Dinuclear copper(II) complexes with Schiff bases derived from 2-hydroxy-5-methylisophthalaldehyde and histamine or 2-(2-aminoethyl)pyridine and their application as magnetic and fluorescent materials in thin film deposition

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Figure S1. ¹H NMR spectrum of ligand HL2 (700 MHZ, CDCl₃).
Figure S2. $^{13}$C NMR spectrum of ligand HL2 (700 MHZ, CDCl$_3$).

Figure S3. $^1$H NMR spectrum of ligand HL1 (400 MHZ, DMSO-$d_6$).
Figure 5. $^{13}$C NMR spectrum of ligand HL1 (400 MHz, DMSO-$d_6$).

Table S1. Theoretical chemical shift for $^1$H and $^{13}$C NMR for ligand HL1 and ligand HL2 [ppm] calculated with B3LYP/def2-TZVP approach in the gas phase and solvents.

| Ligand1/2 | Experimental | Theoretical | Theoretical |
|-----------|--------------|-------------|-------------|
| $^1$H [ppm] | $^{13}$C [ppm] | Gas phase | ACN | DMSO | Gas phase | ACN | DMSO |
| CH$_3$ | C1 | 2.21 (s, 3H) | 2.03, 2.55, 2.57 | 2.57, 2.14, 2.56 | 2.16, 2.56, 2.57 |
| CH$_2$ | C7 | 4.10 (m, 2H) | 3.50, 4.47 | 3.60, 4.36 | 3.61, 4.35 |
| CH$_2$ | C8 | 3.16 (m, 2H) | 2.74, 3.16 | 2.51, 3.23 | 2.51, 3.24 |
| N=CH- | C6 | 8.48 (s, 1H) | 8.74, 8.74 | 8.82, 8.86 | 8.82, 8.86 |
| OH | C12 | 10.32 (s, 1H) | 14.01 | 14.51 | 14.55 |
| Ar-H | C10 | 7.12 (s, 1H) | 7.54, 7.71 | 7.50, 7.72 | 7.50, 7.72 |
| Ar-H | C11 | 7.48 (m, 1H) | 7.58, 7.33 | 7.25, 7.32 | 7.26, 7.32 |
| Ar-H | C12 | 7.29 (m, 1H) | 7.04, 8.30 | 7.48, 7.48 | 7.48, 7.49 |
| OH | C5 | 5.75 (s, 1H) | 17.02 | 169.75 | 169.74 |
| CH$_3$ | C9 | 20.07 (m, 2H) | 163.65, 170.43 | 169.37, 173.08 | 169.46, 173.12 |
| CH$_2$ | C7 | 51.43 (m, 2H) | 70.62, 70.76 | 71.19, 75.77 | 71.20, 75.82 |
| CH$_2$ | C8 | 37.83 (m, 2H) | 36.22, 37.84 | 37.26, 38.22 | 37.24, 38.24 |
| CHN | C6 | 167.14 (s, 1H) | 163.65, 170.43 | 169.37, 173.08 | 169.46, 173.12 |
| C12 | 134.45 (s, 1H) | 133.40, 137.29 | 137.92, 138.79 | 138.00, 138.83 |
| C10 | 117.07 (s, 1H) | 114.10, 120.02 | 117.10, 117.66 | 117.19, 117.74 |
| C4 | 139.76 (s, 1H) | 125.44, 131.49 | 126.37, 130.52 | 126.38, 130.51 |
| C2 | 132.50 (s, 1H) | 131.62 | 135.13 | 135.22 |
| C3 | 160.54 (s, 1H) | 139.66, 145.78 | 142.22, 147.92 | 142.27, 147.96 |
| C5 | 134.19 (s, 1H) | 170.23 | 169.75 | 169.74 |
| CH$_3$ | C9 | 150.86, 150.66 | 150.74, 151.92 | 150.76, 151.91 |
| 1H (s, 1H) | –N=CH– | 3.42,3.20 | 2.82,3.50 | 2.82,3.50 |
| 1H (s, 1H) | –OH | 8.19,8.75 | 8.51,8.85 | 8.31,8.86 |
| 1H (s, 1H) | Ar-H | 7.13,7.24 | 7.40,7.43 | 7.41,7.44 |
| 1H (m, 1H) | Ar-H | 7.03,7.92 | 7.64,7.85 | 7.65,7.86 |
| 1H (m, 1H) | Ar-H | 7.33,8.01 | 7.98,8.14 | 7.98,8.14 |
| 1H (m, 1H) | Ar-H | 6.98,7.31 | 7.36,7.60 | 7.36,7.60 |

