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# *Powder X-Ray Reference Patterns of* $Sr_2RGaCu_2O_y$ (R = Pr, Nd, Sm, Eu, Gd, Dy, Ho, Er, Tm, *and* Y)

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X-Ray Rietveld refinements were conducted on a series of eleven lanthanide phases, $Sr_2RGaCu_2O_y$ (2112 phase, R = Pr, Nd, Sm, Eu, Gd, Dy, Ho, Y, Er, Tm, and Yb) that are structurally related to the high $T_c$ superconductor $Ba_2YCu_3O_7$ (213). In the 2112 structure, instead of square planar Cu-O chains, tetrahedral GaO4 chains were found to run in a zig-zag fashion along the diagonal of the basal 213 *ab*-direction. Reference powder patterns for these compounds were prepared by using the Rietveld decomposition technique. The unit cell volume of these compounds follows the expected trend of the lanthanide contraction. The lattice parameters range from $a = 22.9694(3)$ Å, $b = 5.5587(2)$ Å, and $c = 5.44743(7)$ Å for R = Pr, to $a = 22.8059(2)$ Å, $b = 5.46031(5)$ Å, and $c = 5.37773(5)$ Å for R = Yb. An electon diffraction study of the Sm- and Er-analogs showed characteristic diffuse streaks along the *b*-axis, suggesting some disorder within the $GaO_4$ chains.

**Key words:** Rietveld refinements; $Sr_2RGaCu_2O_7$, superconductor related phases; x-ray powder patterns.

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## 1. Introduction

During the search of high $T_c$ superconductors, various related phases built from the alternate blocks of perovskite ($ABO_{3-x}$) and rock salt (AO) units were discovered; these compounds have a general formula $(AO)_m(ABO_{3-x})_n$. Two such families are the well-known high temperature superconductor $Ba_2RCu_3O_7$ (213, R = lathanides and yttrium) [1], and also the $Sr_2R(M_{3-x}Cu_x)O_y$ series [2-5], where R = lanthanides and Y. Superconductivity was observed in some $Sr_2R(M_{3-x}Cu_x)O_y$ compounds [2,3]. The structure with $x = 1$ is known as the 2112 type. Detailed structural analysis of these compounds can provide further understanding of the behavior of cuprate superconductors.

$Sr_2RGaCu_2O_y$ (Ga-2112) crystallizes in a space group Ima2 [4] with structure related to that of $Ba_2YCu_3O_7$. $Ba_2YCu_3O_7$ crystallizes in a space group Pmmm with lattice parameters of $a$ = 3.8198(1) Å, $b$ = 3.8849(1) Å, and $c$ = 11.6762(3) Å [1]. Substitution of one-third of Cu in $Sr_2RCu_3O_{6+y}$ by Ga results in the chemical formula of $Sr_2RGaCu_2O_y$. The relationship between the lattice parameters of $Sr_2RGaCu_2O_y$ and those of $Ba_2YCu_3O_7$ was found to be: $a_{(2112)} \approx 22.8$ Å $\approx 2 \cdot c_{(213)}$, $b_{(2112)} \approx 5.5$ Å $\approx \sqrt{2} \cdot b_{(213)}$ and $c_{(2112)} \approx 5.4$ Å $\approx \sqrt{2} \cdot a_{(213)}$. The structure of the 2112 phase (Fig. 1) has been discussed in detail by Vaughey et al. [4] and Roth et al. [5]. In both the 2112 and 213 structures [6], double-layers of corner-sharing $CuO_5$ pyramids are separated by the lanthanide ions. In $Sr_2RGaCu_2O_y$, the connection between two double-layers of $CuO_5$ along the $a$-axis is mediated by $GaO_4$ tetrahedra. Tetrahedral $GaO_4$ chains were found running along the $c$-axis (the diagonal of the basal plane of the $Ba_2YCu_3O_7$ compound) in a zig-zag fashion, which is contrast to the square-planar copper chains typically observed in the 213 compounds. The 8-fold oxygen coordination of R is similar to that found in the 213-phase. Sr plays the role of Ba in 213 by filling the large voids located approximately at the same $x$-coordinates as the apical oxygens of the $CuO_5$ units. As a result, Sr has a total of 9-fold coordination.

As the powder x-ray diffraction technique is of primary importance for phase characterization, extensive coverage and accurate reference diffraction patterns of the superconductor and related phases in the Powder Diffraction File (PDF) [7] is essential for the high $T_c$ superconductivity community. The main goal of this paper is to prepare the standard reference patterns for this series of compounds using the Rietveld refinement method. An electron diffraction study was also carried out to determine if the superlattice lattice exists for the lanthanide Ga-2112 structures.

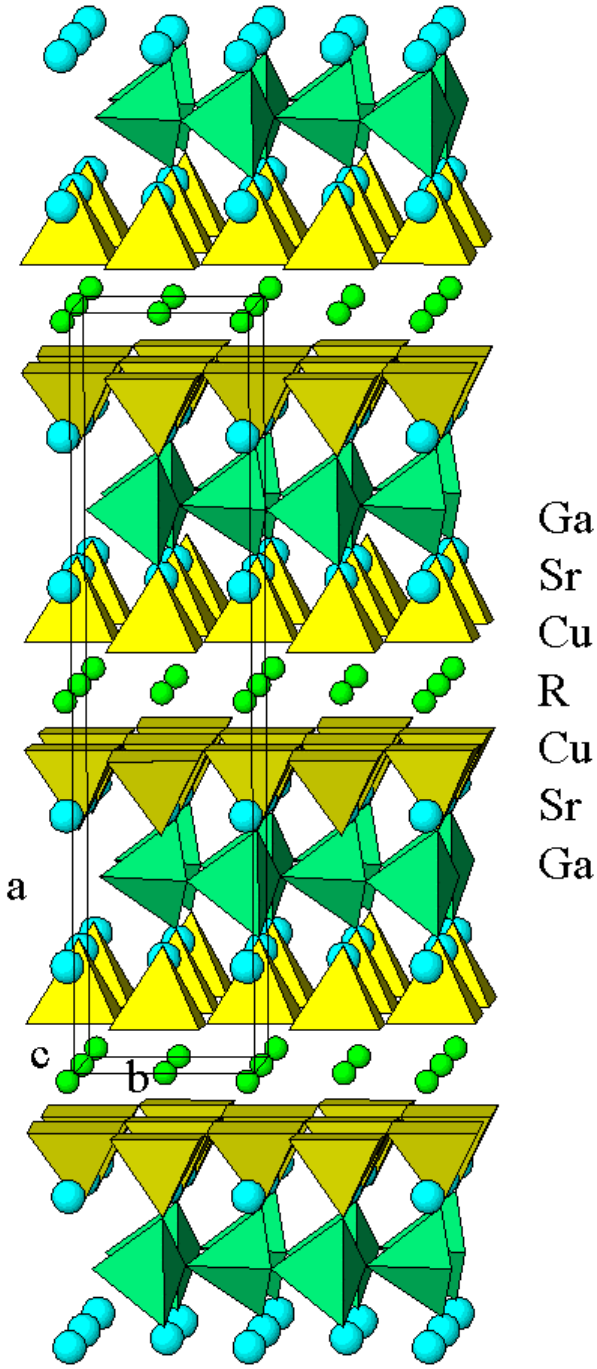


**Fig. 1.** Crystal Structure of $Sr_2RGaCu_2O_y$ [5].

## 2. Experimental

### 2.1 Sample Preparation

About (1-2) g each of the eleven polycrystalline samples of the $Sr_2RGaCu_2O_y$ series (R = Pr, Nd, Sm, Eu, Gd, Dy, Ho, Er, Tm,Y, and Yb) were prepared by the high temperature solid state sintering method. Stoichiometric powders of $SrCO_3$, $R_2O_3$ (R = Nd to Lu) or $Pr_6O_{11}$, $Ga_2O_3$ and CuO were mixed and compacted by pressing the powder in a pelletizing die, and were heat treated in air according to the schedule of 850 °C for 2 d, 960 °C for 5 d and 1000 °C for 8 d. Each time after the samples were taken out of the furnace, they were reground and repelletized. Since the differential thermal analysis (DTA) melting temperatures of the Y- and Nd-analogs take place at 1080 °C and 1130 °C, respectively [5], the highest temperature of sample preparation for most samples is below 1050 °C to avoid melting. The highest temperatures of heat treatment for the Tm, Yb, and Lu compositions were around 975 °C and 980 °C. X-Ray powder diffraction was used to identify the phases synthesized and to confirm phase purity.

### 2.2 Reference Powder X-ray Patterns

#### 2.2.1 Experimental Measurement

For standard pattern measurements, the black $Sr_2RGaCu_2O_y$ powders were mounted in zero-background quartz holders with double-sided adhesive tape. A Scintag PAD V diffractometer[1] equipped with an Ortec intrinsic Ge detector was used to measure the powder patterns (CuKα radiation, 40 KV, 30 mA) from 3°–140° 2θ in 0.02° steps every 10 s.

#### 2.2.2 Patterns Analysis

All data processing was carried out using the Rietveld structural refinement technique [8] with the computer program suite GSAS [9]. Published structural models were used [4,5]. A scale factor, a sample displacement coefficient, the atomic coordinates, isotropic displacement coefficients, and the orthorhombic lattice parameters were refined. The diffraction peak profiles were described using a pseudo-Voigt function; only the Gaussian W and Cauchy X (size) terms were refined. Background intensities were described using a 3-term cosine Fourier series.

Reference x-ray patterns of the 10 $Sr_2RGaCu_2O_y$ compounds, where R = Pr, Nd, Sm, Eu, Gd, Dy, Ho, Er, Tm, and Y were obtained with a Rietveld pattern decomposition technique. These patterns represent ideal specimen patterns. They are corrected for systematic errors both in $d$-spacings and intensity $I$. The reported peak positions are calculated from the refined lattice parameters, as they represent the best measure of the true positions. For peaks resolved at the instrument resolution function, the individual peak positions are reported. For overlapping peaks, the intensity-weighted average peak position is reported with multiple indices. For marginally-resolved peaks, individual peaks are reported to simulate the visual appearance of the pattern.

#### 2.2.3 Electron Diffraction Studies

Electron diffraction patterns were measured for the R = Sm and R = Er samples to ensure that a superlattice does not exist in these compounds. The specimens were prepared from the sintered pellets by conventional grinding, polishing and ion thinning. The specimens were examined using a Phillips 430 TEM operated at 200 kV.

[1] Certain commercial equipment, instruments, or materials are identified in this paper to foster understanding. Such identification does not imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the materials or equipment identified are necessarily the best available for the purpose.

## 3. Results and Discussion

All samples except the Tm and Yb compounds were confirmed to contain a single phase. A small quantity of $Yb_2Cu_2O_5$, $SrYb_2O_4$ and $GaCuO_2$ were found to coexist with the $Sr_2YbGaCu_2O_y$ phase. The pattern for the Yb-analog was not measured because of impurities in the powder. In addition, the smaller size Lu analog cannot be prepared even at a relatively high temperature of 1050 °C. Rather, an x-ray diffraction pattern of a specimen with a nominal composition of $Sr_2LuGaCu_2O_y$ clearly showed a mixture of $Lu_2Cu_2O_5$, $(Sr,Lu)_{14}Cu_{24}O_{41}$, and $Sr_4Ga_2O_7$, etc. Apparently, the $Lu^{3+}$ ion is too small for the 8-fold oxygen coordination cage; therefore, the compound $Sr_2LuGaCu_2O_y$ is unstable.

The Rietveld refinement results in an acceptable fit to the experimental data (Fig. 2). The similarity of both $Sr_2NdGaCu_2O_y$ and $Ba_2NdCu_3O_{6+y}$ structures is revealed in the similarity of their x-ray powder patterns (Fig. 3). X-ray diffraction patterns of three selected samples ($Sr_2RGaCu_2O_y$, R = Nd, Gd, and Ho) are shown in Fig. 4; as expected, the patterns of these analogs are similar up to the small displacements of the corresponding reflections.

X-ray powder diffraction showed the structure of $SR_2RGaCu_2O_y$ to be Ima2. The lattice parameters, densities, and ionic radii [10,11] of these phases are listed in Table 1. The lattice parameters of $Sr_2RGaCu_2O_y$ range from $a = 23.129(1)$ Å, $b = 5.5587(2)$ Å, and $c = 5.4596(3)$ Å for R = La [12], to $a = 22.7964(3)$ Å for R = Er, and $b = 5.46031(5)$ Å, and $c = 5.37773(5)$ Å for R = Yb. The numbers in parentheses indicate the standard uncertainties, Type A, calculated by the GSAS program suite [9]. Fig. 5 shows a dependence of the unit cell volume on the ionic radius $r$ ($R^{3+}$) of R = La, Pr, Nd, Sm, Eu, Gd, Dy, Ho, Y, Er, Tm, and Yb. Except for Ho, a monotonic decrease in volume on going from La to Yb is observed.

