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Editorial

The challenges for superconducting wires and tapes today and tomorrow

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The main advantages of superconducting wires and tapes is lossless flow of transport current, lossless storage of energy, and generation of high magnetic fields. These advantages can help solve the most critical problems that world faces. Currently, humanity's primary concern is energy security. Humanity for stable development needs cheap, stable, and non-polluting energy sources. A fusion reactor can meet such expectations because it will produce a large amount of stable energy without pollution of the natural environment. This reactor needs cheap superconducting coils and superconducting wires with high critical parameters. Various superconducting wires and tapes e.g., NbTi, Nb_3Sn, MgB_2, HTS, and iron-based superconductors are being considered and tested. It seems that in the future, MgB_2 wires with isotopic boron (^{11}B) may be necessary for fusion reactors because irradiation does not degrade the transport critical current density and has a short decay time of about 1 year [1]. Another crucial application of superconductivity could be the combination of renewable energy sources with superconducting magnetic energy storage. This opens up prospects for cheap and clean energy on a small scale (small family businesses).

The next challenge for humanity is health. Humanity needs fast, precise and non-invasive diagnostic methods. Magnetic resonance imaging (MRI) has such capabilities [2]. Cheaper superconducting wires and tapes with high transport critical current density would allow to lower production costs of MRI devices, which would increase the availability of such diagnostic method for patients.

Superconducting wires and tape also have great potential for space and aerospace applications: electric motors, space propulsion [3], energy storage, and cosmic radiation shielding. These applications require superconducting coils with high magnetic fields. High-field superconducting coils enable more straightforward and cheaper space exploration.

An essential element of all considered and tested superconducting wires and tapes applications in superconducting coils is superconducting joints, e.g., MgB_2 [4], HTS [5]. Superconducting joints allow lossless energy storage in the magnetic field and maintain high magnetic fields without an external current source. Moreover, the superconducting joints significantly improve the competitiveness of superconducting devices.

Intensive research is being conducted on several types of superconducting wires and tapes. The aim is to increase critical parameters and mechanical properties and reduce production costs. Even though the superconductivity in Nb_3Sn was discovered in the last century, this superconducting material is still being developed and improved because it has a high transport critical current density [6]. Significant superconducting material for applications is MgB_2 superconductors. The MgB_2 wires made by powder-in-tube technique (PIT) [7] and internal Mg diffusion (IMD) technique [8] have high critical parameters, low cost, and the possibility of working at liquid hydrogen temperature. Currently, iron-based superconducting materials are being intensively studied. These superconductors have high critical temperatures and upper critical fields [9,10]. In addition, the critical current density decreases slightly with increasing magnetic fields, and there is a high critical current density in high magnetic fields. These properties of iron-based superconducting materials indicate that the future of superconductivity may belong to them. High-temperature superconducting cuprates are interesting for applications because they might operate at the temperature of liquid nitrogen [11]. This allows for the reduction of the cost of their use. Currently, unfortunately, it has a high price that limits its use.

Intensive research is still being conducted on thermal treatment methods of superconducting materials. Promising results are obtained with spark plasma sintering [12], cold high-pressure densification [13], and doping [14]. Still, a vital issue studied in superconducting wires, tapes, and bulks is the interaction of the vortex lattice with structural defects and n-value. A better understanding of vortex lattice trapping will allow for an increase in the critical current density in superconducting materials.

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References

1. Gajda D, Zaleski AJ, Morawski AJ, et al. Superior engineering critical current density obtained via hot isostatic pressing of MgB_2 wires manufactured using nano-amorphous isotopic boron. Journal of Alloys and Compounds. 2021; 871: 159579. doi: 10.1016/j.jallcom.2021.159579
2. Minervini J, Parizh M, Schippers M. Recent advances in superconducting magnets for MRI and hadron radiotherapy: An introduction to '*Focus on superconducting magnets for hadron therapy and MRI*'. Superconductor Science and Technology. 2018; 31(3): 030301. doi: 10.1088/1361-6668/aaa826
3. Olatunji JR, Goddard-Winchester M, Mallett B, et al. Design of a superconducting magnet for space propulsion on the international space station. IEEE Transactions on applied Superconductivity. 2024; 34(3): 3601006. doi: 10.1109/TASC.2024.3353710
4. Liang H, Patel D, Shahbazi M, et al. Recent progress in MgB_2 superconducting joint technology. Journal of Magnesium and Alloys. 2023; 11(7): 2217-2229. doi: 10.1016/j.jma.2023.07.010
5. Brittles GD, Mousavi T, Grovenor CR, et al. Persistent current joints between technological superconductors. Superconductor Science and Technology. 2015; 28(9): 093001. doi: 10.1088/0953-2048/28/9/093001
6. Bovone G, Buta F, Lonardo F, et al. Effects of the oxygen source configuration on the superconducting properties of internally-oxidized internal-Sn Nb_3Sn wires. Superconductor Science and Technology. 2023; 36(9): 095018. doi: 10.1088/1361-6668/aced25
7. Tomsic M, Rindfleisch M, Yue J, et al. Overview of MgB_2 superconductor applications. International Journal of Applied Ceramic Technology. 2007; 4(3): 250-259. doi: 10.1111/j.1744-7402.2007.02138.x
8. Yetiş H, Karaboğa F, Avcı D, Belenli İ. Nano-sized amorphous/semi-crystalline boron ratio and external Mg effects on transport and structural properties in MgB_2 IMD wires. Physica C: Superconductivity and its Applications. 2021; 581: 1353807. doi: 10.1016/j.physc.2020.1353807
9. Yamamoto A, Tokuta S, Ishii A, et al. Superstrength permanent magnets with iron-based superconductors by data-and researcher-driven process design. NPG Asia Materials. 2024; 16(1): 29. doi: 10.1038/s41427-024-00549-5
10. Singh SJ, Sturza MI. Bulk and single crystal growth progress of iron-based superconductors (FBS): 1111 and 1144. Crystals. 2021; 12(1): 20. doi: 10.3390/cryst12010020

11. Yang T, Li W, Xin Y. Comparative study of current carrying capacity between 1G and 2G HTS tape samples at different temperatures and magnetic fields. Physica Scripta. 2024; 99(3): 035911. doi: 10.1088/1402-4896/ad2044
12. Noudem JG, Xing Y, Bernstein P, et al. Improvement of critical current density of MgB_2 bulk superconductor processed by Spark Plasma Sintering. Journal of the American Ceramic Society. 2020; 103(11): 6169-6175. doi: 10.1111/jace.17366
13. Hossain MS, Senatore C, Flükiger R, et al. The enhanced J_c and B_{irr} of *in situ* MgB_2 wires and tapes alloyed with $C_4H_6O_5$ (malic acid) after cold high pressure densification. Superconductor Science and Technology. 2009; 22(9): 095004. doi: 10.1088/0953-2048/22/9/095004
14. Gajda D, Babij M, Zaleski A, et al. The influence of Sm_2O_3 dopant on structure, morphology and transport critical current density of MgB_2 wires investigated by using the transmission electron microscope. Journal of Magnesium and Alloys. 2024; 12(12): 5061-5078. doi: 10.1016/j.jma.2024.12.009