ArHpyalfa 8.49 (broad signal) OH 6.98,8.98 8.77,9.01 8.77,9.01

Table 1. 

| C1σ | 21.42 | Gas phase | 22.12 | 22.28 | 22.28 |
| C7σ | 49.36 | 62.89,71.67 | 69.46,73.54 | 69.45,73.53 |
| C8σ | 51.70 | 45.04,45.80 | 46.72,47.68 | 46.75,47.68 |
| C6σ | 161.03 | 165.69,171.42 | 169.65,173.59 | 169.74,173.62 |
| C12σ | 122.30 | 124.59,125.09 | 127.12,127.54 | 127.16,127.57 |
| C10σ | 124.31 | 125.18,130.02 | 129.05,129.44 | 129.12,129.51 |
| C4σ | 125.27 | 124.70,131.25 | 126.16,129.98 | 126.17,129.96 |
| C2σ | 128.45 | 131.95 | 135.11 | 135.19 |
| C3σ | 129.59 | 139.60,146.30 | 142.22,147.84 | 143.37,147.88 |
| C11σ | 137.39 | 139.86,141.59 | 143.41,143.85 | 143.47,143.90 |
| C13σ | 150.27 | 155.70,156.12 | 156.62,156.92 | 156.62,156.90 |
| C5σ | 155.15 | 170.02 | 169.70 | 169.69 |
| C9σ | 161.03 | 168.72,170.79 | 172.29 | 172.30 |

**Figure S5.** IR spectrum of ligand HL1.
Figure S6. IR spectrum of ligand HL2.

Figure S7. IR spectrum of complex ([Cu(L1):Cl]3[CuCl3]·2MeCN 1.
Thermal analysis

For all the complexes, thermal decomposition studies were performed in the presence of air. The final decomposition product was mixture of copper and copper oxide.

The thermogram of \({\left[\text{Cu}_{2}(L1)\text{Cl}_2\right]_2\left[\text{CuCl}_4\right]_2\text{MeCN}\cdot2\text{H}_2\text{O}}\) (Figure S9) presents four DTG peaks with maxima at 206, 325, 428, and 577 °C, which reveal two stages on a TG curve, with 2.3, 19.10, and 66.60% sample mass loss. The partial mass loss in the first step corresponds to water molecules detachment; the second one is connected with CuCl\(_4\) and acetonitrile detachment (cal. 17.42%). Further mass reduction in the sample results from the remaining molecules decomposition (found 70.82%; cal. 71.4%) and copper oxide formation at 820 °C.

The \([\text{Cu}_2(L2)\text{Cl}_3]_{0.5}\text{MeCN}\cdot2\) thermogram reveals two decomposition peaks on the DTG curve. The first peak can be assigned to 1.5 Cl\(_2\), and acetonitrile molecules detachment (exp. 24.69%, cal. 24.4%), (Figure S10). The second DTG peak corresponds to 58.54% mass loss, which can be related to the remaining molecules decomposition followed by CuO formation at 880 °C. The first exothermic peak appeared at 197 °C, the next two - at 444°C, 534°C, and the final one - at 640 °C.
Figure S9. TG-DTA traces of \([\text{Cu}_2(L_1)_2\text{Cl}_2\text{CuCl}_2]\cdot2\text{MeCN}\cdot2\text{H}_2\text{O}\ 1.\)

Figure 10. TG-DTA traces of \([\text{Cu}(L_2)\text{Cl}]0.5\text{MeCN}\cdot2.\)
**Figure S11.** $[\text{CuCl}_4]^2-$ unit, acetonitrile and O34 water (hydrogen atoms are missing) molecules of 1 with ellipsoids plotted at 30% probability level.

**Figure S12.** Perspective view of packing of 1 along $a$ axis with chains composed of dimers connected by chloride bridges running along this axis and with $[\text{CuCl}_4]^2-$ units and acetonitrile molecules located between adjacent $ab$ layers.
**Figure 13.** Packing of 1 along a axis with chains composed of dimers connected by chloride bridges running along this axis and with [CuCl]₂⁻ units and acetonitrile molecules located between adjacent ab layers.