In the 2112 structure, instead of square planar Cu-O chains, tetrahedral $GaO_4$ chains were found to run in a zig-zag fashion along the diagonal of the basal 213 $ab$-direction. A set of selected area (electron) diffraction (SAD) patterns for the R = Sm sample is illustrated in Fig. 6. In addition to the strong fundamental reflections, the pattern of the [100] zone axis exhibits continuous streaks of diffuse intensity along the $b$-direction. Formation of a superstructure with a doubled periodicity along the $c$-direction has been reported for the $Sr_2YCoCu_2O_7$ and $Sr_2$ $(Nd,Ce)_2GaCu_2O_9$ compounds by Krekels et al. [13]. However, in the present study, no such doubling was observed. The observed streaks can be attributed to a disorder due to presence of oxygen vacancies and/or copper atoms within tetrahedral $GaO_4$

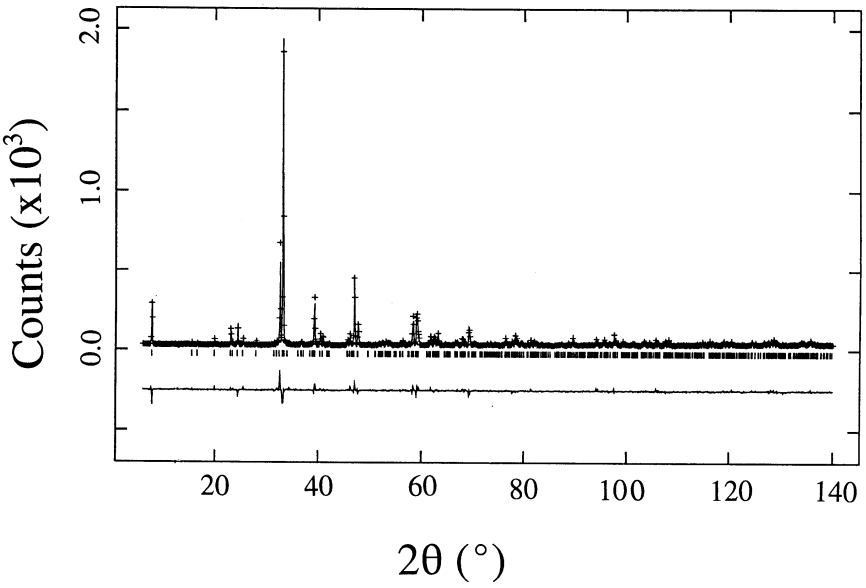


**Fig. 2.** Observed, calculated, and difference x-ray Rietveld powder patterns of $Sr_2EuGaCu_2O_y$. The crosses represent the observed data points, and the solid line represent the calculated pattern. The difference pattern is plotted at the same scale as the other patterns. The row of tick marks indicates the calculated peak positions.

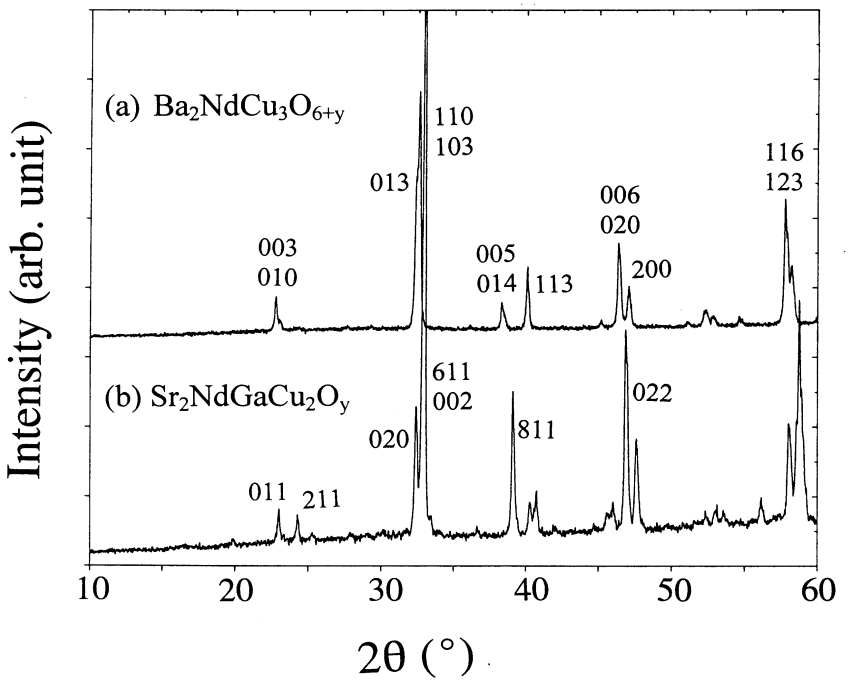


**Fig. 3.** X-Ray diffraction patterns of $Sr_2NdGaCu_2O_y$ and $Ba_2NdCu_3O_{6+y}$. Similarity of these patterns is discernible. Representative *hkl* values are indicated.

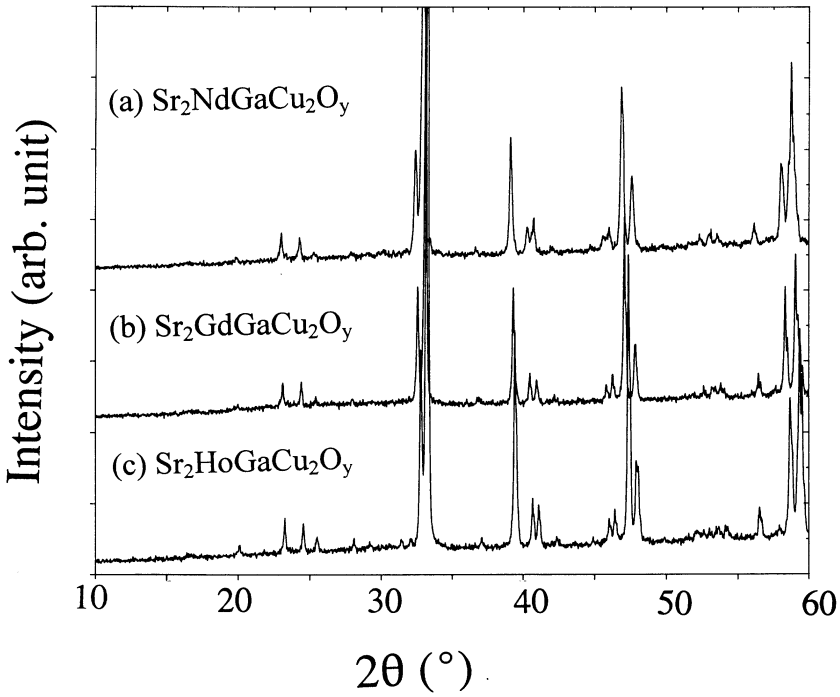


**Fig. 4.** X-Ray diffraction patterns of three selected samples ($Sr_2RGaCu_2O_y$, R = Nd, Gd and Ho).

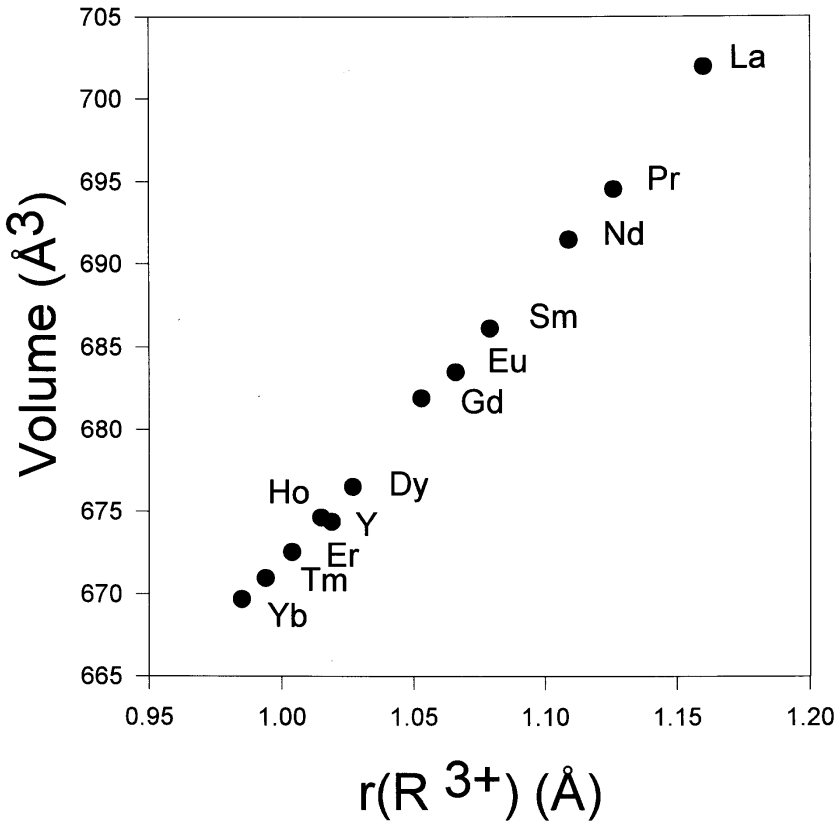


**Fig. 5.** Plots of the unit cell volumes of $Sr_2NdGaCu_2O_y$ vs ionic radius of $R^{3+}$, $r(R^{3+})$ [10,11]. A general trend parallel to the lanthanide contraction is shown.

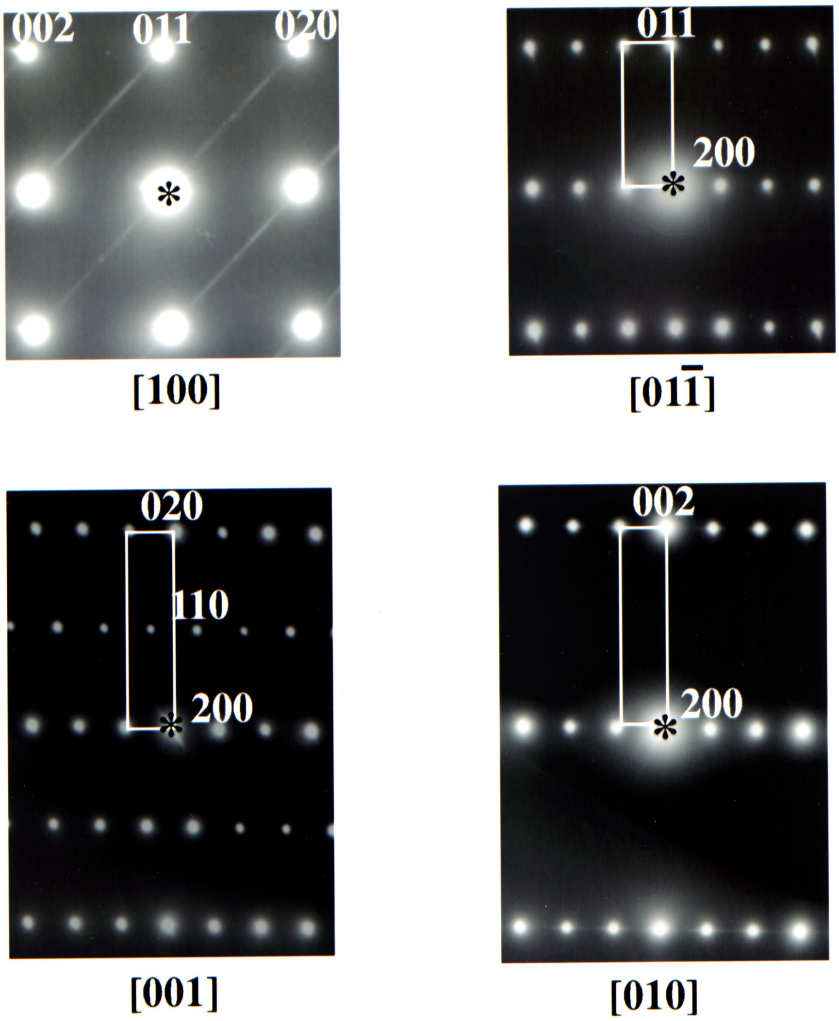


**Fig. 6.** Selected area (electron) diffraction (SAD) patterns of $Sr_2SmGaCu_2O_y$ showing various zone-axis orientations. Continuous streaks of diffuse intensity along the *b*-direction is observed in the [100] zone-axis pattern.

**Table 1.** Crystallographic data for the $Sr_2RGaCu_2O_y$ series (Ima2, $Z = 4$; R = La, Pr, Nd, Sm, Eu, Gd, Dy, Y, Ho, Er, Tm, and Yb). The effective ionic radii of $R^{3+}$ (eight-coordination) were taken from Shannon's Table [10,11]. $D_c$ refers to calculated density

| R | $R^{3+}$ Å | *a* (Å) | *b* (Å) | *c* (Å) | Volume (Å$^3$) | $D_c$(kg/m$^2$) |
|---|---|---|---|---|---|---|
| La | 1.160 | 23.129(1) | 5.5587(2) | 5.4596(3) | 701.93 | 5.895 [12] |
| Pr | 1.126 | 22.9694(3) | 5.55081(7) | 5.44743(7) | 694.54 | 5.977 |
| Nd | 1.109 | 22.9206(2) | 5.54344(5) | 5.44229(5) | 691.49 | 6.035 |
| Sm | 1.079 | 22.8708(2) | 5.52690(5) | 5.42790(5) | 686.11 | 6.147 |
| Eu | 1.066 | 22.8441(3) | 5.51870(8) | 5.42102(8) | 683.47 | 6.181 |
| Gd | 1.053 | 22.8294(2) | 5.51236(5) | 5.41835(5) | 681.87 | 6.247 |
| Dy | 1.027 | 22.8015(2) | 5.49286(5) | 5.40138(5) | 676.50 | 6.348 |
| Y | 1.019 | 22.8113(2) | 5.48069(5) | 5.39397(5) | 674.36 | 5.643 |
| Ho | 1.015 | 22.7975(2) | 5.48433(5) | 5.39562(5) | 674.61 | 6.390 |
| Er | 1.004 | 22.7964(3) | 5.47497(6) | 5.38837(6) | 672.52 | 6.433 |
| Tm | 0.994 | 22.8024(3) | 5.46762(7) | 5.38158(7) | 670.95 | 6.464 |
| Yb | 0.985 | 22.8059(2) | 5.46031(5) | 5.37773(5) | 669.67 | 6.554 |

chains extending along the *b*-direction, similar to that described by Krekels et al. [12]. X-ray diffraction, however, is not as sensitive as neutron diffraction to the disorder of light elements such as oxygen, as reflected in relatively small values (≈ 0.004 Å) of the refined isotropic temperature factors ($U_{iso}$).

