Coexistence of high electrical conductivity and weak ferromagnetism in Cr doped $Y_2Ir_2O_7$ pyrochlore iridate

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We report the structural, magnetic and electrical transport properties of $Y_2Ir_{1-x}Cr_xO_7$ pyrochlore iridates. The chemical doping leads to order of magnitude enhancement of electrical conductivity. The introduction of Cr$^{3+}$ at $Ir^{4+}$ site tends to distort the Ir$-O_8$ octahedra and suppresses antiferromagnetic correlation. The X-ray photoemission spectroscopy measurements suggest the coexistence of $Ir^{4+}$ and $Ir^{5+}$ valence states in the $Y_2Ir_{1-x}Cr_xO_7$ compounds. The concentration of $Ir^{5+}$ is enhanced with Cr doping, leading to weak ferromagnetism and enhanced electrical conductivity. A cluster-glass like transition is also observed at low temperature with Cr doping, possibly due to competing ferromagnetic and antiferromagnetic interaction.

I. INTRODUCTION

The interplay of electron correlation, spin-orbit coupling (SOC), crystal field effect and geometric frustration can lead to many emergent quantum phases and interesting phenomenology such as spin-liquid[1], spin-ice[2], spin glass[3,4], anomalous Hall effect[5], frustrated Kondo lattice[6], superconductivity[7], etc. in 5d transition metal oxides in general and pyrochlore iridates $A_2Ir_2O_7$ in particular[8,9]. For $Y_2Ir_2O_7$, the magnetic properties are determined by the contribution from $Ir^{4+}$ ion and the complex magnetic ground states emerging from $f-d$ exchange interactions are avoided[10]. This allows us to study Ir order by separating out the properties emerging from interaction between the rare-earth and $Ir^{4+}$ ions. $Y_2Ir_2O_7$ is expected to be a Weyl semimetal with all-in/all-out antiferromagnetic (AFM) ground state[10]. Since the ground state of pyrochlore iridates is sensitive to the SOC, crystal field effect and on-site Coulomb repulsion (governed inter-alia by the Ir$-O$ - Ir bond angle and Ir$-O$ bond length), a small change in A site radius by chemical doping or substitution at the Ir site may easily alter the balance between the competing energies with varying consequence[11,12].

The low temperature magnetic state of $Y_2Ir_2O_7$ is still debated, because neutron diffraction and inelastic scattering analysis do not show clear evidence of long range magnetic ordering[13,14]. On the other hand, muon spin rotation and relaxation experiment analysed with ab initio modeling[15] suggest a long range magnetic transition with all-in/all-out AFM ground state at low temperatures. There are fewer earlier reports which also suggest existence of weak ferromagnetic component over the AFM background in $Y_2Ir_2O_7$[16,17]. Since, pyrochlore iridates are geometrically frustrated, therefore the low temperature magnetic state of $Y_2Ir_2O_7$ could show glass-like behaviour[13,18,19], similar to other Y-based pyrochlores such as $RuOs_2O_7$ (R = Y and Ho)[20], $Y_2Ru_2O_7$[21] and $Y_2Mo_2O_7$[22]. Despite these advances, a conclusive understanding of the precise nature of the low temperature magnetic state is far from being realized. While hole doping by the introduction of $Ca^{2+}$ at $Y^{3+}$ site in $Y_2Ir_2O_7$ compound modifies the Ir-$t_{2g}$ electron band width leading to enhanced electrical conductivity and ferromagnetism[21,22], replacement of $Y^{3+}$ with isovalent ion $Bi^{3+}$, on the other hand, also shows insulator to metal transition and spin-glass like magnetic transition[23] similar to $Y_{2-x}Bi_xRu_2O_7[6]$ and $Bi_{2-x}Y_xRu_2O_7$ compounds[24]. In the context of electrical charge transport in nanoscale systems, a gapped out Weyl-Semimetal phase has also been reported in $Y_{2-x}Bi_xIr_2O_7[25,26]$. Previous studies on doping of isovalent magnetic $Ru^{4+}(4d^n)$[21] and nonmagnetic $Ti^{4+}(3d^0)$[23] ions separately at magnetic $Ir^{4+}$ site in $Y_2Ir_2O_7$ compounds show enhancement in AFM correlation with negligible increase in electrical conductivity. However, the influence of substitution of magnetic 3d ions at magnetic $Ir^{4+}(5d^5)$-site in $Y_2Ir_2O_7$ has not been investigated yet.

