LOW TEMPERATURE MAGNETORESISTANCE IN SILICON DOPED BY ANTIMONY

ALEXANDER L. DANILYUK, ANTON G. TRAFIMENKO, SERGHEJ L. PRISCHEPA

Belarusian State University of Informatics and Radioelectronics, Minsk, Belarus

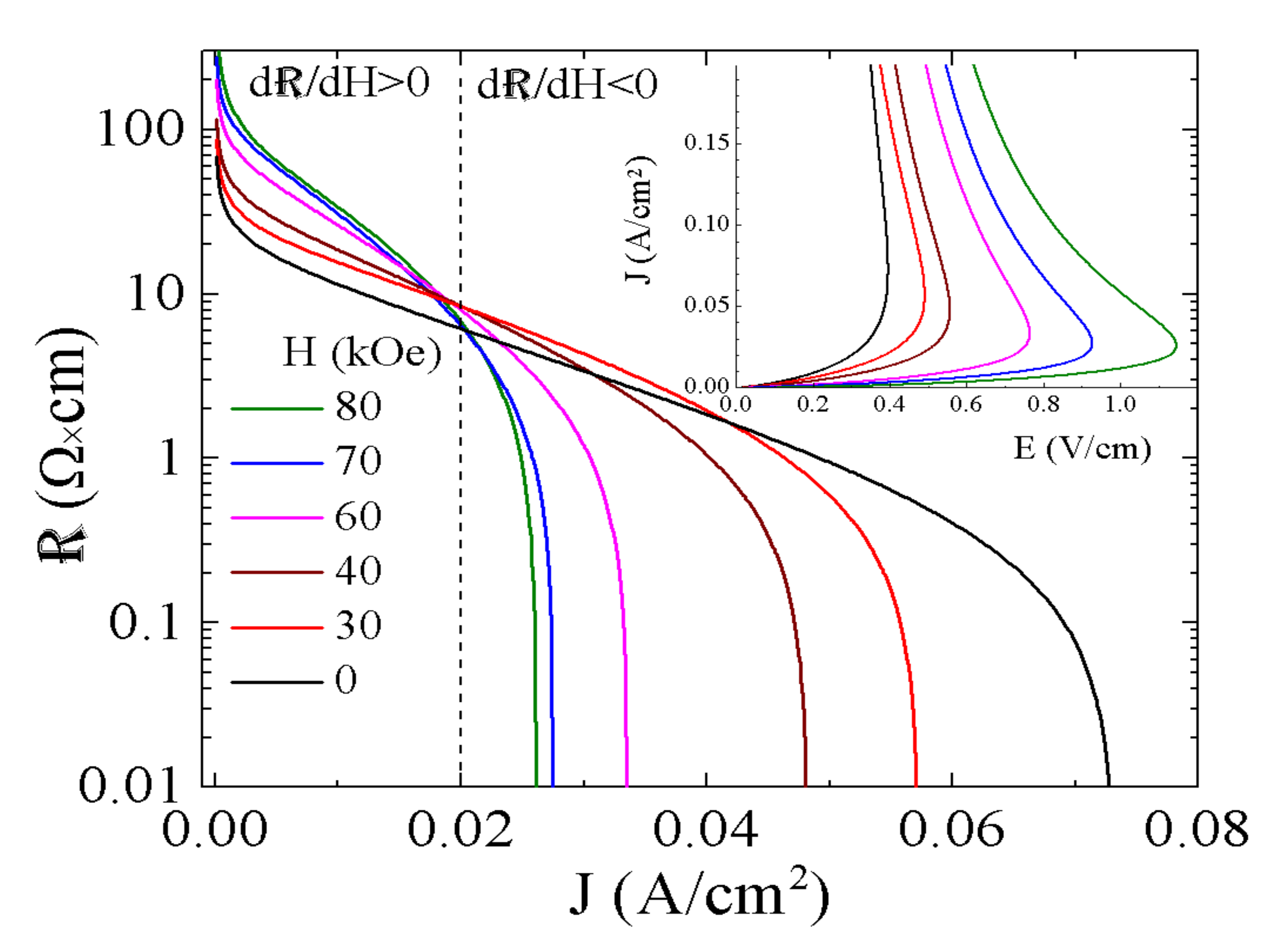
DESCRIPTION

- Magnetoresistance and magnetotransport in silicon and silicon-based nanostructures has great impact on the development of silicon spintronics and quantum information processing.
- In this contribution, the magnetoresistance (MR) of Si doped by Sb with the concentration of N_d=10^{18} cm^{-3} and temperature T = 2 K within the current range 0.015 – 0.050 A/cm^2 in magnetic field up to 80 kOe is considered. Samples were grown by Czochralski method.

THE MODEL

Calculations of the MR were performed within the model of week localization for 3D samples considering different scattering mechanisms. Theory of week localization was developed by many authors. The main results for 3D case were obtained by Kawabata. He deduced the main equation for the 3D case. In the present work we apply the Fukuyama model [1] in which week localization includes mechanisms of scattering on magnetic impurities, spin-flip scattering due to spin-orbit interaction, inelastic scattering.