Tables 2-11 list the reference patterns for $Sr_2RGaCu_2O_y$ (R = Pr, Nd, Sm, Eu, Gd, Dy, Ho, Er, Tm, and Y). The tables present the *d*-spacing values, Miller indices and integrated intensities which were normalized to a maximum value of 999. The symbols "M" and "+" refer to peaks containing two or more than two reflections, respectively.

**Table 2.** X-Ray reference pattern for $Sr_2PrGaCu_2O_y$ (space group Ima2, $Z = 4$, $a = 22.9694(3)$ Å, $b = 5.55081(7)$ Å, and $c = 5.44743(7)$ Å)

| *d* | *I* | *h* | *k* | *l* | *d* | *I* | *h* | *k* | *l* | *d* | *I* | *h* | *k* | *l* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11.4847 | 91 | 2 | 0 | 0 | 5.39550 | 6 | 1 | 1 | 0 | 4.49403 | 20 | 3 | 1 | 0 |
| 3.88795 | 59 | 0 | 1 | 1 | 3.82823 | 6 | 6 | 0 | 0 | 3.68265 | 47 | 2 | 1 | 1 |
| 3.53906 | 21 | 5 | 1 | 0 | 3.21943 | 11 | 4 | 1 | 1 | 2.87117 | 11 | 8 | 0 | 0 |
| 2.82470 | 16 | 7 | 1 | 0 | 2.77541191 | | 0 | 2 | 0 | 2.72689999* | | 6 | 1 | 1M |
| 2.72689999* | | 0 | 0 | 2M | 2.69775 | 5 | 2 | 2 | 0 | 2.65020 | 10 | 2 | 0 | 2 |
| 2.49884 | 5 | 4 | 2 | 0 | 2.45922 | 14 | 4 | 0 | 2M | 2.45922 | 14 | 1 | 2 | 1M |
| 2.30965179 | | 8 | 1 | 1 | 2.24701 | 50 | 6 | 2 | 0 | 2.21932 | 40 | 6 | 0 | 2 |
| 2.15848 | 7 | 5 | 1 | 2 | 1.99551 | 22 | 8 | 2 | 0 | 1.97617 | 29 | 8 | 0 | 2+ |
| 1.94397207 | | 0 | 2 | 2 | 1.91671 | 26 | 2 | 2 | 2 | 1.91412 | 87 | 12 | 0 | 0 |
| 1.84132 | 8 | 4 | 2 | 2 | 1.77598 | 7 | 9 | 2 | 1 | 1.75197 | 10 | 0 | 3 | 1 |
| 1.73330 | 9 | 6 | 2 | 2 | 1.72582 | 6 | 0 | 1 | 3 | 1.71629 | 11 | 5 | 3 | 0 |
| 1.70665 | 5 | 2 | 1 | 3 | 1.65278 | 5 | 4 | 1 | 3 | 1.64067 | 27 | 14 | 0 | 0 |
| 1.61078 | 11 | 7 | 3 | 0M | 1.61078 | 11 | 8 | 2 | 2M | 1.59307129 | | 6 | 3 | 1 |
| 1.57571 | 39 | 12 | 2 | 0 | 1.57333157 | | 6 | 1 | 3 | 1.56607 | 53 | 12 | 0 | 2 |
| 1.51618 | 7 | 1 | 2 | 3 | 1.51159 | 43 | 14 | 1 | 1 | 1.49553 | 46 | 8 | 3 | 1 |
| 1.47917 | 34 | 8 | 1 | 3 | 1.45205 | 10 | 5 | 3 | 2 | 1.41235 | 21 | 14 | 2 | 0 |
| 1.40539 | 11 | 14 | 0 | 2 | 1.38757 | 26 | 0 | 4 | 0M | 1.38757 | 26 | 7 | 3 | 2 |
| 1.37768 | 10 | 2 | 4 | 0 | 1.36392 | 75 | 12 | 2 | 2 | 1.36186 | 29 | 0 | 0 | 4 |
| 1.34246 | 5 | 1 | 4 | 1 | 1.29598 | 5 | 0 | 3 | 3 | 1.25381 | 36 | 14 | 2 | 2 |
| 1.23647 | 16 | 0 | 4 | 2 | 1.22937 | 5 | 2 | 4 | 2 | 1.22755 | 40 | 6 | 3 | 3 |
| 1.22260 | 25 | 0 | 2 | 4 | 1.21244 | 15 | 18 | 1 | 1 | 1.19754 | 10 | 14 | 3 | 1 |
| 1.18923 | 23 | 9 | 4 | 1M | 1.18923 | 23 | 14 | 1 | 3M | 1.18123 | 20 | 8 | 3 | 3 |
| 1.17662 | 14 | 6 | 4 | 2 | 1.16465 | 10 | 6 | 2 | 4 | 1.12351 | 12 | 12 | 4 | 0 |
| 1.10966 | 14 | 12 | 0 | 4 | 1.10142 | 39 | 20 | 1 | 1 | 1.08780 | 5 | 0 | 5 | 1 |
| 1.06120 | 6 | 20 | 2 | 0 | 1.05953 | 16 | 14 | 4 | 0 | 1.05824 | 9 | 20 | 0 | 2 |
| 1.04789 | 12 | 14 | 0 | 4 | 1.04638 | 23 | 6 | 5 | 1 | 1.03862 | 13 | 12 | 4 | 2 |
| 1.03147 | 10 | 18 | 3 | 1 | 1.02991 | 58 | 12 | 2 | 4M | 1.02991 | 58 | 6 | 1 | 5M |
| 1.02606 | 11 | 18 | 1 | 3 | 1.01716 | 25 | 8 | 5 | 1M | 1.01716 | 25 | 14 | 3 | 3M |
| 1.00323 | 6 | 5 | 5 | 2 | 1.00189 | 11 | 8 | 1 | 5 | 0.98880 | 7 | 20 | 2 | 2 |
| 0.98745 | 19 | 14 | 4 | 2 | 0.98034 | 17 | 14 | 2 | 4 | 0.97199 | 17 | 0 | 4 | 4 |
| 0.96852 | 5 | 2 | 4 | 4 | 0.96049 | 36 | 20 | 3 | 1 | 0.95611 | 26 | 20 | 1 | 3 |
| 0.94717 | 7 | 0 | 5 | 3 | 0.91944 | 21 | 6 | 5 | 3 | 0.91180 | 27 | 6 | 3 | 5 |
| 0.90928 | 7 | 18 | 3 | 3 | 0.90790 | 9 | 0 | 0 | 6 | 0.89942 | 23 | 8 | 5 | 3M |
| 0.89942 | 23 | 6 | 6 | 0M | 0.89571 | 10 | 14 | 1 | 5 | 0.89233 | 14 | 8 | 3 | 5 |
| 0.88342 | 11 | 26 | 0 | 0M | 0.88342 | 11 | 6 | 0 | 6M | 0.87796 | 6 | 20 | 0 | 4 |
| 0.87598 | 15 | 0 | 6 | 2 | 0.87345 | 9 | 2 | 6 | 2 | 0.86665 | 24 | 12 | 4 | 4 |
| 0.86291 | 28 | 0 | 2 | 6 | 0.86148 | 23 | 26 | 1 | 1 | 0.86048 | 6 | 2 | 2 | 6 |
| 0.85953 | 49 | 20 | 3 | 3 | 0.85875 | 10 | 9 | 6 | 1M | 0.85875 | 10 | 24 | 2 | 2M |
| 0.85391 | 6 | 6 | 6 | 2 | 0.84874 | 11 | 12 | 5 | 3M | 0.84874 | 11 | 21 | 4 | 1M |
| 0.84171 | 30 | 26 | 2 | 0M | 0.84171 | 30 | 20 | 4 | 2M | 0.84034 | 14 | 26 | 0 | 2 |
| 0.83705 | 26 | 20 | 2 | 4M | 0.83705 | 26 | 24 | 1 | 3M | 0.83620 | 43 | 14 | 4 | 4M |
| 0.83620 | 43 | 11 | 6 | 1M | 0.83295 | 5 | 12 | 6 | 0 | 0.82783 | 9 | 18 | 5 | 1 |
| 0.82030 | 26 | 12 | 0 | 6M | 0.82030 | 26 | 14 | 5 | 3M | | | | | |

**Table 3.** X-Ray reference pattern for $Sr_2NdGaCu_2O_y$ (space group Ima2, $Z = 4$, $a = 22.9206(2)$ Å, $b = 5.54344(5)$ Å, and $c = 5.44229(5)$ Å)

| *d* | *I* | *h* | *k* | *l* | *d* | *I* | *h* | *k* | *l* | *d* | *I* | *h* | *k* | *l* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11.46031 | 45 | 2 | 0 | 0 | 4.48683 | 15 | 3 | 1 | 0 | 3.88355 | 68 | 0 | 1 | 1 |
| 3.82010 | 6 | 6 | 0 | 0 | 3.67810 | 45 | 2 | 1 | 1 | 3.53269 | 18 | 5 | 1 | 0 |
| 3.21478 | 6 | 4 | 1 | 1 | 2.86508 | 8 | 8 | 0 | 0 | 2.81928 | 16 | 7 | 1 | 0 |
| 2.77172 | 209 | 0 | 2 | 0 | 2.72286 | 999* | 6 | 1 | 1M | 2.72286 | 999* | 0 | 0 | 2M |
| 2.69405 | 6 | 2 | 2 | 0 | 2.64754 | 9 | 2 | 0 | 2 | 2.45564 | 8 | 1 | 2 | 1 |
| 2.30555 | 212 | 8 | 1 | 1 | 2.29206 | 5 | 10 | 0 | 0 | 2.24341 | 57 | 6 | 2 | 0 |
| 2.21634 | 53 | 6 | 0 | 2 | 2.15576 | 7 | 5 | 1 | 2 | 1.99209 | 24 | 8 | 2 | 0 |
| 1.94177 | 234 | 0 | 2 | 2 | 1.91449 | 27 | 2 | 2 | 2 | 1.91005 | 93 | 12 | 0 | 0 |
| 1.77301 | 8 | 9 | 2 | 1 | 1.75304 | 5 | 10 | 0 | 2 | 1.74971 | 12 | 0 | 3 | 1 |
| 1.73099 | 10 | 6 | 2 | 2 | 1.72412 | 9 | 0 | 1 | 3 | 1.71382 | 13 | 5 | 3 | 0 |
| 1.70494 | 5 | 2 | 1 | 3 | 1.63719 | 26 | 14 | 0 | 0 | 1.60838 | 11 | 7 | 3 | 0M |
| 1.60838 | 11 | 8 | 2 | 2M | 1.59078 | 153 | 6 | 3 | 1 | 1.57174 | 191 | 12 | 2 | 0M |
| 1.57174 | 191 | 6 | 1 | 3M | 1.56336 | 52 | 12 | 0 | 2 | 1.51457 | 8 | 1 | 2 | 3 |
| 1.50861 | 48 | 14 | 1 | 1 | 1.49327 | 49 | 8 | 3 | 1 | 1.47727 | 44 | 8 | 1 | 3 |
| 1.45017 | 13 | 5 | 3 | 2 | 1.40964 | 32 | 14 | 2 | 0 | 1.40285 | 19 | 14 | 0 | 2 |
| 1.38571 | 25 | 0 | 4 | 0M | 1.38571 | 25 | 7 | 3 | 2M | 1.37584 | 9 | 2 | 4 | 0 |
| 1.36138 | 95 | 12 | 2 | 2M | 1.36138 | 95 | 0 | 0 | 4M | 1.35108 | 6 | 2 | 0 | 4 |
| 1.34402 | 6 | 16 | 1 | 1 | 1.34070 | 6 | 1 | 4 | 1 | 1.29452 | 5 | 0 | 3 | 3 |
| 1.25166 | 43 | 14 | 2 | 2 | 1.23493 | 23 | 0 | 4 | 2 | 1.22782 | 6 | 2 | 4 | 2 |
| 1.22603 | 50 | 6 | 3 | 3 | 1.22136 | 30 | 0 | 2 | 4 | 1.20999 | 17 | 18 | 1 | 1 |
| 1.19547 | 12 | 14 | 3 | 1 | 1.18737 | 20 | 9 | 4 | 1M | 1.18737 | 20 | 14 | 1 | 3M |
| 1.17969 | 18 | 8 | 3 | 3 | 1.17505 | 15 | 6 | 4 | 2 | 1.16335 | 11 | 6 | 2 | 4 |
| 1.12353 | 5 | 8 | 2 | 4 | 1.12171 | 13 | 12 | 4 | 0 | 1.10817 | 18 | 12 | 0 | 4 |
| 1.09917 | 46 | 20 | 1 | 1 | 1.08637 | 5 | 0 | 5 | 1 | 1.05907 | 8 | 20 | 2 | 0 |
| 1.05777 | 22 | 14 | 4 | 0 | 1.05618 | 8 | 20 | 0 | 2 | 1.04640 | 15 | 14 | 0 | 4 |
| 1.04494 | 32 | 6 | 5 | 1 | 1.03705 | 15 | 12 | 4 | 2 | 1.02873 | 60 | 12 | 2 | 4M |
| 1.02873 | 60 | 6 | 1 | 5M | 1.02429 | 10 | 18 | 1 | 3 | 1.01568 | 29 | 8 | 5 | 1M |
| 1.01568 | 29 | 14 | 3 | 3 | 1.00079 | 13 | 8 | 1 | 5 | 0.98696 | 7 | 20 | 2 | 2 |
| 0.98590 | 23 | 14 | 4 | 2 | 0.97896 | 20 | 14 | 2 | 4 | 0.97089 | 13 | 0 | 4 | 4 |
| 0.95869 | 29 | 20 | 3 | 1 | 0.95442 | 30 | 20 | 1 | 3 | 0.91827 | 22 | 6 | 5 | 3 |
| 0.91080 | 27 | 6 | 3 | 5 | 0.90779 | 6 | 18 | 3 | 3 | 0.90705 | 6 | 0 | 0 | 6 |
| 0.89823 | 23 | 8 | 5 | 3 | 0.89823 | 23 | 6 | 6 | 0 | 0.89454 | 9 | 14 | 1 | 5 |
| 0.89131 | 15 | 8 | 3 | 5 | 0.88251 | 6 | 6 | 0 | 6 | 0.88156 | 5 | 26 | 0 | 0 |
| 0.87485 | 14 | 0 | 6 | 2 | 0.87232 | 10 | 2 | 6 | 2 | 0.86549 | 25 | 12 | 4 | 4 |
| 0.86206 | 21 | 0 | 2 | 6 | 0.85967 | 23 | 26 | 1 | 1M | 0.85967 | 23 | 2 | 2 | 6M |
| 0.85808 | 39 | 20 | 3 | 3 | 0.85278 | 7 | 6 | 6 | 2 | 0.84773 | 6 | 12 | 5 | 3 |
| 0.84701 | 6 | 21 | 4 | 1 | 0.84092 | 7 | 6 | 2 | 6 | 0.84007 | 26 | 26 | 2 | 0M |
| 0.84007 | 26 | 20 | 4 | 2M | 0.83865 | 15 | 26 | 0 | 2 | 0.83573 | 19 | 20 | 2 | 4 |
| 0.83509 | 34 | 14 | 4 | 4 | 0.83461 | 5 | 11 | 6 | 1 | 0.83172 | 6 | 12 | 6 | 0 |
| 0.82647 | 8 | 18 | 5 | 1 | | | | | | | | | | |