In the present work, we have studied the effect of magnetic Cr ion introduction at magnetic Ir-site in $Y_2Ir_{1-x}Cr_xO_7$. Since, the $Ir^{4+}$($5d^5$) exhibit stronger SOC and less on-site Coulomb repulsion (U) as compared to $Cr^{3+}$($3d^3$), the doping of Cr$^{3+}$ at $Ir^{4+}$ site acts not only as hole doping, but at the same time likely to reduce the SOC and amplify U. We show that Cr doping at magnetic $Ir^{4+}$-site in $Y_2Ir_2O_7$ compound leads to cluster-glass like behaviour and orders of magnitude enhancement of electrical conductivity with interesting consequences on the transport and magnetic properties.

II. EXPERIMENTAL METHODS

The parent sample $Y_2Ir_2O_7$ was prepared by solid state reaction method reported by same authors[25,26,27]. On the other hand, $Y_2Ir_{1-x}Cr_xO_7$, $x = 0.05, 0.1, 0.2$ series were prepared using the method described elsewhere[28]. The crystal structure was analyzed by powder X-ray diffraction (XRD) using a PANalytical Xpert PRO diffractometer with Cu Kα radiation ($\lambda = 1.54$ Å) at room temperature. The actual composition of the samples were determined using energy dispersive x-ray spectrometry (EDX) with the help of field emission scanning electron microscope (FE-SEM) [JSM-7100F, JEOL].
Figure 1 shows the powder XRD patterns along with Rietveld refinement for \( Y_2Ir_{2-x}Cr_xO_7 \) samples at room temperature. Inset of Fig. 1 shows goodness of fit (GOF) defined as \( F^2 = [R_{wp}/R_{exp}]^2 \), where, \( R_{wp} \) is the expected weighed profile factor and \( R_{exp} \) the observed weighed profile factor. The accuracy of all refined values of XRD data is \( \sim \pm 0.009^\circ \). Analysis of XRD spectra indicate that all the samples crystallize in the F-centered cubic unit cell with \( Fd\bar{3}m \) symmetry, which is consistent with previous reports. XRD pattern shows no major changes in the peak positions with doping. Note the slight mismatch in ionic radii between \( Ir^{4+} = 0.625 \text{ Å} \) and \( Cr^{3+} = 0.615 \text{ Å} \). Interestingly, Fig. 2 shows that the lattice constant decreases marginally for \( Y_2Ir_{2-x}Cr_xO_7 \) (YICO). The cubic pyrochlore oxide with general formula \( A_2B_2O_7 \) having space group \( Fd\bar{3}m \) has 8 atoms per unit cell. The four non equivalent atoms occupy the following positions: \( A \) at 16d site \( (\frac{1}{2}, \frac{1}{2}, \frac{1}{2}) \), \( Ir \) at 16c site \( (0, 0, 0) \), \( O1 \) at 48f site \( (p, \frac{1}{3}, \frac{1}{3}) \) and \( O2 \) at 8b site \( (\frac{1}{3}, \frac{1}{3}, \frac{1}{3}) \), with \( p \) being the only one adjustable positional parameter. In this pyrochlore structure 16d sites contain larger \( A \)-type cations thus forming an axially compressed scalenohedron which are coordinated to six \( O1 \) atoms and two \( O2 \) atoms. The 16c site exhibit smaller \( Ir \)-cation coordinated with six \( O1 \) atoms at equal distances from the central \( Ir \) ion in a trigonal antiprisms. The shorter \( A - O2 \) bond length depends only on lattice constant, while the \( A - O1 \) and \( Ir - O2 \) distances depend on both lattice parameters and the position parameters. For \( p = 0.3125 \) one has a perfect octahedron about 16c site where \( Ir \) cations reside under a perfect cubic field. Figure 2 shows the positional parameter \( p \) as a function of doping content \( x \). The value of \( p \) for undoped sample turns out to be 0.355, larger than the ideal value suggesting compressed and distorted octahedra of \( IrO_6 \). \( p \) value increases as \( Cr \) concentration increases in \( Y_2Ir_{2-x}Cr_xO_7 \) samples suggesting more distorted and elongated \( IrO_6 \) octahedra, which gives rise to enhanced crystal fields. The doping dependence of \( Ir - O \) bond angle and \( Ir - O \) bond length are shown in Fig. 2c and d, respectively. The bond angle decreases and bond length increases with increasing \( Cr \) content in \( Y_2Ir_{2-x}Cr_xO_7 \) samples. This results in more distortion in \( IrO_6 \) octahedra and enhancement in mixing between \( Ir(5d)/Cr(3d) \) and \( O(2p), Y(4p) \) states.

