Magnetotransport Studies in Oxide and Nitride Semiconductors Assisted with Mobility Spectrum Analysis

Sebastian Złotnik [1], Jerzy Wróbel [1,2] and Jarosław Wróbel [1]

[1] *Institute of Applied Physics, Military University of Technology, 2 Kaliskiego Str., 00-908 Warsaw, Poland*
[2] *Institute of Physics, Polish Academy of Science, Aleja Lotników 32/46, 02-668 Warsaw, Poland*

Magnetotransport studies are significant in the evaluation of electronic transport characteristics of any semiconductor materials and heterostructures targeting photonic applications. Temperature-dependent Hall effect and resistivity measurements at a constant magnetic field are normally conducted, though only adding magnetic-field-dependent datasets may give a more detailed picture of potentially multiple carrier types present in modern materials. A mobility spectrum analysis (MSA) is the methodology to be proven to be effective in determining parallel conductions in various compounds. The MSA approach was recently successfully implemented by our research group for studies of electronic transport in various materials [1-3]. Moreover, original variants of the MSA method for data treatment have been used [4].

Here, certain groups of semiconductor compounds were explored using the aforementioned approach, and a superconducting 16T Cryogen-Free Magnet System (CFMS) fabricated by Cryogenic Ltd. The CFMS has a high magnetic field homogeneity and allows good temperature stabilization. The studies were conducted on wide bandgap (WBG) semiconductors, namely III-nitrides (GaN) and metal oxides (Ga_2O_3, In_2O_3- and ZnO-based compounds). In the Ga-containing materials, either unintentionally doped or donor-doped ones, the number of distinct separated electronic carrier channels, electron- and hole-like, can be revealed with their precise carrier concentration and mobility parameters. Importantly, the dominant electron-type conduction channels present in these compounds are characterized by electron mobility not exceeding 1000 $cm^2\ V^{-1}s^{-1}$. On the other hand, in transparent conductive oxides (TCOs), normally an unimodal electron population can be solely detected (associated with a bulk-like conduction), and there is an absence of parallel conductions. The confirmed experimental datasets in TCOs can be viewed as an important validation of exclusively donor-type defects and/or impurities contributing to total conductivity. The results collected so far will assist in refining the physical materials models and will be helpful in designing a new generation of optoelectronic devices.

Acknowledgments: This research was completed with the financial support under the program of the Minister of Science and Higher Education (Poland): "Regional Initiative of Excellence" in 2019–2023; project number 014/RID/2018/19, funding amount of PLN 4 589 200.00 (rid.wtc.wat.edu.pl).

[1] S. Złotnik, A. Pianelli, J. Boguski, M. A. Kojdecki, P. Moszczyński, J. Parka, and J. Wróbel, *Phys. Status Solidi RRL* **16**, 2200170 (2022).
[2] D. Śnieżek, J. Wróbel, M. A. Kojdecki, C. Śliwa, S. Schreyeck, K. Brunner, L. W. Molenkamp, G. Karczewski, J. Wróbel, *Phys. Rev. B* **107**, 045103 (2023).
[3] J. Wróbel, G. A. Umana-Membreno, J. Boguski, S. Złotnik, A. Kowalewski, P. Moszczyński, J. Antoszewski, L. Faraone, J. Wróbel, *Opto-Electron. Rev.* **31**, e144567 (2023).
[4] i) M. A. Kojdecki, J. Wróbel, Know-how WAT-MSA, 51/2023 (CTT WAT), ii) J. Wróbel, J. Wróbel, Know-how WAT-MSA, 52/2023 (CTT WAT).