**Table 4.** X-Ray reference pattern for $Sr_2SmGaCu_2O_y$ (space group Ima2, $Z = 4$, $a = 22.8708(2)$ Å, $b = 5.52690(5)$ Å, and $c = 5.42790(5)$ Å)

| *d* | *I* | *h* | *k* | *l* | *d* | *I* | *h* | *k* | *l* | *d* | *I* | *h* | *k* | *l* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11.4356 | 213 | 2 | 0 | 0 | 5.71781 | 8 | 4 | 0 | 0 | 5.37248 | 6 | 1 | 1 | 0 |
| 4.47485 | 14 | 3 | 1 | 0 | 3.87263 | 56 | 0 | 1 | 1 | 3.81187 | 6 | 6 | 0 | 0 |
| 3.66801 | 60 | 2 | 1 | 1 | 3.52395 | 20 | 5 | 1 | 0 | 3.20641 | 6 | 4 | 1 | 1 |
| 2.85891 | 6 | 8 | 0 | 0 | 2.81264 | 12 | 7 | 1 | 0 | 2.76356 | 242 | 0 | 2 | 0 |
| 2.71613999* | | 6 | 1 | 1M | 2.71613999* | | 0 | 0 | 2M | 2.64051 | 5 | 2 | 0 | 2 |
| 2.44856 | 5 | 1 | 2 | 1 | 2.30005 | 186 | 8 | 1 | 1 | 2.28712 | 23 | 10 | 0 | 0 |
| 2.23742 | 43 | 6 | 2 | 0 | 2.21079 | 31 | 6 | 0 | 2 | 2.15014 | 7 | 5 | 1 | 2 |
| 1.96932 | 21 | 10 | 1 | 1 | 1.93632 | 220 | 0 | 2 | 2 | 1.90620 | 119 | 2 | 2 | 2M |
| 1.90620 | 119 | 12 | 0 | 0M | 1.76852 | 7 | 9 | 2 | 1 | 1.72551 | 14 | 6 | 2 | 2M |
| 1.72551 | 14 | 2 | 3 | 1M | 1.70958 | 13 | 12 | 1 | 1M | 1.70958 | 13 | 5 | 3 | 0M |
| 1.70034 | 7 | 2 | 1 | 3 | 1.63366 | 18 | 14 | 0 | 0 | 1.60482 | 5 | 7 | 3 | 0 |
| 1.58871 | 5 | 11 | 2 | 1 | 1.58636 | 125 | 6 | 3 | 1 | 1.56898 | 34 | 12 | 2 | 0 |
| 1.56737 | 157 | 6 | 1 | 3 | 1.55972 | 49 | 12 | 0 | 2 | 1.51039 | 6 | 1 | 2 | 3 |
| 1.50521 | 41 | 14 | 1 | 1 | 1.48922 | 44 | 8 | 3 | 1 | 1.48471 | 5 | 3 | 2 | 3 |
| 1.47782 | 6 | 10 | 2 | 2 | 1.47348 | 31 | 8 | 1 | 3 | 1.46985 | 5 | 15 | 1 | 0 |
| 1.44612 | 9 | 5 | 3 | 2 | 1.40632 | 29 | 14 | 2 | 0 | 1.39963 | 12 | 14 | 0 | 2 |
| 1.38162 | 40 | 0 | 4 | 0M | 1.38162 | 40 | 7 | 3 | 2M | 1.37180 | 5 | 2 | 4 | 0 |
| 1.35831 | 70 | 12 | 2 | 2 | 1.35692 | 23 | 0 | 0 | 4 | 1.34747 | 5 | 2 | 0 | 4 |
| 1.34101 | 9 | 16 | 1 | 1 | 1.29853 | 5 | 3 | 1 | 4 | 1.28689 | 5 | 12 | 3 | 1 |
| 1.24863 | 45 | 14 | 2 | 2 | 1.23136 | 14 | 0 | 4 | 2 | 1.22267 | 48 | 6 | 3 | 3 |
| 1.21802 | 24 | 0 | 2 | 4 | 1.20730 | 19 | 18 | 1 | 1 | 1.20376 | 5 | 4 | 4 | 2 |
| 1.19247 | 7 | 14 | 3 | 1 | 1.18455 | 18 | 9 | 4 | 1M | 1.18455 | 18 | 14 | 1 | 3 |
| 1.17650 | 18 | 8 | 3 | 3 | 1.17174 | 10 | 6 | 4 | 2 | 1.16023 | 13 | 6 | 2 | 4 |
| 1.11871 | 16 | 12 | 4 | 0 | 1.10553 | 13 | 16 | 3 | 1M | 1.10553 | 13 | 12 | 0 | 4M |
| 1.09676 | 41 | 1 | 4 | 3M | 1.09676 | 41 | 20 | 1 | 1M | 1.05667 | 8 | 20 | 2 | 0 |
| 1.05501 | 21 | 14 | 4 | 0 | 1.05382 | 8 | 20 | 0 | 2 | 1.04382 | 13 | 14 | 0 | 4 |
| 1.04194 | 25 | 6 | 5 | 1 | 1.03428 | 13 | 12 | 4 | 2 | 1.02618 | 69 | 12 | 2 | 4+ |
| 1.02618 | 69 | 6 | 1 | 5+ | 1.02188 | 8 | 18 | 1 | 3 | 1.01292 | 23 | 8 | 5 | 1 |
| 0.99904 | 5 | 5 | 5 | 2 | 0.99816 | 13 | 8 | 1 | 5 | 0.98466 | 10 | 20 | 2 | 2 |
| 0.98332 | 18 | 14 | 4 | 2 | 0.97648 | 13 | 14 | 2 | 4 | 0.96816 | 20 | 0 | 4 | 4 |
| 0.96560 | 8 | 10 | 1 | 5 | 0.95641 | 30 | 20 | 3 | 1 | 0.95457 | 5 | 4 | 4 | 4 |
| 0.95220 | 29 | 20 | 1 | 3 | 0.94329 | 5 | 0 | 5 | 3 | 0.93530 | 5 | 18 | 4 | 0 |
| 0.93294 | 5 | 16 | 4 | 2 | 0.91574 | 23 | 22 | 2 | 2M | 0.91574 | 23 | 6 | 5 | 3M |
| 0.90832 | 31 | 6 | 3 | 5 | 0.90461 | 10 | 0 | 0 | 6 | 0.89579 | 18 | 8 | 5 | 3 |
| 0.89521 | 5 | 19 | 4 | 1 | 0.89350 | 7 | 4 | 0 | 6 | 0.89227 | 5 | 14 | 1 | 5 |
| 0.88915 | 17 | 22 | 1 | 3M | 0.88915 | 17 | 8 | 3 | 5M | 0.88017 | 6 | 6 | 0 | 6 |
| 0.87215 | 20 | 0 | 6 | 2M | 0.87215 | 20 | 10 | 5 | 3M | 0.86978 | 5 | 2 | 6 | 2 |
| 0.86568 | 5 | 10 | 3 | 5 | 0.86318 | 12 | 12 | 4 | 4 | 0.86233 | 7 | 4 | 6 | 2 |
| 0.85973 | 26 | 0 | 2 | 6 | 0.85781 | 18 | 26 | 1 | 1 | 0.85599 | 48 | 20 | 3 | 3 |
| 0.85523 | 8 | 9 | 6 | 1 | 0.85413 | 10 | 16 | 1 | 5 | 0.85303 | 5 | 1 | 4 | 5 |
| 0.85017 | 7 | 4 | 2 | 6 | 0.84493 | 11 | 21 | 4 | 1 | 0.83822 | 33 | 26 | 2 | 0 |
| 0.83656 | 27 | 26 | 0 | 2M | 0.83656 | 27 | 24 | 3 | 1M | 0.83351 | 22 | 24 | 1 | 3 |
| 0.83288 | 27 | 14 | 4 | 4 | 0.83227 | 8 | 11 | 6 | 1 | 0.82939 | 7 | 12 | 6 | 0 |
| 0.82524 | 6 | 22 | 0 | 4 | 0.82431 | 7 | 18 | 5 | 1 | 0.82038 | 5 | 1 | 6 | 3 |

**Table 5.** X-Ray reference pattern for $Sr_2EuGaCu_2O_y$ (space group Ima2, $Z = 4$, $a = 22.8441(3)$ Å, $b = 5.51870(8)$ Å, and $c = 5.42102(8)$ Å)