The temperature dependence of the zero field cooled (ZFC) and field cooled (FC) magnetic susceptibilities for \( Y_2Ir_{2-x}Cr_xO_7 \) \( (x = 0.05, 0.1 \text{ and } 0.2) \) is shown in Fig. 3a. For undoped \( (x = 0.0) \) sample, irreversibility sets in between the FC and ZFC magnetization below \( \sim 160 \text{ K} \). Inset of Fig. 3a suggests a magnetic transition, consistent with previous reports. Recent studies seem to suggest coexistence of a weak FM component on the large AFM background. As shown in the Fig. 3b, with \( Cr \) doping the FC magnetic susceptibility is enhanced and the temperature for the magnetic irreversibility \( T_{irr} \)
shifts towards the lower temperature side. This might be due to the double exchange interaction between neighbouring $\text{Ir}^{4+}, \text{Ir}^{5+}/\text{Cr}^{3+}$ ions via $\text{Ir}^{4+} - O^2 - \text{Ir}^{5+}$ and $\text{Ir}^{4+} - O^2 - \text{Cr}^{3+}$ paths in terms of the magnetically compatible electronic orbitals $t_{2g}^0$ between $\text{Ir}^{4+}$ and $\text{Cr}^{3+}$ ions. It can be noticed that ZFC magnetization for Cr doped samples show distinct cusp at lower temperature compared to $T_{\text{irr}}$ [Fig. 3a] suggesting a cluster-glass-like transition. This cusp is absent in the parent compound [inset of Fig. 3a].

At high temperature, the temperature dependence of susceptibility for all the samples is described by the Curie-Weiss (CW) law, $\chi = \frac{C}{T - \theta_{\text{CW}}}$, where $C$ and $\theta_{\text{CW}}$ are the Curie constant and Curie-Weiss temperature, respectively shown in Fig. 3b. The estimated value of $\theta_{\text{CW}}$ for undoped sample show consistency with few reported values, however it shows large deviation with other reported values. This discrepancy is due to the choice of fitting parameters, particularly the temperature independent constant term $\chi_0$ in $\chi = \frac{C}{T - \theta_{\text{CW}}} + \chi_0$. We have also fitted the data using this extra term $\chi_0$ and the estimated $\theta_{\text{CW}}$ turns out to be consistent with values reported in Reference. The negative value of $\theta_{\text{CW}}$ for undoped as well as doped samples suggests AFM correlation. The absolute value of $\theta_{\text{CW}}$ temperature decreases with increased Cr doping [Fig. 3c], which indicates the weakening of AFM coupling. It can be noticed that negative $\theta_{\text{CW}}$ decreases but the actual ordering temperature increases with Cr doping content. This suggests reduction of frustration parameter $|f = \theta_{\text{CW}}/T_{\text{irr}}|$ with Cr doping, leading to large enhancement of the magnetization.

We have calculated the effective magnetic moment $\mu_{\text{eff}}$ for all samples. We estimate $\mu_{\text{eff}} = 2.01 \mu_B/\text{f.u.}$ for parent compound, which is greater than the expected Hund’s rule value of 1.73 $\mu_B/\text{f.u.}$ for $S = 1/2$. Similar discrepancy [i.e. obtained experimental value of $\mu_{\text{eff}}$ being larger than expected theoretical value for spin 1/2] has also been reported elsewhere. Such disagreement with Hund’s rule value is not unusual in presence of crystal field effect and strong spin-orbit coupling. It is observed that $\mu_{\text{eff}}$ increases as Cr concentration increases [Fig. 3d]. Generally, assuming spin-only contribution for the $\text{Cr}^{3+}(3d^5)$ gives the magnetic moment of 3.9 $\mu_B/\text{Cr}$. On the other hand, calculation of the same in the strong SOC regime gives 0.33 $\mu_B/\text{Ir}$. Theoretical effective magnetic moment $\mu_{\text{eff}}$ per f.u. can be calculated as $\mu_{\text{eff}} = (2 - x)\mu_{\text{Ir}}^2 + x\mu_{\text{Cr}}^2$. The estimated $\mu_{\text{eff}}$ turns out to be 2.57 $\mu_B/\text{f.u.}$, 2.68 $\mu_B/\text{f.u.}$ and 2.9 $\mu_B/\text{f.u.}$ for $x = 0.05, 0.1$ and 0.2 samples, respectively. The enhancement in $\mu_{\text{eff}}$ with $x$ is anyway expected due to the substitution of the high $\text{Cr}$ moment for the low moment of $\text{Ir}$.