J-E CHARACTERISTICS, MAGNETORESISTANCE



CALCULATING THE QUANTUM CORRECTION TO CONDUCTANCE

$$\Delta\sigma = \left(\frac{q^2}{2\pi^2\hbar}\right)\frac{1}{l_n}F(H,\tau_i)$$

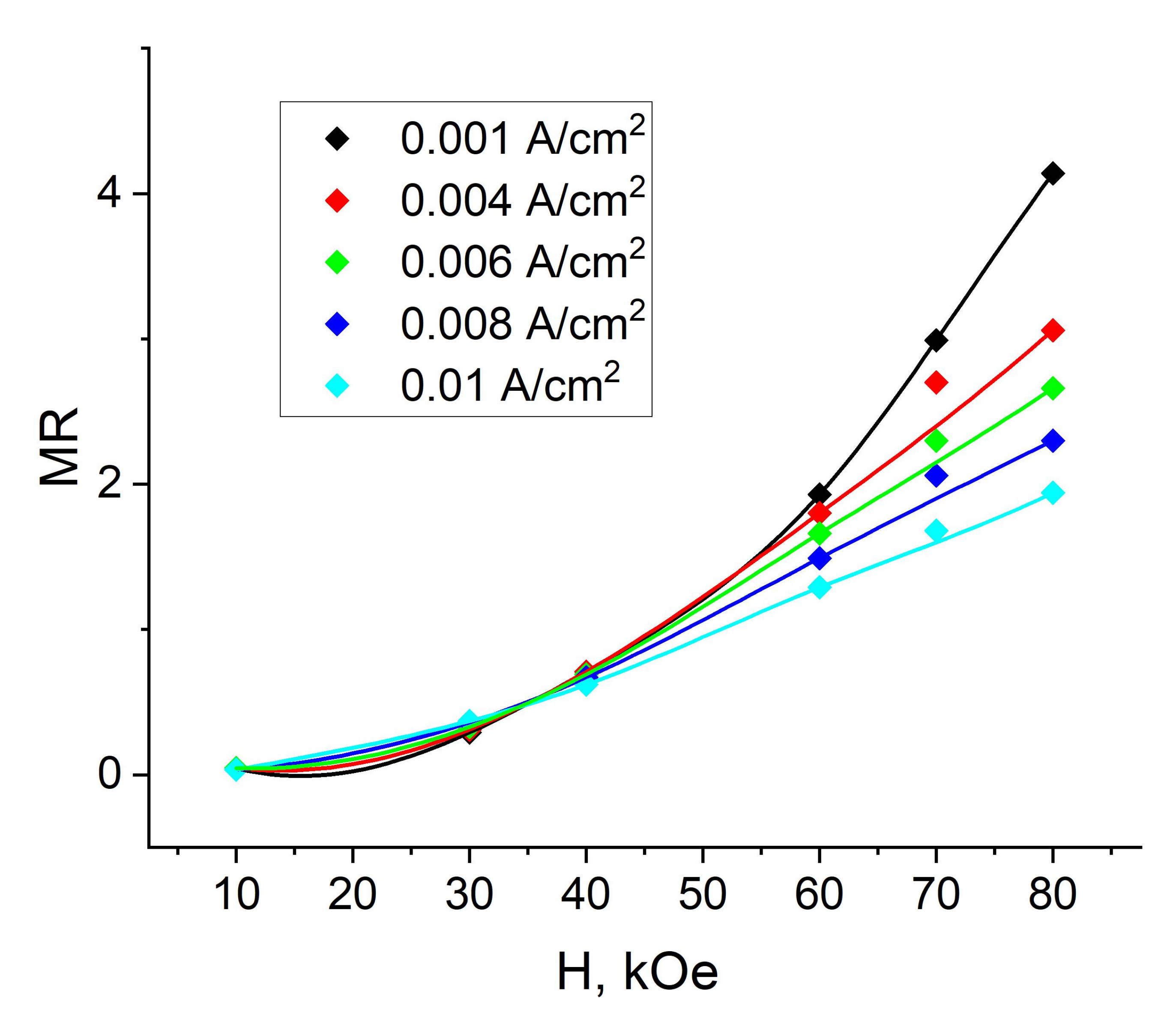
$$l_n = \lambda_e\sqrt{\tau_{so}/3\tau}$$