| *d* | *I* | *h* | *k* | *l* | *d* | *I* | *h* | *k* | *l* | *d* | *I* | *h* | *k* | *l* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11.42211 | 75 | 2 | 0 | 0 | 5.71104 | 5 | 4 | 0 | 0 | 4.46854 | 16 | 3 | 1 | 0 |
| 3.86731 | 55 | 0 | 1 | 1 | 3.80736 | 7 | 6 | 0 | 0 | 3.66305 | 53 | 2 | 1 | 1 |
| 3.51929 | 21 | 5 | 1 | 0 | 3.20220 | 7 | 4 | 1 | 1 | 2.85552 | 7 | 8 | 0 | 0 |
| 2.80905 | 11 | 7 | 1 | 0 | 2.75935347 | | 0 | 2 | 0 | 2.71251999* | | 6 | 1 | 1M |
| 2.71251999* | | 0 | 0 | 2M | 2.63727 | 12 | 2 | 0 | 2 | 2.44499 | 10 | 1 | 2 | 1 |
| 2.29717191 | | 8 | 1 | 1 | 2.28441 | 10 | 10 | 0 | 0 | 2.23427 | 47 | 6 | 2 | 0 |
| 2.20811 | 42 | 6 | 0 | 2 | 2.14742 | 6 | 5 | 1 | 2 | 1.98428 | 21 | 8 | 2 | 0 |
| 1.96589 | 29 | 8 | 0 | 2 | 1.93366275 | | 0 | 2 | 2 | 1.90418 | 98 | 2 | 2 | 2M |
| 1.90418 | 98 | 12 | 0 | 0M | 1.78813 | 5 | 3 | 3 | 0 | 1.76617 | 10 | 9 | 2 | 1 |
| 1.75964 | 5 | 10 | 2 | 0 | 1.74678 | 6 | 10 | 0 | 2 | 1.74200 | 10 | 0 | 3 | 1 |
| 1.72405 | 12 | 6 | 2 | 2 | 1.71729 | 10 | 0 | 1 | 3 | 1.70644 | 10 | 5 | 3 | 0 |
| 1.69821 | 6 | 2 | 1 | 3 | 1.64455 | 5 | 4 | 1 | 3 | 1.63172 | 22 | 14 | 0 | 0 |
| 1.60110 | 5 | 8 | 2 | 2 | 1.58407142 | | 6 | 3 | 1 | 1.56577188 | | 12 | 2 | 0M |
| 1.56577188 | | 6 | 1 | 3M | 1.55785 | 58 | 12 | 0 | 2 | 1.50840 | 5 | 1 | 2 | 3 |
| 1.50338 | 46 | 14 | 1 | 1 | 1.48712 | 48 | 8 | 3 | 1 | 1.47591 | 7 | 10 | 2 | 2 |
| 1.47166 | 50 | 8 | 1 | 3 | 1.44409 | 8 | 5 | 3 | 2 | 1.40453 | 17 | 14 | 2 | 0 |
| 1.39796 | 16 | 14 | 0 | 2 | 1.37963 | 37 | 0 | 4 | 0M | 1.37963 | 37 | 7 | 3 | 2M |
| 1.36972 | 7 | 2 | 4 | 0 | 1.35617 | 92 | 12 | 2 | 2M | 1.35617 | 92 | 0 | 0 | 4M |
| 1.33939 | 10 | 16 | 1 | 1 | 1.33477 | 5 | 1 | 4 | 1 | 1.29714 | 5 | 6 | 4 | 0 |
| 1.28910 | 5 | 0 | 3 | 3 | 1.24705 | 37 | 14 | 2 | 2 | 1.22956 | 22 | 0 | 4 | 2 |
| 1.22102 | 47 | 6 | 3 | 3 | 1.21645 | 29 | 0 | 2 | 4 | 1.20585 | 18 | 18 | 1 | 1 |
| 1.19088 | 12 | 14 | 3 | 1 | 1.18290 | 18 | 14 | 1 | 3 | 1.17493 | 21 | 8 | 3 | 3 |
| 1.17006 | 11 | 6 | 4 | 2 | 1.15875 | 10 | 6 | 2 | 4 | 1.11714 | 9 | 12 | 4 | 0 |
| 1.10405 | 12 | 12 | 0 | 4 | 1.09543 | 32 | 20 | 1 | 1 | 1.05536 | 8 | 20 | 2 | 0 |
| 1.05355 | 18 | 14 | 4 | 0 | 1.05257 | 11 | 20 | 0 | 2 | 1.04255 | 12 | 14 | 0 | 4 |
| 1.04039 | 27 | 6 | 5 | 1 | 1.03285 | 14 | 12 | 4 | 2 | 1.02491 | 61 | 12 | 2 | 4+ |
| 1.02491 | 61 | 6 | 1 | 5+ | 1.02065 | 9 | 18 | 1 | 3 | 1.01146 | 24 | 14 | 3 | 3M |
| 1.01146 | 24 | 8 | 5 | 1M | 0.99711 | 18 | 5 | 5 | 2M | 0.99711 | 18 | 8 | 1 | 5M |
| 0.98345 | 10 | 20 | 2 | 2 | 0.98198 | 23 | 14 | 4 | 2 | 0.97526 | 16 | 14 | 2 | 4 |
| 0.96683 | 24 | 0 | 4 | 4 | 0.95519 | 30 | 20 | 3 | 1 | 0.95105 | 28 | 20 | 1 | 3 |
| 0.91978 | 8 | 0 | 6 | 0 | 0.91436 | 23 | 6 | 5 | 3 | 0.90715 | 26 | 6 | 3 | 5 |
| 0.90439 | 5 | 18 | 3 | 3 | 0.90350 | 6 | 0 | 0 | 6 | 0.90150 | 5 | 14 | 5 | 1 |
| 0.89440 | 29 | 8 | 5 | 3M | 0.89440 | 29 | 6 | 6 | 0M | 0.89118 | 10 | 14 | 1 | 5 |
| 0.88776 | 18 | 8 | 3 | 5 | 0.87909 | 5 | 6 | 0 | 6 | 0.87100 | 16 | 0 | 6 | 2 |
| 0.86848 | 10 | 2 | 6 | 2 | 0.86203 | 21 | 12 | 4 | 4 | 0.85865 | 20 | 0 | 2 | 6 |
| 0.85679 | 20 | 26 | 1 | 1 | 0.85623 | 5 | 2 | 2 | 6 | 0.85490 | 43 | 20 | 3 | 3 |
| 0.84907 | 9 | 6 | 6 | 2 | 0.83722 | 34 | 26 | 2 | 0+ | 0.83581 | 13 | 26 | 0 | 2 |
| 0.83267 | 17 | 20 | 2 | 4 | 0.83178 | 28 | 14 | 4 | 4 | 0.82318 | 7 | 18 | 5 | 1 |

**Table 6.** X-Ray reference pattern for $Sr_2GdGaCu_2O_y$ (space group Ima2, $Z = 4$, $a = 22.8294(2)$ Å, $b = 5.51236(5)$ Å, and $c = 5.41835(5)$ Å)

| *d* | *I* | *h* | *k* | *l* | *d* | *I* | *h* | *k* | *l* | *d* | *I* | *h* | *k* | *l* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11.41472 | 08 | 2 | 0 | 0 | 4.46419 | 12 | 3 | 1 | 0 | 3.86416 | 57 | 0 | 1 | 1 |
| 3.80491 | 7 | 6 | 0 | 0 | 3.66013 | 49 | 2 | 1 | 1 | 3.51630 | 20 | 5 | 1 | 0 |
| 3.19976 | 6 | 4 | 1 | 1 | 2.85368 | 6 | 8 | 0 | 0 | 2.80688 | 13 | 7 | 1 | 0 |
| 2.75618 | 209 | 0 | 2 | 0 | 2.71072 | 999* | 6 | 1 | 1M | 2.71072 | 999* | 0 | 0 | 2M |
| 2.67919 | 5 | 2 | 2 | 0 | 2.63595 | 14 | 2 | 0 | 2 | 2.44252 | 8 | 1 | 2 | 1 |
| 2.29555 | 189 | 8 | 1 | 1 | 2.28294 | 16 | 10 | 0 | 0 | 2.23210 | 46 | 6 | 2 | 0 |
| 2.20691 | 36 | 6 | 0 | 2 | 2.14608 | 5 | 5 | 1 | 2 | 1.98249 | 20 | 8 | 2 | 0 |
| 1.96432 | 29 | 8 | 0 | 2M | 1.96432 | 29 | 7 | 2 | 1M | 1.93208 | 237 | 0 | 2 | 2 |
| 1.90315 | 94 | 2 | 2 | 2M | 1.90315 | 94 | 12 | 0 | 0M | 1.76469 | 6 | 9 | 2 | 1 |
| 1.74012 | 10 | 0 | 3 | 1 | 1.72271 | 12 | 6 | 2 | 2 | 1.71634 | 7 | 0 | 1 | 3 |
| 1.70460 | 10 | 5 | 3 | 0 | 1.69726 | 6 | 2 | 1 | 3 | 1.63067 | 19 | 14 | 0 | 0 |
| 1.60086 | 7 | 7 | 3 | 0 | 1.58248 | 120 | 6 | 3 | 1 | 1.56478 | 174 | 12 | 2 | 0M |
| 1.56478 | 174 | 6 | 1 | 3M | 1.55692 | 43 | 12 | 0 | 2 | 1.50736 | 5 | 1 | 2 | 3 |
| 1.50238 | 39 | 14 | 1 | 1 | 1.48569 | 43 | 8 | 3 | 1 | 1.47481 | 8 | 10 | 2 | 2 |
| 1.47081 | 45 | 8 | 1 | 3 | 1.44277 | 10 | 5 | 3 | 2 | 1.40344 | 17 | 14 | 2 | 0 |
| 1.39711 | 15 | 14 | 0 | 2 | 1.37809 | 17 | 0 | 4 | 0 | 1.36816 | 8 | 2 | 4 | 0 |
| 1.35527 | 81 | 12 | 2 | 2M | 1.35527 | 81 | 0 | 0 | 4M | 1.33851 | 8 | 16 | 1 | 1 |
| 1.28805 | 5 | 0 | 3 | 3 | 1.24616 | 42 | 14 | 2 | 2 | 1.22831 | 17 | 0 | 4 | 2 |
| 1.22015 | 58 | 6 | 3 | 3+ | 1.21570 | 29 | 0 | 2 | 4 | 1.20505 | 11 | 18 | 1 | 1 |
| 1.18987 | 8 | 14 | 3 | 1 | 1.18209 | 19 | 14 | 1 | 3M | 1.18209 | 19 | 9 | 4 | 1 |
| 1.17400 | 20 | 8 | 3 | 3 | 1.16891 | 12 | 6 | 4 | 2 | 1.15803 | 9 | 6 | 2 | 4 |
| 1.11605 | 7 | 12 | 4 | 0 | 1.10345 | 11 | 12 | 0 | 4 | 1.09471 | 42 | 20 | 1 | 1 |
| 1.05461 | 6 | 20 | 2 | 0 | 1.05237 | 28 | 14 | 4 | 0M | 1.05237 | 28 | 20 | 0 | 2 |
| 1.04198 | 16 | 14 | 0 | 4 | 1.03926 | 26 | 6 | 5 | 1 | 1.03192 | 12 | 12 | 4 | 2 |
| 1.02455 | 16 | 18 | 3 | 1M | 1.02455 | 16 | 12 | 2 | 4M | 1.02408 | 36 | 6 | 1 | 5 |
| 1.02002 | 7 | 18 | 1 | 3 | 1.01048 | 20 | 14 | 3 | 3M | 1.01048 | 20 | 8 | 5 | 1 |
| 0.99640 | 12 | 8 | 1 | 5 | 0.98277 | 7 | 20 | 2 | 2 | 0.98111 | 23 | 14 | 4 | 2 |
| 0.97465 | 13 | 14 | 2 | 4 | 0.96604 | 18 | 0 | 4 | 4 | 0.96260 | 5 | 2 | 4 | 4 |
| 0.95445 | 28 | 20 | 3 | 1 | 0.95047 | 32 | 20 | 1 | 3 | 0.91349 | 16 | 6 | 5 | 3 |
| 0.90655 | 27 | 6 | 3 | 5 | 0.90335 | 12 | 18 | 3 | 3M | 0.90335 | 12 | 0 | 0 | 6M |
| 0.89368 | 15 | 8 | 5 | 3 | 0.89306 | 6 | 6 | 6 | 0 | 0.89069 | 7 | 14 | 1 | 5 |
| 0.88717 | 12 | 8 | 3 | 5 | 0.87865 | 6 | 6 | 0 | 6 | 0.87006 | 11 | 0 | 6 | 2 |
| 0.86754 | 10 | 2 | 6 | 2 | 0.86135 | 16 | 12 | 4 | 4 | 0.85817 | 18 | 0 | 2 | 6 |
| 0.85623 | 16 | 26 | 1 | 1 | 0.85429 | 33 | 20 | 3 | 3 | 0.84817 | 7 | 6 | 6 | 2 |
| 0.83661 | 32 | 26 | 2 | 0+ | 0.83528 | 14 | 26 | 0 | 2 | 0.83215 | 13 | 20 | 2 | 4 |
| 0.83114 | 33 | 14 | 4 | 4 | 0.82731 | 5 | 12 | 6 | 0 | 0.82242 | 5 | 18 | 5 | 1 |

