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Structural and Magnetic Study of $Cu_xFeCr_{1-x}O_2$ Oxides Under High External Magnetic Fields

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The structural, electronic, and magnetic behaviors of $Cu_xFeCr_{1-x}O_2$ polycrystals are investigated. Investigations are conducted for increasing chromium substitution, according to varying x values in the formula versus copper, for $x = 0$, 0.2, 0.4, 0.6, 0.8, and 1. The magnetic response of polycrystalline samples under increasing external magnetic field from 0.4 T to 5 T is also studied. The partial crystal structure deformation/transition from delafossite $CuFeO_2$ structure to corundum-type $FeCrO_3$ structure containing CrO_2 and Cr_2O_3 blocks is determined. The change in the crystal structure geometry with increasing Cr substitution is observed. Besides, prominent changes in magnetic ordering are observed from antiferromagnetic ($x = 1$, 0.8, and 0.6) to ferromagnetic ordering ($x = 0.4$ and 0.2) for high applied external magnetic fields above 2 T.

Key words: Circular dichroism, magnetism, electronic structure, absorption spectroscopy

INTRODUCTION

Magnetic materials have a vast field of application in both science and technology. Due to the increasing interest in magnetic properties of materials, scientific investigations have boosted the discovery of new magnetic materials with special properties, such as high-T_c superconducting, huge magnetoelectric effects, semiconductor properties, etc.[1–3] The most popular magnetic materials are ferromagnetic 3d transition metals, i.e., Fe, Co, and Ni, and their oxides. Interesting properties of d valence electrons keep the 3d transition metals in the center of various fields of research and technological applications. Iron-based ferromagnetic materials are of foremost interest in magnetic studies. Iron is a ferromagnetic member of the magnetic materials and has a huge field of application in present technologies. Despite the ferromagnetic properties of iron, most of the iron oxides, such as Fe_2O_3 and $CuFeO_2$, show antiferromagnetic ordering.

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The low-dimensional transition-metal oxide $CuFeO_2$ is a delafossite ABO_2 compound. Additionally, it is also one of the leading antiferromagnetic iron oxides with space group $R{-}3m$.[4,5] ABO_2 compounds (A = Cu; B = Cr, Fe, Co, Ni) can be either stoichiometric or highly oxidized as $ABO_{2+\delta}$.[6] Delafossite oxides are candidate p-type transparent conducting oxides and thermoelectric materials.[7–9] Delafossite $CuFeO_2$ forms in a triangular structure with hexagonal layers. In this structure, triangular lattices of magnetic Fe^{3+} layers are separated by Cu^{1+} and O^{2-} layers.[4,5] Below $T_N = 11$ K, $CuFeO_2$ shows antiferromagnetic behavior. This behavior is largely affected by oxygen nonstoichiometry due to change in cation valence-band lattice parameters.[10]

As a member of the 3d row, chromium is an interesting element and reported elsewhere to show large magnetic moment and respond superparamagnetically to applied magnetic fields, which can influence the spin and electronic properties of neighboring clusters.[11] In the past, high corrosion resistance and hardness were the major features of interest of chromium. Especially in the last decade, interesting magnetic properties of some chromium oxides (e.g., Cr_2O_3 and CrO_2) above room temperature