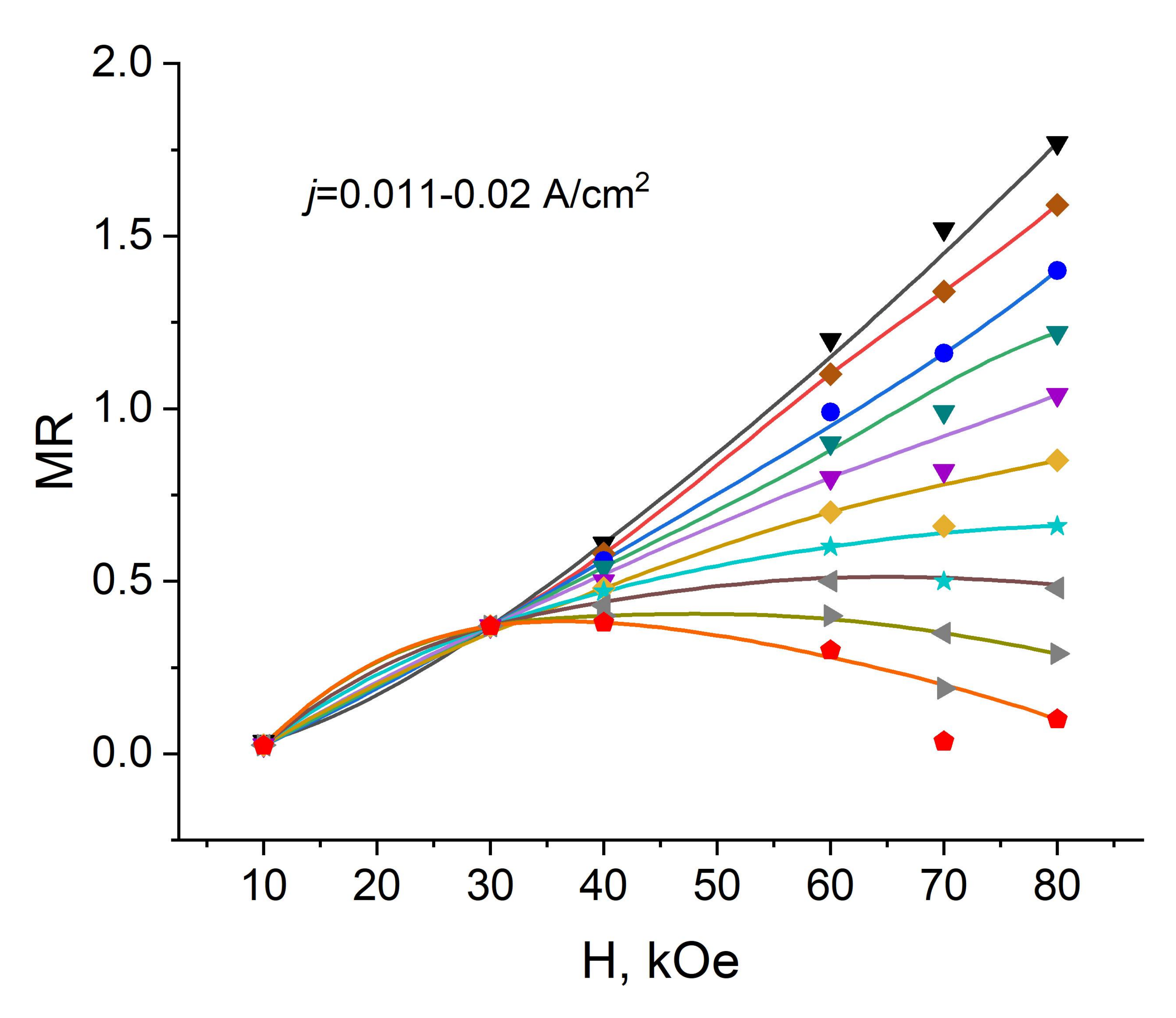
$$F(H,\tau_i)=\sqrt{h}f\left(\frac{1+t}{h}\right)+0.5\sqrt{\frac{h}{1-\gamma}}\left[f\left(\frac{t_+}{h}\right)-f\left(\frac{t_-}{h}\right)\right]-\frac{1}{\sqrt{1-\gamma}}\left[\sqrt{t_-}-\sqrt{t_+}\right]+\sqrt{t}-\sqrt{t+1}$$

$$f(z)=\sum_{N=0}^{\infty}\left[2\left(\sqrt{N+1+z}-\sqrt{N+z}\right)-\frac{1}{\sqrt{N+\left(\frac{1}{2}\right)+z}}\right]$$

where $t=\tau_{so}/4\tau_\varepsilon$, $h=(\lambda_e/l_H)^2(\tau_{so}/3\tau)$, $t_\pm=t+0.5[1\pm(1-\gamma)^{1/2}]$, $\lambda_e=v_e\tau$, $l_H=(\hbar/q\mu_0 H)^{1/2}$, $\gamma=(g\mu_B\mu_0 H\tau_{so}/2\hbar)^2$

Dependences of the MR on magnetic field strength. Experimental and calculated data





CONCLUSIONS

The MR of antimony-doped silicon was studied at an impurity concentration of 10^{18} cm^{-3} and a temperature of 2 K. It was shown that at low current densities, the manifestation of positive MR is due to the prevailing contribution of spin-orbit scattering. At increased current densities, the manifestation of negative MR is associated with the suppression of a weak localization by a magnetic field. At intermediate current densities, the manifestation of crossovers from positive to negative MR is associated with the competition of spin-orbit scattering and inelastic scattering, which causes a dephasing of interfering electrons.

[1] H. Fukuyama, K. Hoshino. Journal of the Physical Society of Japan, Vol.50, No.7, 1981, pp. 2131.