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Single Crystal Growth in Floating-Zone Method and Properties of Spin Ladders: Quantum Magnets

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Abstract : Materials in which the electrons are strongly correlated provide some of the most challenging and exciting problems in condensed matter physics today. After the discovery of high critical temperature superconductivity in layered or two-dimensional copper oxides, many physicists got attention in cuprates and it led to an upsurge of interest in the synthesis and physical properties of copper-oxide based material. The quest to understand superconducting mechanism in high-temperature cuprates, drew physicist's attention to somewhat simpler compounds consisting of spin-chains or one-dimensional lattice of coupled spins. Low-dimensional quantum magnets are of huge contemporary interest in basic sciences as well emerging technologies such as quantum computing and quantum information theory, and heat management in microelectronic devices. Spin ladder is an example of quasi one-dimensional quantum magnets which provides a bridge between one and two dimensional materials. One of the examples of quasi one-dimensional spin-ladder compounds is Sr14Cu24O41, which exhibits a lot of interesting and exciting physical phenomena in low dimensional systems. Very recently, the ladder compound Sr14Cu24O41 was shown to exhibit long-distance quantum entanglement crucial to quantum information theory. Also, it is well known that hole-compensation in this material results in very high (metal-like) anisotropic thermal conductivity at room temperature. These observations suggest that Sr14Cu24O41 is a potential multifunctional material which invites further detailed investigations. To investigate these properties one must needs a large and high quality of single crystal. But these systems are showing incongruently melting behavior, which brings many difficulties to grow a large and quality of single crystals. Hence, we are using TSFZ (Travelling Solvent Floating Zone) method to grow the high quality of single crystals of the low dimensional magnets. Apart from this, it has unique crystal structure (alternating stacks of plane containing edge-sharing CuO2 chains, and the plane containing two-leg Cu2O3 ladder with intermediate Sr layers along the b- axis), which is also incommensurate in nature. It exhibits abundant physical phenomenon such as spin dimerization, crystallization of charge holes and charge density wave. The maximum focus of research so far involved in introducing defects on A-site (Sr). However, apart from the A-site (Sr) doping, there are only few studies in which the B-site (Cu) doping of polycrystalline Sr14Cu24O41 have been discussed and the reason behind this is the possibility of two doping sites for Cu (CuO2 chain and Cu2O3 ladder). Therefore, in our present work, the crystals (pristine and Cu-site doped) were grown by using TSFZ method by tuning the growth parameters. The Laue diffraction images, optical polarized microscopy and Scanning Electron Microscopy (SEM) images confirm the quality of the grown crystals. Here, we report the single crystal growth, magnetic and transport properties of Sr14Cu24O41 and its lightly doped variants (magnetic and non-magnetic) containing less than 1% of Co, Ni, Al and Zn impurities. Since, any real system will have some amount of weak disorder, our studies on these ladder compounds with controlled dilute disorder would be significant in the present context.

Keywords : low-dimensional quantum magnets, single crystal, spin-ladder, TSFZ technique
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