**Table 7.** X-Ray reference pattern for $Sr_2DyGaCu_2O_y$ (space group Ima2, $Z = 4$, $a = 22.8015(2)$ Å, $b = 5.49286(5)$ Å, and $c = 5.40138(5)$ Å)

| *d* | *I* | *h* | *k* | *l* | *d* | *I* | *h* | *k* | *l* | *d* | *I* | *h* | *k* | *l* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11.40081 | 92 | 2 | 0 | 0 | 4.45195 | 17 | 3 | 1 | 0 | 3.85129 | 75 | 0 | 1 | 1 |
| 3.80025 | 6 | 6 | 0 | 0 | 3.64872 | 57 | 2 | 1 | 1 | 3.50868 | 18 | 5 | 1 | 0 |
| 3.19122 | 10 | 4 | 1 | 1 | 2.85019 | 10 | 8 | 0 | 0 | 2.80176 | 15 | 7 | 1 | 0 |
| 2.74643 | 209 | 0 | 2 | 0 | 2.70407 | 999* | 6 | 1 | 1M | 2.70407 | 999* | 0 | 0 | 2M |
| 2.67005 | 6 | 2 | 2 | 0 | 2.62796 | 17 | 2 | 0 | 2 | 2.43414 | 10 | 1 | 2 | 1 |
| 2.33024 | 5 | 3 | 2 | 1 | 2.29103 | 203 | 8 | 1 | 1 | 2.28015 | 16 | 10 | 0 | 0 |
| 2.22597 | 43 | 6 | 2 | 0 | 2.20141 | 34 | 6 | 0 | 2 | 2.14013 | 5 | 5 | 1 | 2 |
| 1.97768 | 17 | 8 | 2 | 0 | 1.96040 | 24 | 8 | 0 | 2 | 1.92564 | 237 | 0 | 2 | 2 |
| 1.89969 | 92 | 12 | 0 | 0M | 1.89969 | 92 | 2 | 2 | 2M | 1.78003 | 5 | 3 | 3 | 0 |
| 1.76050 | 6 | 9 | 2 | 1 | 1.74224 | 5 | 10 | 0 | 2 | 1.73404 | 13 | 0 | 3 | 1 |
| 1.71771 | 10 | 6 | 2 | 2 | 1.71089 | 7 | 0 | 1 | 3 | 1.69912 | 10 | 5 | 3 | 0 |
| 1.69195 | 6 | 2 | 1 | 3 | 1.63868 | 5 | 4 | 1 | 3 | 1.62868 | 26 | 14 | 0 | 0 |
| 1.59609 | 7 | 7 | 3 | 0 | 1.58196 | 5 | 11 | 2 | 1 | 1.57757 | 161 | 6 | 3 | 1 |
| 1.56260 | 46 | 12 | 2 | 0 | 1.56008 | 147 | 6 | 1 | 3 | 1.55403 | 51 | 12 | 0 | 2 |
| 1.50247 | 6 | 1 | 2 | 3 | 1.50006 | 34 | 14 | 1 | 1 | 1.48141 | 53 | 8 | 3 | 1 |
| 1.47119 | 11 | 10 | 2 | 2 | 1.46690 | 47 | 8 | 1 | 3 | 1.43817 | 10 | 5 | 3 | 2 |
| 1.40088 | 18 | 14 | 2 | 0 | 1.39469 | 17 | 14 | 0 | 2 | 1.37339 | 34 | 7 | 3 | 2M |
| 1.37339 | 24 | 0 | 4 | 0M | 1.36336 | 10 | 2 | 4 | 0 | 1.35252 | 49 | 12 | 2 | 2 |
| 1.35034 | 27 | 0 | 0 | 4 | 1.34097 | 5 | 2 | 0 | 4 | 1.33653 | 8 | 16 | 1 | 1 |
| 1.24354 | 41 | 14 | 2 | 2 | 1.22407 | 17 | 0 | 4 | 2 | 1.21707 | 5 | 2 | 4 | 2 |
| 1.21624 | 41 | 6 | 3 | 3 | 1.21179 | 18 | 0 | 2 | 4 | 1.20333 | 12 | 18 | 1 | 1 |
| 1.18715 | 9 | 14 | 3 | 1 | 1.17964 | 12 | 14 | 1 | 3 | 1.17051 | 21 | 8 | 3 | 3 |
| 1.16512 | 16 | 6 | 4 | 2 | 1.15452 | 9 | 6 | 2 | 4 | 1.10070 | 10 | 12 | 0 | 4 |
| 1.09318 | 29 | 20 | 1 | 1 | 1.05296 | 5 | 20 | 2 | 0 | 1.05032 | 5 | 20 | 0 | 2 |
| 1.04985 | 15 | 14 | 4 | 0 | 1.03952 | 20 | 14 | 0 | 4 | 1.03577 | 30 | 6 | 5 | 1 |
| 1.02903 | 13 | 12 | 4 | 2 | 1.02288 | 6 | 18 | 3 | 1 | 1.02123 | 50 | 12 | 2 | 4M |
| 1.02123 | 50 | 6 | 1 | 5M | 1.01807 | 9 | 18 | 1 | 3 | 1.00822 | 6 | 14 | 3 | 3 |
| 1.00709 | 14 | 8 | 5 | 1 | 0.99349 | 16 | 8 | 1 | 5 | 0.98103 | 6 | 20 | 2 | 2 |
| 0.97852 | 20 | 14 | 4 | 2 | 0.97221 | 24 | 14 | 2 | 4 | 0.96282 | 18 | 0 | 4 | 4 |
| 0.95262 | 32 | 20 | 3 | 1 | 0.94873 | 23 | 20 | 1 | 3 | 0.91048 | 31 | 6 | 5 | 3 |
| 0.90372 | 26 | 6 | 3 | 5 | 0.90023 | 9 | 0 | 0 | 6 | 0.89081 | 17 | 8 | 5 | 3 |
| 0.88839 | 6 | 14 | 1 | 5 | 0.88447 | 16 | 8 | 3 | 5 | 0.87698 | 6 | 26 | 0 | 0 |
| 0.87599 | 5 | 6 | 0 | 6 | 0.86702 | 10 | 0 | 6 | 2 | 0.86452 | 17 | 2 | 6 | 2 |
| 0.85886 | 20 | 12 | 4 | 4 | 0.85535 | 37 | 0 | 2 | 6M | 0.85535 | 37 | 26 | 1 | 1M |
| 0.85253 | 38 | 20 | 3 | 3+ | 0.83542 | 15 | 26 | 2 | 0 | 0.83427 | 33 | 20 | 4 | 2+ |
| 0.83041 | 28 | 24 | 1 | 3M | 0.83041 | 28 | 20 | 2 | 4M | 0.82883 | 40 | 14 | 4 | 4 |
| 0.82474 | 7 | 12 | 6 | 0 | 0.82032 | 6 | 18 | 5 | 1 | | | | | |

**Table 8.** X-Ray reference pattern for $Sr_2HoGaCu_2O_y$ (space group Ima2, $Z = 4$, $a = 22.7975(2)$ Å, $b = 5.48433(5)$ Å, and $c = 5.39562(5)$ Å)

| *d* | *I* | *h* | *k* | *l* | *d* | *I* | *h* | *k* | *l* | *d* | *I* | *h* | *k* | *l* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11.39882 | 70 | 2 | 0 | 0 | 4.44713 | 25 | 3 | 1 | 0 | 3.84626 | 66 | 0 | 1 | 1 |
| 3.79959 | 8 | 6 | 0 | 0 | 3.64438 | 57 | 2 | 1 | 1 | 3.50609 | 31 | 5 | 1 | 0 |
| 3.18818 | 20 | 4 | 1 | 1 | 2.84969 | 8 | 8 | 0 | 0 | 2.80026 | 22 | 7 | 1 | 0 |
| 2.74217 | 251 | 0 | 2 | 0 | 2.70306 | 999* | 6 | 1 | 1 | 2.69781 | 297 | 0 | 0 | 2 |
| 2.66611 | 6 | 2 | 2 | 0 | 2.62528 | 17 | 2 | 0 | 2 | 2.43064 | 23 | 1 | 2 | 1 |
| 2.32713 | 9 | 3 | 2 | 1 | 2.30657 | 5 | 3 | 1 | 2 | 2.28972 | 298 | 8 | 1 | 1 |
| 2.27975 | 34 | 10 | 0 | 0 | 2.22357 | 68 | 6 | 2 | 0 | 2.19972 | 53 | 6 | 0 | 2 |
| 2.13811 | 11 | 5 | 1 | 2 | 1.97592 | 26 | 8 | 2 | 0 | 1.95913 | 36 | 8 | 0 | 2 |
| 1.95509 | 6 | 7 | 2 | 1 | 1.92313 | 377 | 0 | 2 | 2 | 1.89979 | 110 | 12 | 0 | 0 |
| 1.89633 | 49 | 2 | 2 | 2 | 1.82219 | 9 | 4 | 2 | 2 | 1.77740 | 6 | 3 | 3 | 0 |
| 1.75903 | 13 | 9 | 2 | 1 | 1.74129 | 8 | 10 | 0 | 2 | 1.73143 | 11 | 0 | 3 | 1 |
| 1.71586 | 13 | 6 | 2 | 2 | 1.70899 | 7 | 0 | 1 | 3 | 1.69681 | 21 | 5 | 3 | 0 |
| 1.69010 | 5 | 2 | 1 | 3 | 1.63698 | 9 | 4 | 1 | 3 | 1.62839 | 43 | 14 | 0 | 0 |
| 1.59414 | 14 | 7 | 3 | 0 | 1.58084 | 8 | 11 | 2 | 1 | 1.57556 | 147 | 6 | 3 | 1 |
| 1.56163 | 55 | 12 | 2 | 0 | 1.55859 | 182 | 6 | 1 | 3 | 1.55330 | 69 | 12 | 0 | 2 |
| 1.51006 | 5 | 1 | 3 | 2 | 1.49974 | 67 | 1 | 2 | 3M | 1.49974 | 67 | 14 | 1 | 1M |
| 1.48423 | 5 | 3 | 3 | 2 | 1.47971 | 74 | 8 | 3 | 1 | 1.46996 | 13 | 10 | 2 | 2 |
| 1.46563 | 69 | 8 | 1 | 3 | 1.43633 | 14 | 5 | 3 | 2 | 1.42484 | 6 | 16 | 0 | 0 |
| 1.40013 | 28 | 14 | 2 | 0 | 1.39412 | 23 | 14 | 0 | 2 | 1.37244 | 7 | 7 | 3 | 2 |
| 1.37108 | 26 | 0 | 4 | 0 | 1.36127 | 13 | 2 | 4 | 0 | 1.35153 | 75 | 12 | 2 | 2 |
| 1.34890 | 38 | 0 | 0 | 4 | 1.33956 | 9 | 2 | 0 | 4 | 1.33611 | 16 | 16 | 1 | 1 |
| 1.32660 | 6 | 1 | 4 | 1 | 1.28209 | 5 | 0 | 3 | 3 | 1.24273 | 44 | 14 | 2 | 2 |
| 1.22229 | 27 | 0 | 4 | 2 | 1.21532 | 6 | 2 | 4 | 2 | 1.21479 | 52 | 6 | 3 | 3 |
| 1.21039 | 28 | 0 | 2 | 4 | 1.20299 | 11 | 18 | 1 | 1 | 1.18620 | 11 | 14 | 3 | 1 |
| 1.17891 | 18 | 14 | 1 | 3 | 1.17675 | 7 | 9 | 4 | 1 | 1.16915 | 37 | 8 | 3 | 3M |
| 1.16915 | 37 | 15 | 3 | 0M | 1.16356 | 14 | 6 | 4 | 2 | 1.15328 | 12 | 6 | 2 | 4 |
| 1.13988 | 6 | 20 | 0 | 0 | 1.11178 | 9 | 12 | 4 | 0 | 1.09986 | 10 | 12 | 0 | 4 |
| 1.09438 | 8 | 16 | 1 | 3 | 1.09289 | 52 | 20 | 1 | 1 | 1.05256 | 5 | 20 | 2 | 0 |
| 1.05000 | 7 | 20 | 0 | 2 | 1.04882 | 19 | 14 | 4 | 0 | 1.03879 | 16 | 14 | 0 | 4 |
| 1.03429 | 26 | 6 | 5 | 1 | 1.02792 | 13 | 12 | 4 | 2 | 1.02223 | 5 | 18 | 3 | 1 |
| 1.02081 | 17 | 12 | 2 | 4 | 1.01996 | 40 | 6 | 1 | 5 | 1.01755 | 8 | 18 | 1 | 3 |
| 1.00734 | 5 | 14 | 3 | 3 | 1.00572 | 23 | 8 | 5 | 1 | 0.99252 | 19 | 8 | 1 | 5 |
| 0.99177 | 7 | 5 | 5 | 2 | 0.98057 | 7 | 20 | 2 | 2 | 0.97754 | 23 | 14 | 4 | 2 |
| 0.97142 | 24 | 14 | 2 | 4 | 0.96156 | 23 | 0 | 4 | 4 | 0.95816 | 5 | 2 | 4 | 4 |
| 0.95208 | 33 | 20 | 3 | 1 | 0.94829 | 31 | 20 | 1 | 3 | 0.90925 | 20 | 6 | 5 | 3 |
| 0.90269 | 33 | 6 | 3 | 5 | 0.89927 | 7 | 0 | 0 | 6 | 0.89055 | 5 | 19 | 4 | 1 |
| 0.88965 | 23 | 8 | 5 | 3 | 0.88870 | 8 | 6 | 6 | 0 | 0.88767 | 8 | 14 | 1 | 5 |
| 0.88608 | 5 | 22 | 1 | 3 | 0.88350 | 20 | 8 | 3 | 5 | 0.87683 | 8 | 26 | 0 | 0 |
| 0.87509 | 11 | 6 | 0 | 6 | 0.87064 | 6 | 20 | 0 | 4 | 0.86572 | 20 | 0 | 6 | 2 |
| 0.86323 | 16 | 2 | 6 | 2 | 0.85793 | 21 | 12 | 4 | 4 | 0.85463 | 57 | 26 | 1 | 1M |
| 0.85463 | 57 | 0 | 2 | 6M | 0.85190 | 57 | 2 | 2 | 6M | 0.85190 | 57 | 20 | 3 | 3M |
| 0.84908 | 6 | 9 | 6 | 1 | 0.84470 | 7 | 15 | 5 | 2 | 0.84408 | 6 | 6 | 6 | 2 |
| 0.84072 | 10 | 21 | 4 | 1 | 0.83995 | 7 | 12 | 5 | 3 | 0.83656 | 11 | 5 | 5 | 4M |
| 0.83656 | 11 | 10 | 0 | 6M | 0.83517 | 15 | 26 | 2 | 0 | 0.83389 | 14 | 26 | 0 | 2 |
| 0.83363 | 9 | 20 | 4 | 2 | 0.83026 | 5 | 24 | 1 | 3 | 0.82982 | 14 | 20 | 2 | 4 |
| 0.82918 | 6 | 23 | 3 | 2 | 0.82799 | 43 | 14 | 4 | 4 | 0.82646 | 7 | 11 | 6 | 1 |
| 0.82351 | 11 | 12 | 6 | 0M | 0.82351 | 11 | 7 | 5 | 4M | 0.82176 | 5 | 22 | 0 | 4 |

