wire and then annealed at 300°C for 1.5 hours. The contact resistance is less than 0.4 ohm. In order to reduce the heating in the measurements and protect the sample, we use pulse current to conduct the four-terminal transport measurements.

## 3. Results and Discussions

Fig. 1 presents the temperature-dependent electrical resistance of the wire under different magnetic field. The zero-field superconducting transition occurs at 39.4K, and the width of the transition (10%-90%) is about 1.1K. The residual resistivity ratio [$\equiv\rho(300\text{K})/\rho(40\text{K})$] is 1.4. It can be easily found that the field dependent transition temperatures obeys the power law: $1\text{-}T_c(H)/T_{c0}\propto H^{2/3}$. According to the scaling analysis, the contribution of thermal fluctuation to the conductivity can be scaled as [3]:

$$G_f = (T^2/H)^{1/3} F[A\frac{T - T_c(H)}{(TH)^{2/3}}], \quad (1)$$

where $G_f$ is the thermal fluctuation magnetoconductance, and $A$ is the field- and temperature- independent coefficient. $F(x)$ is universal for all magnetic fields.

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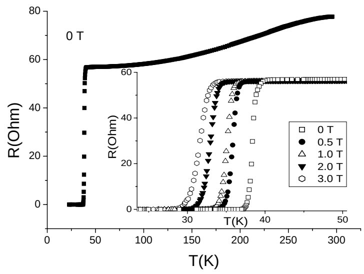


Fig. 1. $R$-$T$ curves of $MgB_2$ wire under various magnetic fields.

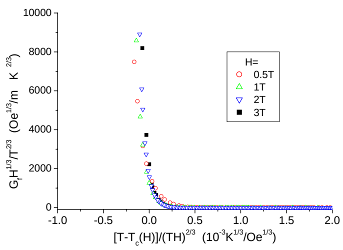


Fig. 2. Scaling of magnetoconductance for $MgB_2$ wire.

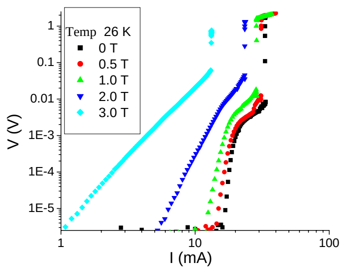


Fig. 3. $I$-$V$ curves of $MgB_2$ wire under various applied fields

The values of $G_f$ can be obtained from $G_f$=$1/R(T)$-$1/R_n(T)$, where $R(T)$ is the electrical resistance and $R_n(T)$ is the linear extrapolation of the normal-state resistance. This scaling law has been successfully applied to polycrystalline $MgB_2$ sample[4]. Fig. 2 shows the value of $G_f H^{1/3}/T^{2/3}$ versus the scaling parameter $[(T\text{-}T_c(H)]/(TH)^{2/3}$ for our $MgB_2$ wire. It can be seen that all the curves in different field converge into a single universal curve. The successful scaling enable us to estimate the upper critical field of our wire according to $H_{c2}(T)$=$H_{c2}(0)[1\text{-}(\mathrm{T}/T_c)^{3/2}]^{3/2}$ and a value of 16-18T is then obtained.

$I$-$V$ characteristics of the $MgB_2$ wire under different applied fields were also studied systematically (Fig. 3). It was found that there is an abrupt jump during the normal-superconducting transition in each $I$-$V$ curve for all the field applied. We attribute this unique feature to the considerable thinner $MgB_2$ layer of the wire, which might cause a loose array between the crys-

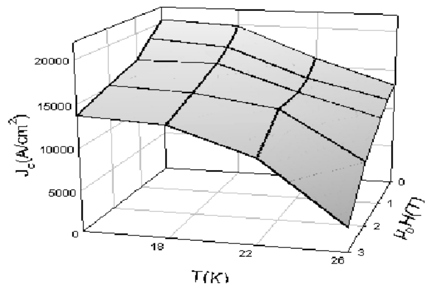


Fig. 4. temperature- and field-dependence of $J_c$ of the $MgB_2$ wire

tal grains, leading to a sudden increase in normal resistivity during the transition. The temperature- and field-dependence of critical current density $J_c$ is plotted in a two dimensional graph (Fig. 4) as part of the phase diagram of the $MgB_2$ wire. It is interesting to point out that though $J_c(H,T)$ of our wire descends with increasing fields and temperatures as expected, the extent of the decrement is much smaller than what has been reported[2]. This is propitious to the application of $MgB_2$ in high fields.

## 4. Conclusion

$MgB_2$ wire was fabricated and its transport properties were studied by pulse current method under different magnetic fields. It is found that the field dependent transition temperatures $T_c(H)$ obeys a power law, $1\text{-}T_c(H)/T_c(0)\propto H^{2/3}$ and by using thermal fluctuation scaling analysis, upper critical field of the wire is estimated to be between 16T to 18T. Systematic $I$-$V$ measurements showed that the decrement of critical current density $J_c(H,T)$ with increasing temperature and/or magnetic field is much smaller than what has been reported, revealing a promising prospect for the application of $MgB_2$ wires in high fields.

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