**Figure S14.** Crystal structure of complex 1. Geometry formed by base-to-edge sharing polyhedra of a square pyramidal doubly chloro bridged dimer and polyhedral representation of complex ([Cu(L1)Cl]₂[CuCl₄]·2MeCN·2H₂O) 1 with SP-1 to show the resemblance.

| Complex                                                                 | Cu–O–Cu Φ [°] | Cu···Cu [Å] | Cu–O/ [Å] | δ⁺ [eV] | J [cm⁻¹] | Ref. |
|------------------------------------------------------------------------|----------------|--------------|-----------|----------|----------|------|
| [CuL₁(μ₂-OH)₂](ClO₄)₄                                                  | 197.90         | 2.939        | 1.961     | 159      | -27      | [1]  |
| [Cu₂(Me₆tacn)(μ₂-OH)₃](ClO₄)₂                                          | 95.70          | 2.939        | 1.975     | 180      | -45      | [2]  |
| [Cu₂L₁(μ₂-OH)₂](ClO₄)₂                                                | 100.1          | 2.971        | 1.939     | 180      | -45      | [3]  |
| [Cu₂(C₆H₁₁NH₂)₂(μ₂-OH)₂](ClO₄)₄                                        | 102.48         | 2.983        | 1.911     | 177.6    | -186     | [3]  |
| [Cu₂(C₆H₁₁NH₂)₂(μ₂-OH)₂](ClO₄)₄                                        | 96.6           | 2.934        | 1.914     | 148      | -128     | [4]  |
[Cu\((\text{CH}_3\text{NH}_2)\)\(_4\)(\(\mu\)-OH)\(_2\)](\text{SO}_4\) \text{H}_2\text{O}

| Complex | Cu–Cl–Cu | Cu–Cu [Å] | Cu–Cl [Å] | \(\Phi\) [°] | \(\delta\) [° Å\(^{-1}\)] | \(J\) [cm\(^{-1}\)] | Ref. |
|---------|---------|-----------|-----------|------------|-----------------|----------------|-----|
| [Cu(dpt)\(_2\)(Cl)]\(_2\) | 91.42 | 3.551 | 2.545 | 35.91 | 35.91 | +85.9 | [7] |
| [Cu(HL)Cl]\(_2\)\(\cdot\)\text{H}_2\text{O} | 84.66 | 3.337 | 2.668 | 31.73 | 31.73 | +43.2 | [8] |
| [CuCl\(_2\)(PyTn)]\(_3\) | 88.60 | 3.612 | 2.906 | 30.49 | 30.49 | +27.7 | [9] |
| [Cu(bpdio)Cl] \(_2\) | 96.68 | 3.842 | 2.844 | 33.99 | 33.99 | +4.87 | [10] |
| [Cu(Hfsaaep)Cl] \(_2\) | 95.27 | 3.445 | 2.846 | 33.6 | 33.6 | +0.30 | [11] |
| C\(_2\)H\(_2\)Cl\(_2\)Cu\(_2\)NaO\(_2\) | 92.65 | 3.708 | 2.827 | 32.77 | 32.77 | −0.47 | [12] |
| [Cu(4-Metz)(DMF)Cl] \(_2\) | 95.30 | 3.386 | 2.724 | 34.99 | 34.99 | −3.60 | [13] |
| [Cu(guaH)Cl] \(_2\) | 95.34 | 3.570 | 2.447 | 37.49 | 37.49 | −3.80 | [14] |

L\(_1\) = (1,4,7-triazacyclonon-1-ylmethyl)benzene, L\(_2\) = N,N,N′,N″,N‴-pentamethyldiethylenetriamine, L\(_3\) = 1,3-bis(1,4,7-triazacyclonon-1-ylmethyl)benzene; dpt, dipropylenetetramine; HL, 2-((E)-(2-hydroxyethylamino)methyl)-4-bromophenol; pytn, 2-(pyrazol-1-yl)-2-thiazoline; bpdio, 2,2-bis(2pyridyl)-1,3-dioxolane; Hfsaaep, 3-[N-2-(pyridylethyl)formimidoyl]-salicylic acid; 4-Metz, 4-methylthiazole; DMF, N,N-dimethylformamide; guaH, guanine.