The magnetization ($M$) as a function of magnetic field ($H$) for all samples measured at temperature 2K are shown in Fig. 4. It is clear that Cr doping leads to enhanced magnetization with clear hysteresis loop as shown in Fig. 4, suggesting enhancement of FM component vis-a-vis the AFM background. Strikingly, M-H curves of Cr
doped compounds shown in Fig. 4 do not show saturation up to 10T. This could be due to the coexistence of antiferromagnetic and ferromagnetic interactions, leading to magnetic frustration. As can be noticed that both $M_S$ and $M_R$ increases with increasing Cr doping concentration consistent with the increase of weak ferromagnetic correlation induced by the double-exchange interaction between $Ir^{4+}$ and $Cr^{3+}$ ions. The coercive field $H_C$ also increases with Cr doping shown in inset of Fig. 4. The introduction of Cr ions should reduce the spin-orbit coupling because of $Cr^{3+} - 3d^5$ (low atomic number) replacing $Ir^{4+} - 5d^5$ (high atomic number). Therefore, magnetocrystalline anisotropy is not responsible for the increase in $H_C$. Another possibility might be pinning of domain wall, which emerges from the frustration of antiferromagnetic phase induced by the randomly distributed Cr ion on the Ir-site. Similar increase in $H_C$, $M_S$ and $M_R$ have been reported in other disordered magnets.

To summarize, cluster-glass-like characteristic with weak ferromagnetic correlation are observed in Cr-doped $Y_2Ir_2O_7$ samples.

In order to further confirm the glassy characteristic in Cr-doped compounds, the isothermal remanent magnetization is measured by cooling the sample in an applied magnetic field $H = 0$ from room temperature to 5K. After stabilizing the temperature and waiting up to $10^3$s, magnetic field $H = 1$kOe is applied, and magnetization as a function of time is recorded. Figure 5 shows time dependent isothermal remanent magnetization data normalized with magnetization value $M(0)$ for two representative samples $x = 0.0$ and 0.2. It can be seen that $M(t)/M(0)$ increases with time without any sign of saturation for all the representative samples. We have fitted the normalized magnetic relaxation data using stretched exponential function as shown below:

$$M(t) / M(t=0) = \exp \left( \frac{t}{\tau} \right)^{\beta}$$

where $\tau$ is the characteristic relaxation time, $\beta$ is the stretching exponent. The value of stretching exponential falls in the range $0 < \beta < 1$. The value $\beta = 1$ represents the magnetic relaxation behaviour arising from a single energy barrier. On the other hand, existence of a distribution of relaxation time produces stretched exponential behaviour. The solid red lines in Fig. 5 represent fitting of data according to Eq. 1. The obtained $\tau$ and $\beta$ are in good agreement with corresponding values for classical spin glass systems $\tau_c : M(t)$.

It can be seen that doping reduces the relaxation time $\tau$ almost by one order $[x = 0.2, \tau \sim 1.7 \times 10^8]$ as compared to parent compound $[\tau \sim 8.5 \times 10^9]$. This obviously demonstrates that doping helps the spins arrangement to relax at a faster rate. Simultaneously, there is an enhancement of the exponent $\beta \sim 0.39 (x = 0.2)$ compared to parent sample $[\beta \sim 0.37]$. Figure 6 shows semi-logarithmic plot of normalized relaxation data as a function of time. All the samples show continuous increase of magnetization with time, do not show any sign of saturation at higher time scale. It suggests existence of uniform distribution of relaxation time of finite width, i.e. $\Delta \tau = \tau_n - \tau_1$. In this regime magnetization enhances logarithmically as shown by green line in Fig. 5. The lower limit $\tau_1$ is indicated in Fig. 5.

Figure 5 shows temperature dependent resistivity for the undoped, and Cr doped compounds, respectively. The parent compound [shown on right y-axis] in Fig. 5a shows an insulating trend throughout the temperature regime. To understand the conduction mechanism at low temperature, the $\rho(T)$ data for undoped sample is analyzed by fitting to the power law in the range 10-70K $[\rho = \rho_0 T^{-\alpha}]$ where $\alpha$ is the power law exponent & $\rho_0$ is the prefactor, respectively and Mott variable range hopping (VRH) expected for a 3-dimensional (3D) disordered system $[\rho(T) = \rho_0 T^{0.39}(T_0/T)^{1/4}]$, where $T_0$ is the characteristic temperature, are shown in Fig. 5b. The fitting suggests validity of power law description in the intermediate temperature range as opposed to the VRH model. Similar power law driven electronic transport has been observed for undoped compound by other groups.

