Phase transition in high-mobility Si MOSFET

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ABSTRACT

we re-analyzed the data taken by Pudalov and co-workers, the insulating and metallic behaviour in high mobility 2D Si-MOSFETs at very low temperature with parallel magnetic field. At the lowest carrier densities, insulating behaviour is observed with the resistivity increasing with decreasing temperature. As the carrier density increased a transition to metallic behaviour occurs. Despite exhibiting all the properties of the metallic behaviour observed in other material systems, localising corrections due both to weak localization and electron-electron interactions are still present in the metallic regime. For higher carrier densities the metallic regime becomes weaker and the saturation becomes visible at higher temperatures.

INTRODUCTION

- In 2D electron systems, the electrons are confined to move in a plane in the presence of a random potential.
- In 2D the scaling theory of localization (Abrahams 1979) predicts insulating behavior: with decreasing temperature the resistance grows (for non-interacting electrons).
- Experiments on low-disordered silicon samples (Kravchenko *et al* 1994, 1995, 1996) demonstrated dramatic differences between the behaviour of strongly interacting systems as compared with weakly interacting systems: with increasing electron density, one can cross from the regime where the resistance diverges with decreasing temperature (insulating behaviour) to a regime where the resistance decreases strongly with decreasing *T* (metallic behaviour).

RESULTS

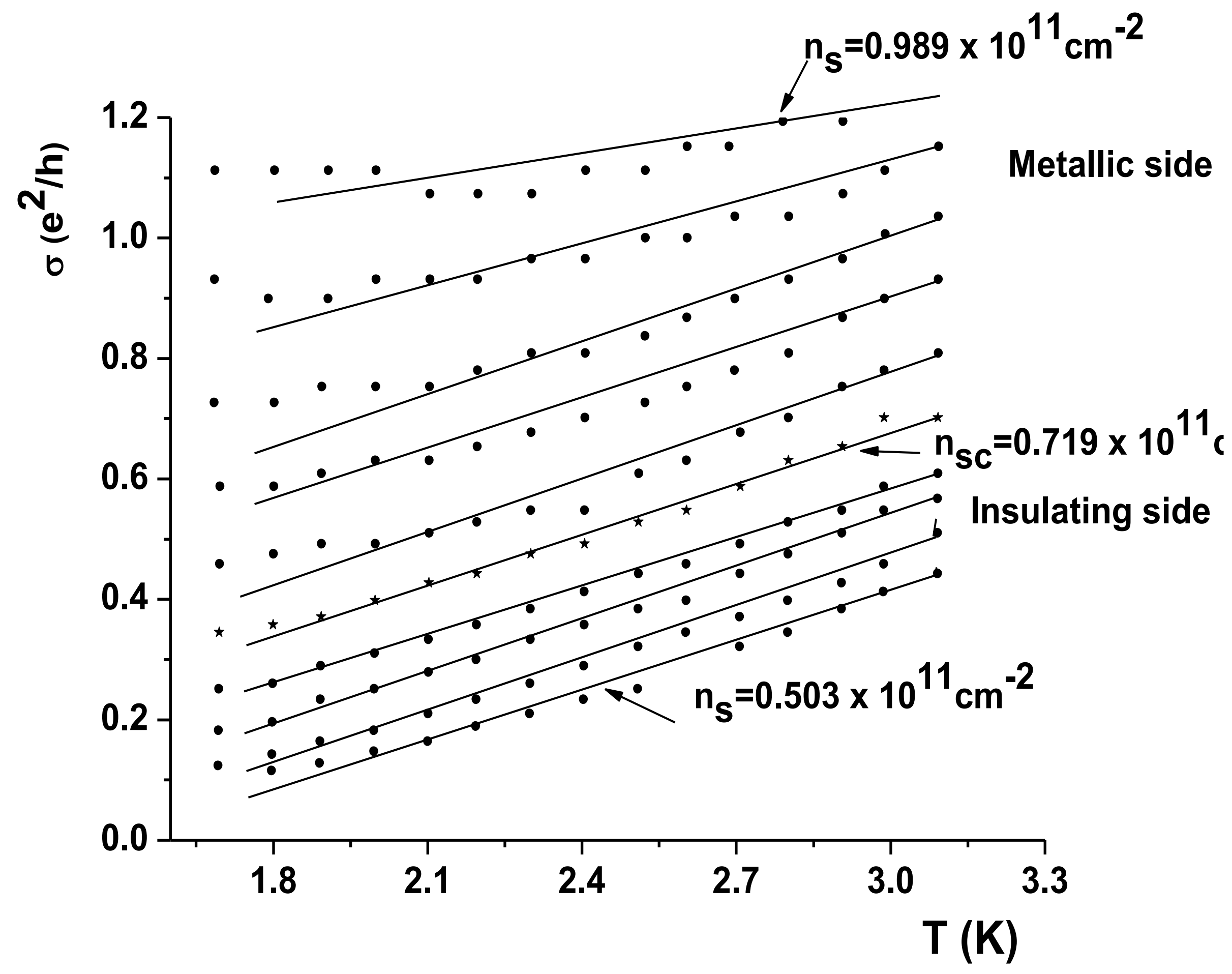

Figure 1. Electrical conductivity as a function of the temperature T in the vicinity of the critical density .