**Figure S15.** The X-band powder EPR spectra of complexes 1 and 2 at 77 K.
Table S3. Relevant photophysical data of studied compounds, ($\lambda_{\text{ex}}, \lambda_{\text{em}}$ nm, $\epsilon$ [dm$^3$ mol$^{-1}$ cm$^{-1}$]).

| Compound | Solvent   | $\lambda_{\text{ex}}$ [nm] | $\lambda_{\text{em}}$ [nm] | $\lambda$ [nm] ($\epsilon$ [dm$^3$ mol$^{-1}$ cm$^{-1}$]) |
|----------|-----------|-----------------------------|-----------------------------|--------------------------------------------------------|
| HL1      | acetonitrile | 296 | 497 | 250 (10180) |
|          |           | 422 | 498 | 325 (2460)  |
|          |           |     |     | 450 (6970)  |
|          | chloroform| 296 | 506 | 245 (4720)  |
|          |           | 422 | 503 | 352 (1569)  |
|          |           |     |     | 455 (1290)  |
|          | methanol  | 296 | 497 | 254 (7116)  |
|          |           | 422 | 500 | 334 (2056)  |
|          |           |     |     | 454 (4522)  |
|          | acetonitrile| 296 | 481 | 254 (27400)|
|          |           | 422 | 498 | 290 (20110)|
|          |           |     |     | 315 (21830)|
|           | chloroform | 296 | 492 | 255 (5400)  |
|           |           | 422 | 471 | 290 (3570)  |
|           |           |     |     | 335 (2310)  |
|           | methanol  | 296 | 470 | 262 (11134) |
|           |           | 422 | 496 | 290 (9448)  |
|           |           |     |     | 342 (4426)  |
|           | acetonitrile| 450 | 509 | 650 (14140) |
|           |           |     |     | 365 (26050)|
|           |           |     |     | 455 (8990)  |
|           | chloroform| 450 | 497 | 320 (1060)  |
|           |           |     |     | 395 (730)   |
|           |           |     |     | 575 (240)   |
|           | methanol  | 450 | 504 | 272 (12300) |
|           |           |     |     | 372 (5800)  |
|           |           |     |     | 666 (165)   |
| 1        | acetonitrile | 450 | 493 | 245 (25610) |
|           |           |     |     | 310 (14560) |
|           |           |     |     | 395 (5880)  |
|           |           |     |     | 500 (910)   |
|           | chloroform| 450 | 489 | 250 (19070) |
|           |           |     |     | 315 (12080) |
|           |           |     |     | 400 (5150)  |
|           |           |     |     | 665 (120)   |
| 2        | chloroform| 450 | 489 | 248 (9836)  |
|           |           |     |     | 312 (9007)  |
|           |           |     |     | 402 (8511)  |
|           |           |     |     | 546 (342)   |
|           |           |     |     | 626 (271)   |

Table S4. Theoretical absorption wavelengths and corresponding oscillator strengths for ligands HL1 and HL2 calculated with def2-TZVP basis set in linear response approach.

| Medium     | B3LYP | CAM-B3LYP | PBE0 |
|------------|-------|-----------|------|
| **Ligand** | $\lambda$ | $f$     | $\lambda$ | $f$     | $\lambda$ | $f$     |
| Gas phase  | 339   | 0.07     | HOMO$\rightarrow$LUMO 82% | 306  | 0.19    | 326   | 0.14   |
|            | 328   | 0.07     | HOMO-1$\rightarrow$LUMO 79% | 322  | 0.48    | 236   | 0.23   |
|            | 254   | 0.31     | HOMO-4$\rightarrow$LUMO 83% | 221  | 0.39    | 229   | 0.24   |
|            | 236   | 0.37     | HOMO-4$\rightarrow$LUMO+178% | 195  | 0.17    | 200   | 0.21   |
| Acetonitrile| 202   | 0.16     | HOMO-4$\rightarrow$LUMO+686% | 234  | 0.54    | 246   | 0.41   |
|            | 253   | 0.14     | HOMO-5$\rightarrow$LUMO 35% | 228  | 0.53    | 236   | 0.53   |
|            | 242   | 0.55     | HOMO-4$\rightarrow$LUMO+169% | 194  | 0.13    | 199   | 0.12   |
| Dimethylsulfoxide | 200   | 0.23     | HOMO-2$\rightarrow$LUMO+251% | 303  | 0.23    | 322   | 0.20   |
|            | 254   | 0.35     | HOMO-4$\rightarrow$LUMO 52% | 234  | 0.56    | 246   | 0.42   |
|            | 242   | 0.56     | HOMO-4$\rightarrow$LUMO+169% | 236  | 0.54    | 236   | 0.53   |
### Ligand Absorption Spectrum