**Table 9.** X-Ray reference pattern for $Sr_2ErGaCu_2O_y$ (space group Ima2, $Z = 4$, $a = 22.7964(3)$ Å, $b = 5.47497(6)$ Å, and $c = 5.38837(6)$ Å)

| *d* | *I* | *h* | *k* | *l* | *d* | *I* | *h* | *k* | *l* | *d* | *I* | *h* | *k* | *l* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11.39822 | 66 | 2 | 0 | 0 | 5.69911 | 15 | 4 | 0 | 0 | 5.32359 | 10 | 1 | 1 | 0 |
| 4.44207 | 29 | 3 | 1 | 0 | 3.84040 | 97 | 0 | 1 | 1 | 3.79940 | 9 | 6 | 0 | 0 |
| 3.63938 | 89 | 2 | 1 | 1 | 3.50354 | 28 | 5 | 1 | 0 | 3.18480 | 17 | 4 | 1 | 1 |
| 2.84955 | 38 | 8 | 0 | 0 | 2.79891 | 23 | 7 | 1 | 0 | 2.73749 | 268 | 0 | 2 | 0 |
| 2.70096 | 999* | 6 | 1 | 1 | 2.69418 | 297 | 0 | 0 | 2 | 2.66180 | 13 | 2 | 2 | 0 |
| 2.62194 | 18 | 2 | 0 | 2 | 2.42672 | 14 | 1 | 2 | 1 | 2.32368 | 7 | 3 | 2 | 1 |
| 2.30360 | 8 | 3 | 1 | 2 | 2.28841 | 315 | 8 | 1 | 1 | 2.27964 | 13 | 10 | 0 | 0 |
| 2.22103 | 66 | 6 | 2 | 0 | 2.19772 | 56 | 6 | 0 | 2 | 2.13573 | 8 | 5 | 1 | 2 |
| 1.97412 | 36 | 8 | 2 | 0 | 1.95770 | 42 | 8 | 0 | 2 | 1.95301 | 6 | 7 | 2 | 1 |
| 1.92020 | 345 | 0 | 2 | 2 | 1.89970 | 92 | 12 | 0 | 0 | 1.89352 | 50 | 2 | 2 | 2 |
| 1.81969 | 6 | 4 | 2 | 2 | 1.77453 | 7 | 3 | 3 | 0 | 1.75750 | 11 | 9 | 2 | 1 |
| 1.74026 | 6 | 10 | 0 | 2 | 1.72854 | 16 | 0 | 3 | 1 | 1.71377 | 17 | 6 | 2 | 2 |
| 1.70663 | 13 | 0 | 1 | 3 | 1.69430 | 15 | 5 | 3 | 0 | 1.68782 | 10 | 2 | 1 | 3 |
| 1.63490 | 7 | 4 | 1 | 3 | 1.62832 | 40 | 14 | 0 | 0 | 1.59222 | 16 | 8 | 2 | 2M |
| 1.59222 | 16 | 7 | 3 | 0M | 1.57971 | 8 | 11 | 2 | 1 | 1.57336 | 190 | 6 | 3 | 1 |
| 1.56071 | 51 | 12 | 2 | 0 | 1.55679 | 194 | 6 | 1 | 3 | 1.55256 | 57 | 12 | 0 | 2 |
| 1.49904 | 60 | 14 | 1 | 1M | 1.49904 | 60 | 1 | 2 | 3M | 1.48196 | 5 | 3 | 3 | 2 |
| 1.47789 | 70 | 8 | 3 | 1 | 1.46862 | 6 | 10 | 2 | 2 | 1.46413 | 76 | 8 | 1 | 3 |
| 1.43426 | 11 | 5 | 3 | 2 | 1.42478 | 6 | 16 | 0 | 0 | 1.39946 | 34 | 14 | 2 | 0 |
| 1.39357 | 32 | 14 | 0 | 2 | 1.37063 | 6 | 7 | 3 | 2 | 1.36874 | 32 | 0 | 4 | 0 |
| 1.35898 | 12 | 2 | 4 | 0 | 1.35048 | 68 | 12 | 2 | 2 | 1.34709 | 34 | 0 | 0 | 4 |
| 1.33778 | 10 | 2 | 0 | 4 | 1.33581 | 10 | 16 | 1 | 1 | 1.28013 | 6 | 0 | 3 | 3 |
| 1.24191 | 70 | 14 | 2 | 2 | 1.22029 | 24 | 0 | 4 | 2 | 1.21316 | 75 | 2 | 4 | 2M |
| 1.21316 | 75 | 6 | 3 | 3M | 1.20868 | 30 | 0 | 2 | 4 | 1.20275 | 12 | 18 | 1 | 1 |
| 1.18524 | 13 | 14 | 3 | 1 | 1.17811 | 18 | 14 | 1 | 3 | 1.17519 | 7 | 9 | 4 | 1 |
| 1.16771 | 34 | 8 | 3 | 3 | 1.16184 | 20 | 6 | 4 | 2 | 1.15180 | 12 | 6 | 2 | 4 |
| 1.11272 | 5 | 8 | 2 | 4 | 1.11052 | 8 | 12 | 4 | 0 | 1.09886 | 18 | 12 | 0 | 4 |
| 1.09271 | 44 | 20 | 1 | 1 | 1.07306 | 7 | 0 | 5 | 1 | 1.05225 | 8 | 20 | 2 | 0 |
| 1.04974 | 8 | 20 | 0 | 2 | 1.04775 | 21 | 14 | 4 | 0 | 1.03794 | 24 | 14 | 0 | 4 |
| 1.03267 | 26 | 6 | 5 | 1 | 1.02672 | 19 | 12 | 4 | 2 | 1.02160 | 7 | 18 | 3 | 1 |
| 1.01977 | 19 | 12 | 2 | 4 | 1.01867 | 42 | 6 | 1 | 5 | 1.01702 | 8 | 18 | 1 | 3 |
| 1.00637 | 7 | 14 | 3 | 3 | 1.00422 | 25 | 8 | 5 | 1 | 1.00042 | 8 | 22 | 1 | 1 |
| 0.99133 | 20 | 8 | 1 | 5 | 0.98015 | 12 | 20 | 2 | 2 | 0.97651 | 30 | 14 | 4 | 2 |
| 0.97052 | 25 | 14 | 2 | 4 | 0.96010 | 22 | 0 | 4 | 4 | 0.95671 | 5 | 2 | 4 | 4 |
| 0.95156 | 41 | 20 | 3 | 1 | 0.94786 | 41 | 20 | 1 | 3 | 0.93495 | 5 | 0 | 5 | 3 |
| 0.92796 | 6 | 0 | 3 | 5 | 0.91250 | 7 | 0 | 6 | 0 | 0.90787 | 31 | 6 | 5 | 3 |
| 0.90146 | 32 | 6 | 3 | 5 | 0.90032 | 5 | 18 | 3 | 3 | 0.89806 | 8 | 0 | 0 | 6 |
| 0.89600 | 5 | 14 | 5 | 1 | 0.88874 | 7 | 22 | 3 | 1 | 0.88835 | 24 | 8 | 5 | 3 |
| 0.88727 | 7 | 6 | 6 | 0 | 0.88681 | 10 | 14 | 1 | 5 | 0.88572 | 9 | 22 | 1 | 3 |
| 0.88235 | 21 | 8 | 3 | 5 | 0.87679 | 7 | 26 | 0 | 0 | 0.87398 | 9 | 6 | 0 | 6 |
| 0.87013 | 6 | 20 | 0 | 4 | 0.86427 | 27 | 0 | 6 | 2 | 0.86180 | 18 | 2 | 6 | 2 |
| 0.85688 | 26 | 12 | 4 | 4 | 0.85479 | 18 | 26 | 1 | 1 | 0.85332 | 38 | 0 | 2 | 6 |
| 0.85123 | 65 | 20 | 3 | 3M | 0.85123 | 65 | 2 | 2 | 6M | 0.84779 | 6 | 9 | 6 | 1 |
| 0.84372 | 5 | 15 | 5 | 2 | 0.84274 | 11 | 6 | 6 | 2 | 0.84012 | 7 | 21 | 4 | 1 |
| 0.83886 | 8 | 12 | 5 | 3 | 0.83500 | 19 | 26 | 2 | 0 | 0.83376 | 23 | 12 | 3 | 5M |
| 0.83376 | 23 | 26 | 0 | 2M | 0.83282 | 21 | 20 | 4 | 2M | 0.83282 | 21 | 6 | 2 | 6M |
| 0.82925 | 22 | 20 | 2 | 4 | 0.82704 | 59 | 14 | 4 | 4 | 0.82527 | 6 | 11 | 6 | 1 |
| 0.82253 | 13 | 12 | 6 | 0 | | | | | | | | | | |

**Table 10.** X-Ray reference pattern for $Sr_2TmGaCu_2O_y$ (space group Ima2, $Z = 4$, $a = 22.8024(3)$ Å, $b = 5.46762(7)$ Å, and $c = 5.38158(7)$ Å)