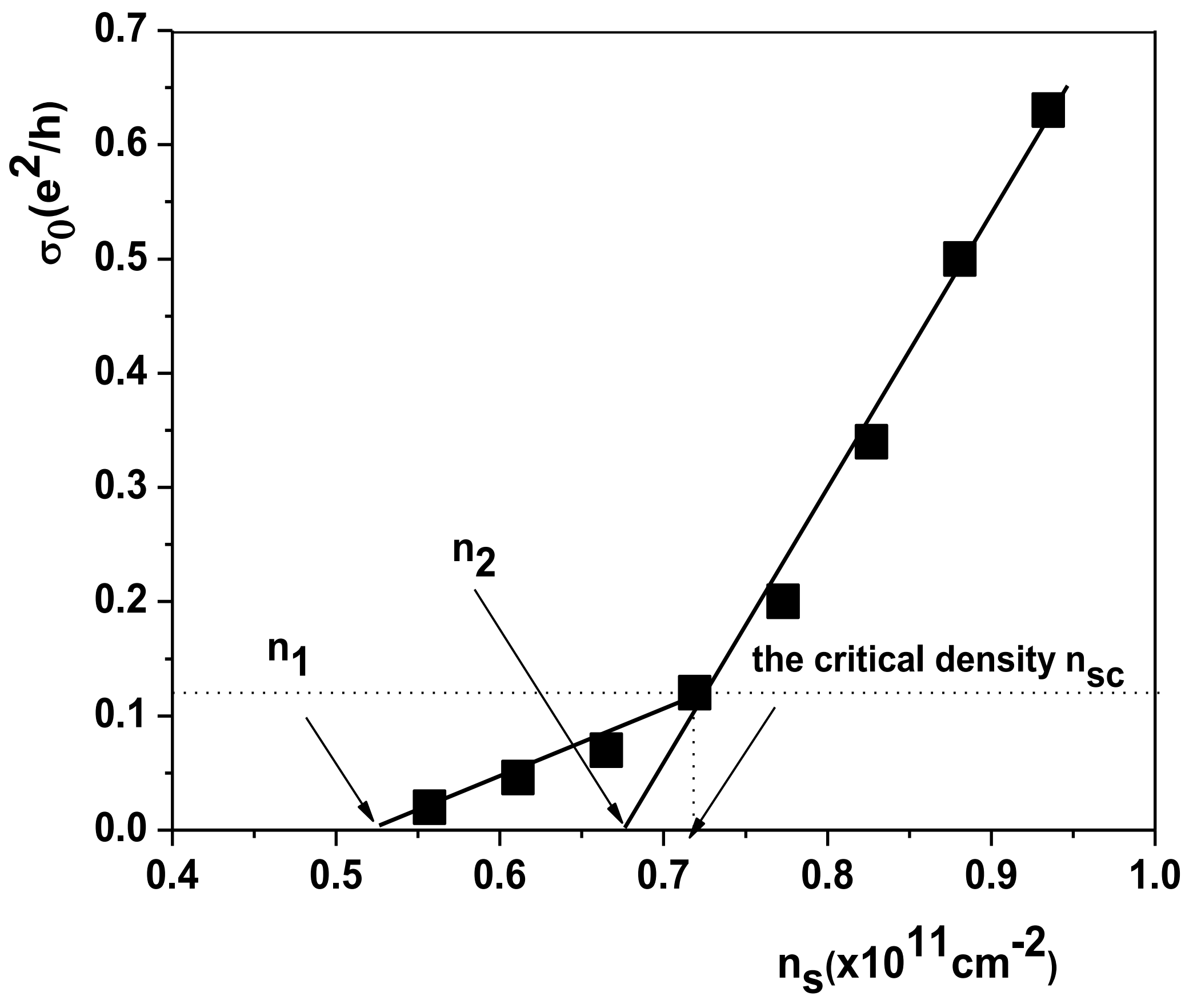

Figure 2. The T = 0 K conductivity , extrapolated from the T linear fit is plotted as a function of the carrier densities . The solid lines are linear fits on both low- and high- regimes and they extrapolate to = 0 at and , respectively.