**Ligand Absorption Spectrum:**

|    |   |   |   |   |   |
|----|---|---|---|---|---|
| 200 | 0.24 | HOMO-2→LUMO+257% | 196 | 0.09 | 199 | 0.12 |
| 199 | 0.30 | HOMO→LUMO+445% | 195 | 0.18 | 198 | 0.06 |
| 334 | 0.14 | HOMO→LUMO 94% | 307 | 0.19 | 325 | 0.15 |
| 257 | 0.21 | HOMO-4→LUMO 34% | 232 | 0.57 | 252 | 0.17 |
| 255 | 0.11 | HOMO→LUMO+328% | 226 | 0.08 | 248 | 0.09 |
| 240 | 0.23 | HOMO-2→LUMO+149% | 221 | 0.36 | 246 | 0.13 |
| 200 | 0.40 | HOMO→LUMO+6 55% | 187 | 0.17 | 194 | 0.35 |
| 330 | 0.17 | HOMO→LUMO 94% | 303 | 0.22 | 321 | 0.19 |
| 260 | 0.22 | HOMO-1→LUMO 49% | 233 | 0.48 | 253 | 0.30 |
| 249 | 0.18 | HOMO-4→LUMO 37% | 226 | 0.10 | 244 | 0.24 |
| 244 | 0.18 | HOMO-6→LUMO 28% | 225 | 0.44 | 239 | 0.15 |
| 231 | 0.12 | HOMO-1→LUMO+222% | 200 | 0.14 | 227 | 0.14 |
| 203 | 0.11 | HOMO-3→LUMO+4 36% | 185 | 0.11 | 193 | 0.54 |
| 330 | 0.18 | HOMO→LUMO 94% | 304 | 0.23 | 322 | 0.19 |
| 260 | 0.22 | HOMO-1→LUMO 46% | 234 | 0.50 | 254 | 0.34 |
| 249 | 0.18 | HOMO-4→LUMO 38% | 228 | 0.29 | 251 | 0.10 |
| 244 | 0.16 | HOMO-6→LUMO 31% | 227 | 0.10 | 244 | 0.26 |
| 225 | 0.44 | HOMO-1→LUMO+219% | 200 | 0.14 | 227 | 0.14 |
| 203 | 0.11 | HOMO-10→LUMO 27% | 185 | 0.16 | 193 | 0.55 |

**Figure S16.** Theoretical prediction of the absorption spectrum of ligand HL1 absorption spectrum in gas phase (upper panel) and acetonitrile (lower panel) calculated with B3LYP (blue line), CAM-B3LYP (green line) and PBE0 (violet line) functionals (numerical values of absorption wavelengths for most intensive transitions given for PBE0 functional).
**Figure S17.** Frontier orbitals of ligand HL1, involved in most intensive transitions (PBE0/def2-TZVP/acetonitrile) with corresponding wavelengths.

**Figure S18.** Theoretical prediction of the absorption spectrum of ligand HL2 in gas phase (upper panel) and acetonitrile (lower panel) calculated with B3LYP (blue line), CAM-B3LYP (green line) and PBE0 (violet line) functionals (numerical values of absorption wavelengths for most intensive transitions given for PBE0 functional).
Figure 19. Frontier orbitals of ligand HL2, involved in most intensive transitions (PBE0/def2-TZVP/CH3CN) with corresponding wavelengths.

Figure S20. [(Cu2(L1)Cl)2][CuCl4]·2MeCN·2H2O (1)/Si, scan size 5 µm, multistage spin coating. Phase images map of layer property including mechanical, chemical, and viscoelastic. Amplitude-the image of height, in which the dimension of z axis was reduced.

Figure S21. [(Cu2(L2)Cl)0.5 MeCN·2/PMMA/Si a) height, b) phase, c) amplitude, scan size 5 µm, Ra = 5.15-19.9 nm, Rd = 3.66-25.9 nm, height 15 nm, 3000 rpm PMMA x1, complex 2 3000 rpm x2, complex + PMMA 3000 rpm x1, complex 3000 rpm x1, 5s.
Literature

1. Graham, B.; Hearn, M.T.W.; Junk, P.C.; Kepert, C.M.; Mabbs, F.E.; Moubaraki, B.; Murray, K.S.; Spiccia, L. Syntheses, Crystal Structures, Magnetic Properties, and EPR Spectra of Tetranuclear Copper(II) Complexes Featuring Pairs of “Roof-Shaped” Cu2X2 Dimers with Hydroxide, Methoxide, and Azide Bridges. Inorg. Chem. 2001, 40, 1536-1543.

2. Chaudhuri, P.; Ventur, D.; Wieghardt, K.; Peters, E.M.; Simon, K.A. Preparation, Magnetism, and Crystal Structures of the Tautomers [LCu(µ-OH):CuL]ClO4: (Blue) and [LCu(µ-OH):(µ-O)CuL]ClO4µµ (Green): µ-Aqua-µ-oxo vs. Di-µ-hydroxo Linkage. Angew. Chem., Int. Ed. Engl. 1985, 24(1), 57-59.

