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Recent development in processing and application of Fe-6.5%Si soft magnetic material (invited)

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As the most widely used soft magnetic material, silicon steel, is known for its high saturation magnetization and low cost. High saturation magnetization is needed for high energy density. However, the increasing eddy current losses at higher switching frequencies must be properly managed to improve energy efficiency, which depends heavily on having a high electrical resistivity. Increasing the silicon content from 3.2% to 6.5% nearly doubles the electrical resistivity and greatly minimizes iron losses. Fe-6.5%Si also has a near-zero crystalline anisotropy and magnetostriction. However, Fe-6.5%Si is difficult to process via traditional routes since the ordered phases form during the slow cooling embrittling the alloy. Rapid solidification is viable route to prepare Fe-6.5%Si since it suppresses the ordering. By tuning the solidification cooling rate, we have established the relationship between cooling rate, chemical ordering, mechanical, and magnetic properties of Fe-6.5%Si. This allows the preparation of Fe-6.5%Si ribbon/tape with a tunable degree of ductility. We constructed typical stack laminates for motor stator using punched Fe-6.5%Si tapes, and developed a novel ribbon bundle stator concept that uses Fe-6.5%Si ribbons. We also developed novel melt spinning techniques that directly yield ductile Fe-6.5%Si thin flakes, which can be coated and near net shape consolidated into motor stators or inductors.

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