Nanostructure and functionalities of the bi-layered ruthenate $Sr_3Ru_2O_7$

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Polymorphic materials are known for being prone to intergrowth. Under this respect, a remarkable example are strontium ruthenates whose properties are heavily affected by impurities and disorder. In particular, a strong variation in transport and magnetic properties is seen in the bi-layered $Sr_3Ru_2O_7$ as a function of the fabrication process [1,2]. Very recently, a superconducting state has been measured in $Sr_3Ru_2O_7$ grown in $Sr_3Ru_2O_7$-Sr_2RuO_4 eutectic crystals by flux feeding floating zone technique [3-5]. Several pictures have been proposed to explain this unusual behaviour such as a proximity effect [4] or an exotic pairing coming from Sr_2RuO_4 inclusions finely dispersed in the $Sr_3Ru_2O_7$ domain [5].

In this scenario, the investigation of the nanostructure of $Sr_3Ru_2O_7$ grown as single crystal and via eutectic solidification is crucial to correlate atomic structure and properties and to identify the intrinsic functionalities of the bi-layered ruthenate $Sr_3Ru_2O_7$.

We report a comparative study between $Sr_3Ru_2O_7$ grown as single phase crystals (SPC) and in $Sr_3Ru_2O_7$-Sr_2RuO_4 eutectics (EC). High resolution transmission electron microscopy on $Sr_3Ru_2O_7$ SPC revealed the presence of atomically layered $Sr_4Ru_3O_{10}$ and $SrRuO_3$ within the $Sr_3Ru_2O_7$ matrix associated with strain and randomly dispersed Sr_2RuO_4 clusters (Fig.1). On the contrary, $Sr_3Ru_2O_7$ grown via eutectic solidification showed a much more ordered microstructure (Fig.2) with a small amount of randomly dispersed Sr_2RuO_4 clusters and only a very diluted presence of layered Sr_2RuO_4 [5]. The profound difference in the nanostructures of the two systems is reflected in their magnetic behaviour: susceptibility versus temperature curves measured on $Sr_3Ru_2O_7$ SPC in low magnetic fields revealed two additional magnetic transitions at 170 and 100 K, compatible with the presence of $SrRuO_3$ and $Sr_4Ru_3O_{10}$, respectively. The same measurement performed on the eutectic material confirmed that the $Sr_3Ru_2O_7$ domain of the EC have less impurities than the $Sr_3Ru_2O_7$ SPC [6].

These results address the $Sr_3Ru_2O_7$ EC as the best candidate to study the intrinsic properties of the $Sr_3Ru_2O_7$ phase and identify the eutectic solidification as a fruitful way to grow highly pure crystals of polymorphic materials.

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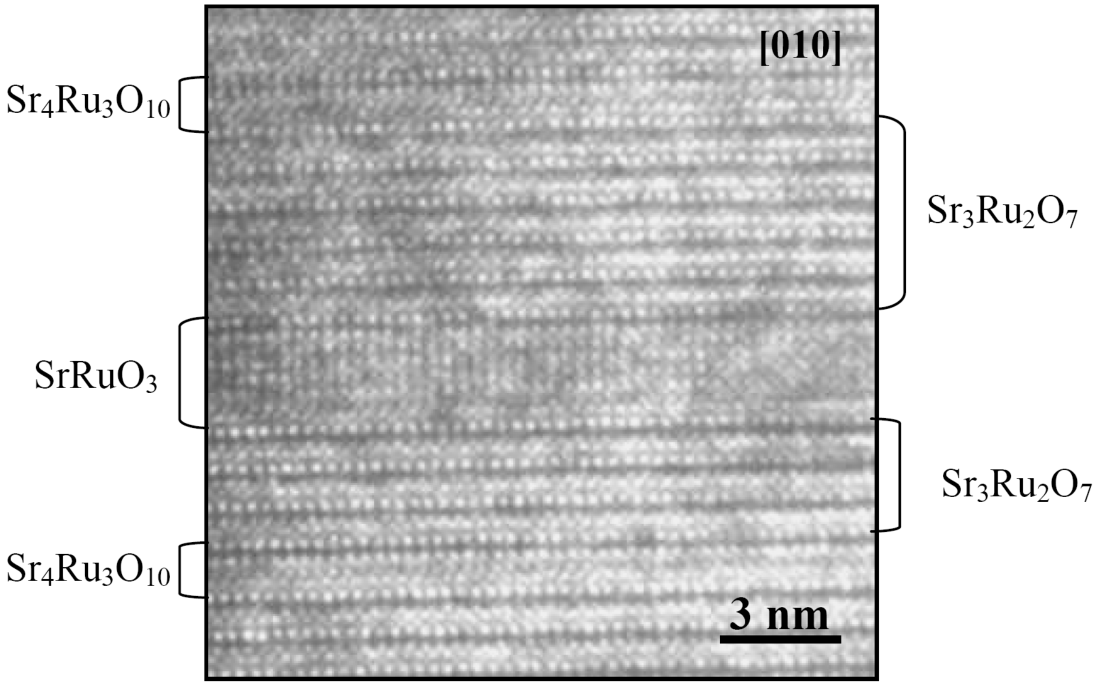

Figure 1. HRTEM micrograph of a $Sr_3Ru_2O_7$ SPC taken in the [010] zone axis. Intergrowths of $SrRuO_3$ slabs intercalating within the $Sr_3Ru_2O_7$ matrix are labelled.

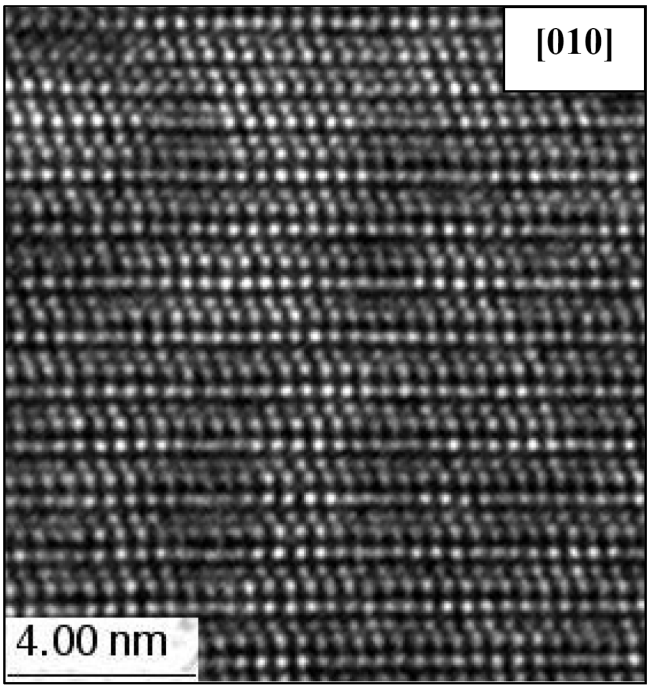

Figure 2. HRTEM image in the [010] zone axis of a crystal fragment of $Sr_3Ru_2O_7$ of the $Sr_3Ru_2O_7$–Sr_2RuO_4 eutectic system.

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