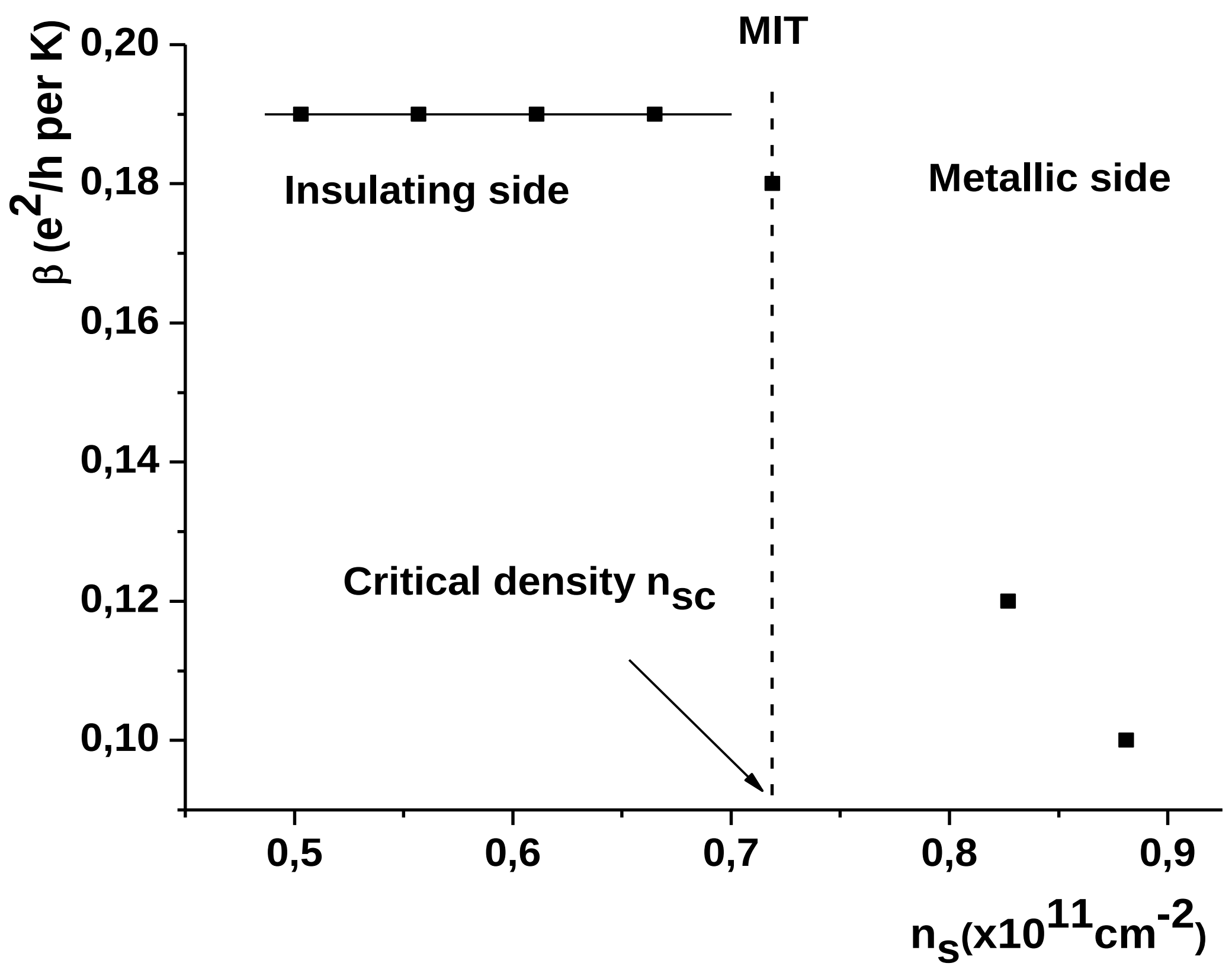

Figure 3. The slope versus carrier density

The insulating behaviour of the MIT can be described by conventional variable range hopping (VRH) conduction.

$$\rho(T) = \rho_0 \exp (T/T_0)^{-m} \qquad (1)$$

At the very lowest densities m=1/2, characteristic of VRH in the presence of a Coulomb gap. At higher densities, close to the transition to metallic behaviour, *m* crosses over to 1/3, characteristic of conventional phonon-assisted VRH .

The collapse of all the ρ(T) data onto a single trace in the insulating regime is not suprising, as it is a natural consequence of conduction by VRH. If the prefactor is constant then Equation (1) implies that ρ(T) depends only upon T/T_0. A gradual crossover from m= 1/2 to 1/3, with a corresponding gradual change of the prefactor ρ_0 , will not affect this collapse as long as the change in ρ_0 is small.

However, the ability to collapse both the insulating and metallic like ρ(T) data onto two branches is less readily explained, and has attracted considerable attention.

CONCLUSIONS

It is now well established that a MIT can be observed in 2D Si-MOSFETs structure, although the physical origins of this phenomena are still a subject of some controversy. We have showed that insulating side of the MIT is observed for lower carrier densities below. In this region we have noticed that the resistivity increases rapidly as the temperature is reduced. We have also obtained a gradual crossover for exponent *m* in equation (1) from to close to the MIT.

At higher densities metallic behaviour is observed, with the resistivity dropping as the temperature is reduced. As the carrier density is increased and we move further from the transition, the metallic behaviour becomes weaker and the saturation becomes visible at higher temperature. The empirical formula given by equation $\rho(T) = \rho_0 + \rho_1 \exp(-T_1/T)^n$ therefore dictates a saturation of as . Although different from the scaling analysis, and the scaling shown in “FIGURE 2”, it is still consistent with the existence of a 2D metallic state because remains finite as .