3. Buchtelova, H.; Skubalova, Z.; Strmiska, V.; Michalek, P.; Kociova, S.; Kruszyński, R.; Bieriko, A.; Kaj, M.; Lewińska, A.; Bieriko, D.; Malik-Gajewska, M.; Milosavljevic, V.; Kopel, P.; Heger, Z.; Adam, V. Synthesis and structural characterization of antimicrobial binuclear copper(II) coordination compounds bridged by hydroxy- and/or thioldipropionic acid. J. of Inorg. Biochem. 2019, 191, 8-20.

4. Charlot, M.F.; Jeannin, S.; Jeannin, Y.; Kahn, O.; Lucrece-Aubal, J.; Martin-Freke, J.S. Crystal structure and magnetic properties of tetrakis(cyclohexylamine)di-mu-hydroxo-dicopper(II) perchlorate. The first example of a roof-shaped hydroxoyo-bridged copper(II) dimer. Inorg. Chem. 1979, 18(6), 1675-1681.

5. Charlot, M.F.; Kahn, O.; Jeannin, S.; Jeannin, Y. Exchange interaction in roof-shaped hydroxoyo-bridged copper(II) dimers. Inorg. Chem. 1980, 19, 1410-1411.

6. Farrugia, L.J.; Lovatt, P.A.; Peacock, R.P. Synthesis of a series of novel binucleating ligands based on 1,4,7-triazacyclononane and α-, m- and p-xylene: structural study of the µ-hydroxo-bridged dicopper(II) complex [Cu(L=α,α′-bis (N-1,4,7-triazacyclononane)-m-xylene). J. Chem. Soc. Dalton Trans. 1997, 911-912.

7. Henry-Mowatt, J.; Dive, C.; Martinou, J.C.; James, D. Role of mitochondrial membrane permeabilization in apoptosis and cancer. Oncogene 2004, 23, 2850-2860.

8. Thakurta, S.; Roy, P.; Rosair, G.; Gómez-Garcia, C.J.; Garribba, E.; Mitra, S. Ferromagnetic exchange coupling in a new bis(µ-chloro)-bridged copper(II) Schiff base complex: Synthesis, structure, magnetic properties and catalytic oxidation of cycloalkanes. Polyhedron 2009, 28, 695-702.

9. Bernalte-Garcia, A.; Lozano-Vila, A.M.; Luna-Giles, F.; Pedrero-Marin, R. Structural characterization of a thiazoline-pyrazole ligand and its complexes with cobalt(II) and copper(II). Polyhedron 2006, 25, 1399.

10. Connor, C.J.O. Ferromagnetic interactions in dimeric dichloro-[2,2-bis-(2-pyridyl)-1,3-dioxolane)copper(II). Inorg. Chim. Acta 1987, 127, L29-L30.

11. Tuna, F.; Patron, L.; Journaux, Y.; Andruh, M.; Plass, W.; Trombe, J.C. Synthesis and magnetic properties of a series of bi- and tri-nuclear complexes of copper(II) with the unsymmetrical tetradentate Schiff-base ligand 3-[N-2-(pyridylethyl)formimidoyl]salicylic acid, H2fsaaep, and crystal structures of [(Cu(Hfsaaep)Cl)] and [(Cu(fsaaep)(H2O))]. J. Chem. Soc., Dalton Trans. 1999, 539-544.

12. Sidar, Y.; Modak, R.; Bose, D.; Banerjee, S.; Bieriko, D.; Zierkiewicz, W.; Bieriko, A.; Das Saha, K.; Goswami, D. Doubly chlоро bridged dimeric copper(II) complex: magneto-structural correlation and anticancer activity. Dalton Trans. 2015, 44, 8876-8888.

13. Drake, R.F.; Crawford, V.H.; Laney, N.W.; Hatfield, W.E. Magnetic properties of di-mu-chlorobis(dichloroguaninium)copper(II) dihydrate. Second determination. Inorg. Chem. 1974, 13(5), 1246-1249.

14. Carrabirie, J.A.; Sundaralingam, M. Stereochemistry of Nucleic Acids and Their Constituents. VIII. Metal Binding Studies. Crystal Structure of a Guanine-Copper Chloride Complex, a Trigonal-Bipyramidally Coordinated Copper. J. Am. Chem. Soc. 1970, 92(2), 369-371.