The
fitting parameters are found to be $\rho_0 \approx 7.4 \times 10^{-5} \Omega \cdot cm$, $n \approx 2.97$. The replacement of $\text{Ir}^{4+} (5d^5)$ with $\text{Cr}^{3+} (3d^3)$ doping significantly reduces the electrical resistivity leading to metal-insulator transition [Fig. 6a]. The $T_{MI}$ decreases monotonically as ionic radius of Ir site decreases. The doping of Cr has two effects: 1) The reduction in Ir site ionic radius due to Cr doping increases the A site ionic radius, which might reduce the electrical resistivity by reducing the trigonal compression on the IrO$_6$ octahedra. 2) The $\text{Cr}^{3+} (3d^3)$ and $\text{Ir}^{4+} (5d^5)$ states have similar electron filling in their $t_{2g}$ and $e_g$ band, respectively with a $S = 1/2$ state, effectively leading to hole doping, which could possibly increase the valence state of Ir from $\text{Ir}^{4+}$ to $\text{Ir}^{5+}$. In pyrochlore iridates $A_2\text{Ir}_2O_7$ the $\text{Ir}^{4+}$ has a fully filled $J_{eff} = 3/2$ level and an unpaired half filled $J_{eff} = 1/2$ level which is localized due to electron-electron interaction. On the other hand, $\text{Ir}^{5+}$ has an empty $J_{eff} = 1/2$ level that would promote the hopping of electrons from the nearby Ir$^{4+}$ ions, leading to the delocalization of electrons and enhancement of electrical conductivity. Later on we shall come back to this point. Figure 7 shows the quadratic field dependence of MR. (g) Enlarged view of the low field portion of MR vs $H^2$ data. (h) Linear variation of MR as a function of square of reduced magnetization. 

FIG. 7: Magnetoresistance (MR) as a function of magnetic field (H) measured at temperature $T = 2K$, $5K$ and $10K$ for (a) $x = 0.0$, (b) $x = 0.05$, (c) $x = 0.1$, and (d) $x = 0.2$ samples. (e) MR vs $H$ of $x = 0.0$, $0.05$, $0.1$, and $0.2$ samples measured at temperature $2K$. (f) Quadratic magnetic field dependence of MR. (g) Enlarged view of the low field portion of MR vs $H$. (h) Linear variation of MR as a function of square of reduced magnetization.
FIG. 8: High resolution XPS of (a) Ir 4f for the x = 0.0, 0.05, 0.1, 0.2 samples, (b) deconvoluted Ir 4f peaks for x = 0.0 and 0.2 samples, (c) Cr 2p for samples x = 0.05, 0.1, 0.2, (d) fitting of Cr 2p region for x = 0.2 sample.

samples, the contribution from Ir$^{5+}$ is enhanced, suggesting coexistence of mixed oxidation states of Ir, i.e. Ir$^{4+}$ and Ir$^{5+}$.

We further analyzed the oxidation state of Cr using XPS spectra of Cr 2p core-level, as shown in Fig. 8c,d. Figure 8c shows the variation in the Cr 2p XPS spectra with different doping concentration of Cr. For lowest doping content x = 0.05, it is difficult to identify the Cr$^{3+}$/2 and Cr$^{1+}$/2 peaks. While on the other hand for x = 0.1 and 0.2 samples, both peaks are clearly visible. Figure 8d shows the XPS spectra of Cr 2p core-level, which indicates the coexistence of Cr$^{3+}$ and Cr$^{4+}$ charge state.

The XPS spectra for Y 3d in x = 0.0, 0.2 compounds suggest the existence of only Y$^{3+}$ oxidation states for undoped and Cr doped samples.