| *d* | *I* | *h* | *k* | *l* | *d* | *I* | *h* | *k* | *l* | *d* | *I* | *h* | *k* | *l* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11.4012 | 282 | 2 | 0 | 0 | 5.70060 | 18 | 4 | 0 | 0 | 4.43854 | 22 | 3 | 1 | 0 |
| 3.83541 | 114 | 0 | 1 | 1 | 3.80040 | 17 | 6 | 0 | 0 | 3.63523 | 98 | 2 | 1 | 1 |
| 3.50216 | 31 | 5 | 1 | 0 | 3.18221 | 12 | 4 | 1 | 1 | 2.85030 | 72 | 8 | 0 | 0 |
| 2.79847 | 40 | 7 | 1 | 0 | 2.73381 | 417 | 0 | 2 | 0 | 2.69958 | 999* | 6 | 1 | 1 |
| 2.69079 | 391 | 0 | 0 | 2 | 2.65846 | 18 | 2 | 2 | 0 | 2.61884 | 31 | 2 | 0 | 2 |
| 2.46501 | 5 | 4 | 2 | 0 | 2.43334 | 5 | 4 | 0 | 2 | 2.42355 | 13 | 1 | 2 | 1 |
| 2.32094 | 6 | 3 | 2 | 1 | 2.28774 | 337 | 8 | 1 | 1 | 2.28024 | 13 | 10 | 0 | 0 |
| 2.21927 | 79 | 6 | 2 | 0 | 2.19607 | 51 | 6 | 0 | 2 | 2.13372 | 12 | 5 | 1 | 2 |
| 1.97299 | 57 | 8 | 2 | 0 | 1.95745 | 50 | 10 | 1 | 1M | 1.95745 | 50 | 8 | 0 | 2M |
| 1.95154 | 5 | 7 | 2 | 1 | 1.93963 | 5 | 7 | 1 | 2 | 1.91771 | 377 | 0 | 2 | 2 |
| 1.90020 | 118 | 12 | 0 | 0 | 1.89114 | 57 | 2 | 2 | 2 | 1.81675 | 10 | 1 | 3 | 0 |
| 1.75651 | 12 | 9 | 2 | 1 | 1.75108 | 8 | 10 | 2 | 0 | 1.73961 | 7 | 10 | 0 | 2 |
| 1.72624 | 18 | 0 | 3 | 1 | 1.71208 | 24 | 6 | 2 | 2 | 1.70374 | 17 | 0 | 1 | 3M |
| 1.70374 | 17 | 12 | 1 | 1M | 1.69240 | 19 | 5 | 3 | 0 | 1.68574 | 18 | 2 | 1 | 3 |
| 1.65215 | 6 | 4 | 3 | 1 | 1.63304 | 12 | 4 | 1 | 3 | 1.62874 | 56 | 14 | 0 | 0 |
| 1.59077 | 23 | 8 | 2 | 2M | 1.59077 | 23 | 7 | 3 | 0M | 1.57908 | 9 | 11 | 2 | 1 |
| 1.57170 | 189 | 6 | 3 | 1 | 1.56031 | 65 | 12 | 2 | 0 | 1.55522 | 239 | 6 | 1 | 3 |
| 1.55218 | 72 | 12 | 0 | 2 | 1.49917 | 76 | 14 | 1 | 1 | 1.49657 | 14 | 1 | 2 | 3 |
| 1.48010 | 8 | 3 | 3 | 2 | 1.47655 | 85 | 8 | 3 | 1 | 1.46767 | 10 | 10 | 2 | 2 |
| 1.46286 | 73 | 8 | 1 | 3 | 1.43260 | 13 | 5 | 3 | 2 | 1.42515 | 9 | 16 | 0 | 0 |
| 1.39924 | 23 | 14 | 2 | 0 | 1.39337 | 23 | 14 | 0 | 2 | 1.36921 | 5 | 7 | 3 | 2 |
| 1.36691 | 30 | 0 | 4 | 0 | 1.35719 | 14 | 2 | 4 | 0 | 1.34979 | 70 | 12 | 2 | 2 |
| 1.34540 | 32 | 0 | 0 | 4 | 1.33600 | 18 | 2 | 0 | 4M | 1.33600 | 18 | 16 | 1 | 1M |
| 1.32261 | 5 | 1 | 4 | 1 | 1.28624 | 7 | 6 | 4 | 0 | 1.27818 | 13 | 0 | 3 | 3M |
| 1.27818 | 13 | 12 | 3 | 1M | 1.24142 | 58 | 14 | 2 | 2 | 1.21868 | 32 | 0 | 4 | 2 |
| 1.21174 | 73 | 2 | 4 | 2M | 1.21174 | 73 | 6 | 3 | 3M | 1.20713 | 39 | 0 | 2 | 4 |
| 1.20289 | 14 | 18 | 1 | 1 | 1.20042 | 7 | 2 | 2 | 4 | 1.18466 | 16 | 14 | 3 | 1 |
| 1.17756 | 23 | 14 | 1 | 3 | 1.16650 | 35 | 8 | 3 | 3 | 1.16047 | 17 | 6 | 4 | 2 |
| 1.15049 | 13 | 6 | 2 | 4 | 1.14387 | 5 | 16 | 2 | 2 | 1.11156 | 5 | 8 | 2 | 4 |
| 1.10963 | 9 | 12 | 4 | 0 | 1.09803 | 9 | 12 | 0 | 4 | 1.09289 | 64 | 20 | 1 | 1+ |
| 1.05228 | 9 | 20 | 2 | 0 | 1.04977 | 11 | 20 | 0 | 2 | 1.04704 | 28 | 14 | 4 | 0 |
| 1.03728 | 22 | 14 | 0 | 4 | 1.03141 | 31 | 6 | 5 | 1 | 1.02583 | 19 | 12 | 4 | 2 |
| 1.02130 | 6 | 18 | 3 | 1 | 1.01892 | 24 | 12 | 2 | 4 | 1.01740 | 60 | 6 | 1 | 5M |
| 1.01740 | 60 | 18 | 1 | 3M | 1.00566 | 9 | 14 | 3 | 3 | 1.00307 | 30 | 8 | 5 | 1 |
| 1.00058 | 11 | 22 | 1 | 1 | 0.99027 | 19 | 8 | 1 | 5 | 0.98896 | 7 | 5 | 5 | 2 |
| 0.98001 | 10 | 20 | 2 | 2 | 0.97577 | 33 | 14 | 4 | 2 | 0.96981 | 25 | 14 | 2 | 4 |
| 0.95885 | 47 | 0 | 4 | 4 | 0.95548 | 11 | 2 | 4 | 4 | 0.95135 | 36 | 20 | 3 | 1 |
| 0.94766 | 43 | 20 | 1 | 3 | 0.93361 | 11 | 0 | 5 | 3M | 0.93361 | 11 | 12 | 5 | 1M |
| 0.92972 | 6 | 6 | 4 | 4 | 0.90837 | 5 | 2 | 6 | 0 | 0.90675 | 23 | 6 | 5 | 3 |
| 0.90033 | 43 | 6 | 3 | 5+ | 0.89693 | 8 | 0 | 0 | 6 | 0.89523 | 6 | 14 | 5 | 1 |
| 0.88860 | 9 | 22 | 3 | 1 | 0.88732 | 30 | 8 | 5 | 3 | 0.88612 | 24 | 6 | 6 | 0M |
| 0.88612 | 24 | 14 | 1 | 5M | 0.88559 | 11 | 22 | 1 | 3 | 0.88135 | 25 | 8 | 3 | 5 |
| 0.87702 | 5 | 26 | 0 | 0 | 0.87295 | 8 | 6 | 0 | 6 | 0.86981 | 8 | 20 | 0 | 4 |
| 0.86312 | 20 | 0 | 6 | 2 | 0.86065 | 16 | 2 | 6 | 2 | 0.85604 | 28 | 12 | 4 | 4 |
| 0.85495 | 30 | 26 | 1 | 1 | 0.85223 | 36 | 0 | 2 | 6 | 0.85091 | 58 | 20 | 3 | 3 |
| 0.84986 | 14 | 2 | 2 | 6 | 0.84505 | 7 | 1 | 4 | 5 | 0.84168 | 15 | 6 | 6 | 2 |
| 0.83980 | 5 | 21 | 4 | 1 | 0.83801 | 12 | 12 | 5 | 3 | 0.83510 | 19 | 26 | 2 | 0 |
| 0.83384 | 16 | 26 | 0 | 2 | 0.83269 | 27 | 12 | 3 | 5M | 0.83269 | 27 | 20 | 4 | 2M |
| 0.83158 | 9 | 6 | 2 | 6 | 0.82887 | 27 | 20 | 2 | 4 | 0.82630 | 68 | 14 | 4 | 4 |
| 0.82438 | 6 | 11 | 6 | 1 | 0.82167 | 11 | 12 | 6 | 0 | | | | | |

**Table 11.** X-Ray reference pattern for $Sr_2YGaCu_2O_y$ (space group Ima2, $Z = 4$, $a = 22.8113(2)$ Å, $b = 5.48069(5)$ Å, and $c = 5.39397(5)$ Å)

| *d* | *I* | *h* | *k* | *l* | *d* | *I* | *h* | *k* | *l* | *d* | *I* | *h* | *k* | *l* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11.4057 | 131 | 2 | 0 | 0 | 5.32904 | 5 | 1 | 1 | 0 | 4.44611 | 21 | 3 | 1 | 0 |
| 3.84441 | 25 | 0 | 1 | 1 | 3.64303 | 18 | 2 | 1 | 1 | 3.50639 | 26 | 5 | 1 | 0 |
| 3.18773 | 44 | 4 | 1 | 1 | 2.85142 | 11 | 8 | 0 | 0 | 2.80103 | 26 | 7 | 1 | 0 |
| 2.74035 | 262 | 0 | 2 | 0 | 2.70325 | 999* | 6 | 1 | 1 | 2.69699 | 308 | 0 | 0 | 2 |
| 2.62461 | 16 | 2 | 0 | 2 | 2.46998 | 8 | 4 | 2 | 0 | 2.42924 | 18 | 1 | 2 | 1 |
| 2.32602 | 7 | 3 | 2 | 1 | 2.30591 | 5 | 3 | 1 | 2 | 2.29022 | 224 | 8 | 1 | 1 |
| 2.28113 | 53 | 10 | 0 | 0 | 2.22306 | 46 | 6 | 2 | 0 | 2.19972 | 34 | 6 | 0 | 2 |
| 2.13777 | 10 | 5 | 1 | 2 | 1.97582 | 22 | 8 | 2 | 0 | 1.95938 | 26 | 8 | 0 | 2 |
| 1.95478 | 6 | 7 | 2 | 1 | 1.92220 | 339 | 0 | 2 | 2 | 1.90094 | 71 | 12 | 0 | 0 |
| 1.89547 | 30 | 2 | 2 | 2 | 1.82152 | 11 | 4 | 2 | 2 | 1.77635 | 8 | 3 | 3 | 0 |
| 1.75900 | 14 | 9 | 2 | 1 | 1.75320 | 8 | 10 | 2 | 0 | 1.74168 | 14 | 10 | 0 | 2 |
| 1.73035 | 8 | 0 | 3 | 1 | 1.71542 | 8 | 6 | 2 | 2 | 1.70841 | 5 | 0 | 1 | 3 |
| 1.69598 | 16 | 5 | 3 | 0 | 1.63655 | 9 | 4 | 1 | 3 | 1.62938 | 28 | 14 | 0 | 0 |
| 1.59356 | 11 | 7 | 3 | 0 | 1.58100 | 7 | 11 | 2 | 1 | 1.57490 | 153 | 6 | 3 | 1 |
| 1.56193 | 56 | 12 | 2 | 0 | 1.55831 | 191 | 6 | 1 | 3 | 1.55377 | 67 | 12 | 0 | 2 |
| 1.50017 | 57 | 14 | 1 | 1M | 1.50017 | 57 | 1 | 2 | 3M | 1.48348 | 6 | 3 | 3 | 2 |
| 1.47928 | 55 | 8 | 3 | 1 | 1.46992 | 26 | 10 | 2 | 2 | 1.46550 | 46 | 8 | 1 | 3 |
| 1.43570 | 15 | 5 | 3 | 2 | 1.40051 | 22 | 14 | 2 | 0 | 1.39462 | 18 | 14 | 0 | 2 |
| 1.37197 | 8 | 7 | 3 | 2 | 1.37017 | 29 | 0 | 4 | 0 | 1.36039 | 11 | 2 | 4 | 0 |
| 1.35162 | 64 | 12 | 2 | 2 | 1.34849 | 38 | 0 | 0 | 4 | 1.33917 | 5 | 2 | 0 | 4 |
| 1.33675 | 22 | 16 | 1 | 1 | 1.32575 | 8 | 1 | 4 | 1 | 1.24292 | 64 | 14 | 2 | 2 |
| 1.22157 | 26 | 0 | 4 | 2 | 1.21434 | 56 | 6 | 3 | 3 | 1.20993 | 33 | 0 | 2 | 4 |
| 1.20359 | 13 | 18 | 1 | 1 | 1.18623 | 11 | 14 | 3 | 1 | 1.17909 | 16 | 14 | 1 | 3 |
| 1.17631 | 6 | 9 | 4 | 1 | 1.16886 | 27 | 8 | 3 | 3 | 1.16301 | 11 | 6 | 4 | 2 |
| 1.15296 | 10 | 6 | 2 | 4 | 1.11153 | 7 | 12 | 4 | 0 | 1.09986 | 13 | 12 | 0 | 4 |
| 1.09462 | 9 | 16 | 1 | 3 | 1.09346 | 42 | 20 | 1 | 1 | 1.05300 | 6 | 20 | 2 | 0 |
| 1.05049 | 8 | 20 | 0 | 2 | 1.04867 | 26 | 14 | 4 | 0 | 1.03886 | 17 | 14 | 0 | 4 |
| 1.03372 | 25 | 6 | 5 | 1 | 1.02767 | 17 | 12 | 4 | 2 | 1.02072 | 24 | 12 | 2 | 4 |
| 1.01970 | 42 | 6 | 1 | 5 | 1.01783 | 7 | 18 | 1 | 3 | 1.00727 | 6 | 14 | 3 | 3 |
| 1.00522 | 23 | 8 | 5 | 1 | 1.00111 | 5 | 22 | 1 | 1 | 0.99232 | 17 | 8 | 1 | 5 |
| 0.99122 | 6 | 5 | 5 | 2 | 0.98089 | 9 | 20 | 2 | 2 | 0.97739 | 29 | 14 | 4 | 2 |
| 0.97140 | 24 | 14 | 2 | 4 | 0.96110 | 23 | 0 | 4 | 4 | 0.95771 | 5 | 2 | 4 | 4 |
| 0.95230 | 38 | 20 | 3 | 1 | 0.94859 | 36 | 20 | 1 | 3 | 0.90879 | 24 | 6 | 5 | 3 |
| 0.90238 | 30 | 6 | 3 | 5 | 0.89900 | 8 | 0 | 0 | 6 | 0.88925 | 21 | 8 | 5 | 3 |
| 0.88787 | 16 | 6 | 6 | 0M | 0.88787 | 16 | 14 | 1 | 5M | 0.88640 | 5 | 22 | 1 | 3 |
| 0.88324 | 17 | 8 | 3 | 5 | 0.87487 | 6 | 6 | 0 | 6 | 0.87084 | 7 | 20 | 0 | 4 |
| 0.86517 | 23 | 0 | 6 | 2 | 0.86269 | 15 | 2 | 6 | 2 | 0.85771 | 22 | 12 | 4 | 4 |
| 0.85537 | 24 | 26 | 1 | 1 | 0.85420 | 45 | 0 | 2 | 6 | 0.85196 | 60 | 20 | 3 | 3M |
| 0.85196 | 60 | 2 | 2 | 6M | 0.84987 | 6 | 16 | 1 | 5 | 0.84864 | 5 | 9 | 6 | 1 |
| 0.84450 | 7 | 15 | 5 | 2 | 0.84361 | 8 | 6 | 6 | 2 | 0.84080 | 8 | 21 | 4 | 1 |
| 0.83967 | 6 | 12 | 5 | 3 | 0.83617 | 6 | 5 | 5 | 4 | 0.83558 | 20 | 26 | 2 | 0 |
| 0.83432 | 17 | 26 | 0 | 2 | 0.83357 | 15 | 20 | 4 | 2M | 0.83357 | 15 | 6 | 2 | 6M |
| 0.82994 | 17 | 20 | 2 | 4 | 0.82782 | 52 | 14 | 4 | 4 | 0.82608 | 5 | 11 | 6 | 1 |
| 0.82333 | 8 | 12 | 6 | 0 | | | | | | | | | | |

## 4. Summary

X-ray diffraction patterns of the $Sr_2RGaCu_2O_y$ phases were prepared for R = Pr, Nd, Sm, Eu, Gd, Dy, Ho, Er, Tm, and Y. These patterns are similar to those of the well known high-temperature superconductors $Ba_2YCu_3O_{6+y}$. The Lu analog could not be prepared even using higher temperature and prolonged heat-treatments, possibly due to a small size of $Lu^{3+}$, which makes it unstable in the 8-fold coordination.

X-ray powder diffraction showed the structure of $SR_2RGaCu_2O_y$ to be Ima2. $GaO_4$ tetrahedral chains were found along the diagonal base of the 213-type cell. Electron diffraction study revealed continuous streaks of diffuse intensity attributed to the presence of oxygen vacancy disorder, and/or the presence of a Cu atom within the $GaO_4$ chains. A neutron diffraction study will be conducted to investigate the possible presence of the disordered chains.

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