Figure 9a shows unit cell structure of Y$_2$Ir$_2$O$_7$ after refining the XRD data. The calculated Ir$-O$-Ir bond angle and Ir$-O$ bond length are consistent with previous report. The oxygen atom is placed at off-centered position and shared by Ir$-O$ octahedra in the unit cell. So far as Y$_2$Ir$_{2-x}$Cr$_x$O$_7$ series is concerned, Cr$^{3+}$ and Ir$^{4+}$ are magnetically active with their S=1/2 electrons. The filling of electrons in their respective d-orbitals are shown in Fig. 9b. It is known that the Ir$O_6$ octahedral oxygen environment in Y$_2$Ir$_2$O$_7$ is slightly distorted due to elongation along crystallographic c-axis, leading to lifting of degeneracy with energy level splitting $\Delta \approx 2$ eV. Furthermore, the octahedral environment splits d orbital into $e_g$ and $t_{2g}$ orbitals. The large SOC further splits the $t_{2g}$ levels into a half filled $J_{eff} = 1/2$ level with a double-degeneracy and a completely filled $J_{eff} = 3/2$ level with a quadruple degeneracy. Hence, in the strong SOC dominated picture, Ir gives a magnetic moment of value 0.33$\mu_B$/Ir. Finally, the on-site Coulomb repulsion U further splits the $J_{eff} = 1/2$ level and opens up a Mott-like gap which makes such systems $J_{eff} = 1/2$ insulators. The population of Ir$^{4+}$ valence electrons with spin up (solid red arrow) and spin down in $t_{2g}$ orbital, $J_{eff} = 1/2$ and $J_{eff} = 3/2$ is shown in Fig. 9b. While on
the other hand, the 3d\(5^+\) electrons contributed by Cr\(3^+\) populate \(d_{xz}, d_{yz}\) and \(d_{yz}\) orbitals of the \(t_{2g}\) level as well, leading to Ir\(5^+\) valence state which should be non-magnetic considering four electrons will fully occupy the \(J_{eff} = \frac{3}{2}\) quartet state.

Now let us recall the major consequences of the doping of Cr\(3^+\) at Ir\(4^+\) site in the \(Y_2Ir_2O_7\) compound on the magnetic and electronic properties: 1) The AFM correlations weaken against Cr doping. 2) Electronic conductivity is enhanced with doping. In \(A_2Ir_2O_7\) pyrochlore systems, magnetic interactions take place at the corner-shared \(Ir-O_6\) octahedra through the mediation of \(O-2p\) orbital. Based on the present scenario, with random ionic distribution, a schematic representation of the magnetic interaction for \(Y_2Ir_2-xCr_xO_7\) series is shown in Fig. 9c. We propose that in \(Y_2Ir_2-xCr_xO_7\) compounds exchange interaction takes place primarily through the Ir\(4^+\)–O\(^{2-}\)–Ir\(4^+\), since Ir\(5^+\) is non-magnetic. With Cr doping, the reduction in the lattice parameter, \(Ir-O-Ir\) bond angle and enhancement in the \(p\) value, \(Ir-O\) bond length are shown in Fig. 2a,b,c,d. In such a situation, the \(Ir\) atoms reside on a more distorted \(Ir_6\) octahedra than parent compound as \(Ir-O-Ir\) bond angle tends towards 90° which might be responsible for weakening of AFM correlations and higher value of magnetic moment. The distorted \(Ir-O_6\) octahedra along the c-axis could weaken AFM correlation, as indicated by reduction in absolute value of Curie-Weiss temperature \(\theta_{CW}\).

**IV. CONCLUSION**

We have investigated the structural, magnetic, and electronic properties of the pyrochlore iridates \(Y_2Ir_{2-x}Cr_xO_7\). The introduction of Cr\(3^+\) at Ir\(4^+\) sites weakens the antiferromagnetic correlation and enhances electrical conductivity. The XRD analysis shows distorted Ir–O\(_6\) octahedra and reduction in Ir–O–Ir bond angle as Cr\(3^+\) doping concentration increases. The X-ray photo-emission spectroscopy measurements suggest the coexistence of Ir\(4^+\) and Ir\(5^+\) in the \(Y_2Ir_{2-x}Cr_xO_7\) compounds, where the amount of Ir\(5^+\) enhances with Cr doping. This explains the possible origin of the weak ferromagnetism and enhanced electrical conductivity in the same. The cusp in ZFC M-T curves, the irreversibility in FC-ZFC magnetization at higher temperature and hysteretic isothermal magnetization with large coercive field for \(Y_2Ir_{2-x}Cr_xO_7\) at low temperature suggest cluster-glass like transition rather than long range ferromagnetic ordering. This is also confirmed by relaxation measurements. We emphasize that doping affects the local chemistry such as bond angle, bond length and oxidation states which in turn influences, *in not necessarily inter-connected fashion*, the electronic transport and magnetic properties in 5d iridates.

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