Electronic Supplementary Information

Spectroscopy, Microscopy, Diffraction and Scattering of Archetypal MOFs: Formation, Metal Sites and Thin Films

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Bibliometric Analysis of Characterization Tools in the Field of MOF Chemistry

In order to estimate and quantify current trends in the field, we have carried out a bibliometric analysis of the use of different characterization techniques for relevant fundamental physico-chemical phenomena that have been intensively researched in the field of MOF materials. The result of this analysis is summarized in Fig. S1 and S2. A database compiled by the authors, comprising 2016 papers, was analysed based on the appearance of 426 keywords in the whole text of each paper. The list of keywords (see Supplementary Information) the documents were scanned for was subdivided into a set of groups, each containing keywords designating a specific subject: (A) mixed-linker MOFs, (B) cation exchange, (C) breathing, (D) crystal-growth, (E) coordinatively unsaturated metal sites, (F) defects, (G) thin-films and (H) post-synthetic cation exchange (see Fig. S1 for details on each group). Based on the occurrence of each keyword in each document, papers were assigned a class membership value to each of the groups A-H. Next, a second set of 31 keyword groups indicating methods was used to evaluate how often each method was mentioned in each manuscript. Finally, the same was done with a set of keyword groups listing the six MOF topologies under review (and the different metal analogues and terminology employed for each structure, see Supplementary information and Fig. S3-S9). In total, 65 groups were used to pool the 426 keywords. This analysis resulted in a unique 'fingerprint' or 'keyword DNA' of studied material properties and methods mentioned in each paper, based on the occurrence of the 426 keywords in each paper. This keyword DNA is shown in Fig. S1 for 14 selected references that are, among others, highlighted in this review article.

To reveal the trends between how material features and techniques are combined we investigated correlations between the techniques and material features mentioned in the papers. To this end a paper network was generated by establishing a connection (network edge) between two papers that were members of the same group A-H. This connection was then weighted by the total number of groups two papers had in common (groups A-H and 1-31). The total number of groups a paper was found to be a member of was further used as the diameter of the circle representing the paper in the network. Next, a force directed graph drawing[26] was used to visualize the network (Fig. S1). The weighting of the edges resulted in a layout were papers belonging to the same group (A-H) were found clustered; within this cluster papers mentioning the same methods are located closer to each other. Manuscripts mentioning multiple material property groups were pushed towards the centre of the plot as they share connections with other 'pure' groups. The more features and techniques are mentioned in a document, the larger and more centred it will be located in the network. It is worth mentioning that dots located at the centre usually correspond to review articles, in which a plethora of both features and techniques (*i.e.*, keywords) are mentioned. The colour of each dot denotes the dominant class membership (most used keyword group A-H in the paper). From Fig. S1 it becomes clear that many papers are members of one of the groups

A-H forming clusters of 'pure groups'. By pooling these articles and inspecting the keyword DNA of the whole group, it is therefore possible to evaluate any correlations between specific techniques (or combinations thereof) and the material property studied. These 'pure' regions (and one mixed cluster) are highlighted in the bottom part of Fig. S1 together with the percentage of papers found in each group. Note that 29% of all papers processed did not mention any of the keywords of groups A-H and are therefore not included in this network.

The keyword fingerprint of each group is reported in Fig. S2, indicating the number of papers (in percent of all papers of the respective cluster) that mention each group. The first observation is that XRD and adsorption are characterization techniques used in almost every MOF paper (Fig. S2 and S3), followed by infrared (IR), nuclear magnetic resonance (NMR), TGA and electron microscopy, the latter in many cases coupled with X-ray photoelectron spectroscopy (XPS) or energy-dispersive spectroscopy (EDS). Indeed, the fact that MOFs are highly crystalline and porous materials, renders diffraction and adsorption techniques very powerful for their study. Recently, Howarth *et al*.[18] defined XRD, N_2 sorption and TGA as "basic techniques" for studying MOFs.[27] This techniques typically include the use of IR and NMR for assessing purity or linker incorporation. Thus, it is evident that this toolkit of characterization techniques should be the baseline for more advanced studies. On the other hand, in articles dedicated to the study of thin-films (layer-by-layer, turquoise colour code, in Fig. S1 and S2), we can find well-suited techniques such as quartz-crystal microbalance (QCM, group 17), TEM (group 28) or atomic force microscopy (AFM, group 30) along with infrared spectroscopy (AFM-IR, group 31).

However, another conclusion that may be drawn from our bibliometric study is that a large number of other techniques that may be very well suited for those features, remain underused. For instance, tools such as grazing-incidence X-ray absorption (GIXAS) or X-ray reflectometry (XRR), could be very useful for the study of the electronic structure of the metals or the morphology of MOF thin-films, respectively. However, the use of X-ray absorption or reflection techniques has been limited to bulk MOFs,[13-17] and they have not been yet used in MOF thin-films to the best of our knowledge. This fact is most probably due to its availability as it requires most often a synchrotron radiation source.

Another conclusion that was extracted is that nano-spectroscopies, in comparison to micro-spectroscopies, have been only recently explored. For instance, Scanning Probe Microscopy (SPM) or techniques, such as AFM-IR, and often related to MOF thin-films characterization are seldomly applied. In general, complementary characterization studies that combine bulk, micro- and nanoscopic tools remain still scarce. Such a multiple length scale approach has gained strong importance over the past few years, in which the use of MOF heterogeneities has emerged as a new strategy to engineer MOF properties.[28, 29] Moreover, even within the class of bulk techniques, there is strong potential for expanding the number of tools available in the characterization toolbox which are seldomly applied. Besides XRD, TGA, and SEM using advanced characterization methods for specific tasks should become a routine when relevant information beyond crystallinity, morphology or stability is needed. In particular, the use of micro- and nano-spectroscopy and chemical imaging techniques has remained largely unexplored to date (see Fig. S2, S6 and S8), which is especially surprising for those areas of study in which intra- and inter-crystal heterogeneities are expected. This is for example the case for defective MOFs or for MOFs with mixed-linkers.[29] We believe, however, that micro- and nano-spectroscopic methods will become increasingly important as MOFs start being studied under dynamic conditions (*i.e.* under *in-situ* or *operando* conditions), where diffraction techniques cannot lead to local information in contrast to other characterization tools, such as *e.g.* X-ray or UV-vis micro-spectroscopies.[30-32]

In our study, the Supplementary Information (SI) and Main Article (MA) documents of the papers in the literature survey were studied as separate elements, and included in the network. It is interesting to observe that while certain MAs mention a large number of features or techniques, the corresponding SI is related to a very particular keyword (or *vice versa*), such as in the case of ref. [33]. Furthermore, it can be seen that some features that are strongly interrelated, *e.g.* 'layer-by-layer synthesis' and 'crystal growth' or 'cation exchange' and 'coordinatively unsaturated metal sites (CUS)', typically share a number of keywords (*i.e.*, techniques for their study), resulting in smaller, mixed clouds located in their vicinities. Surprisingly, this analysis showed that features that may seem relatively far from each other (breathing and defective MOFs) showed a strong correlation.

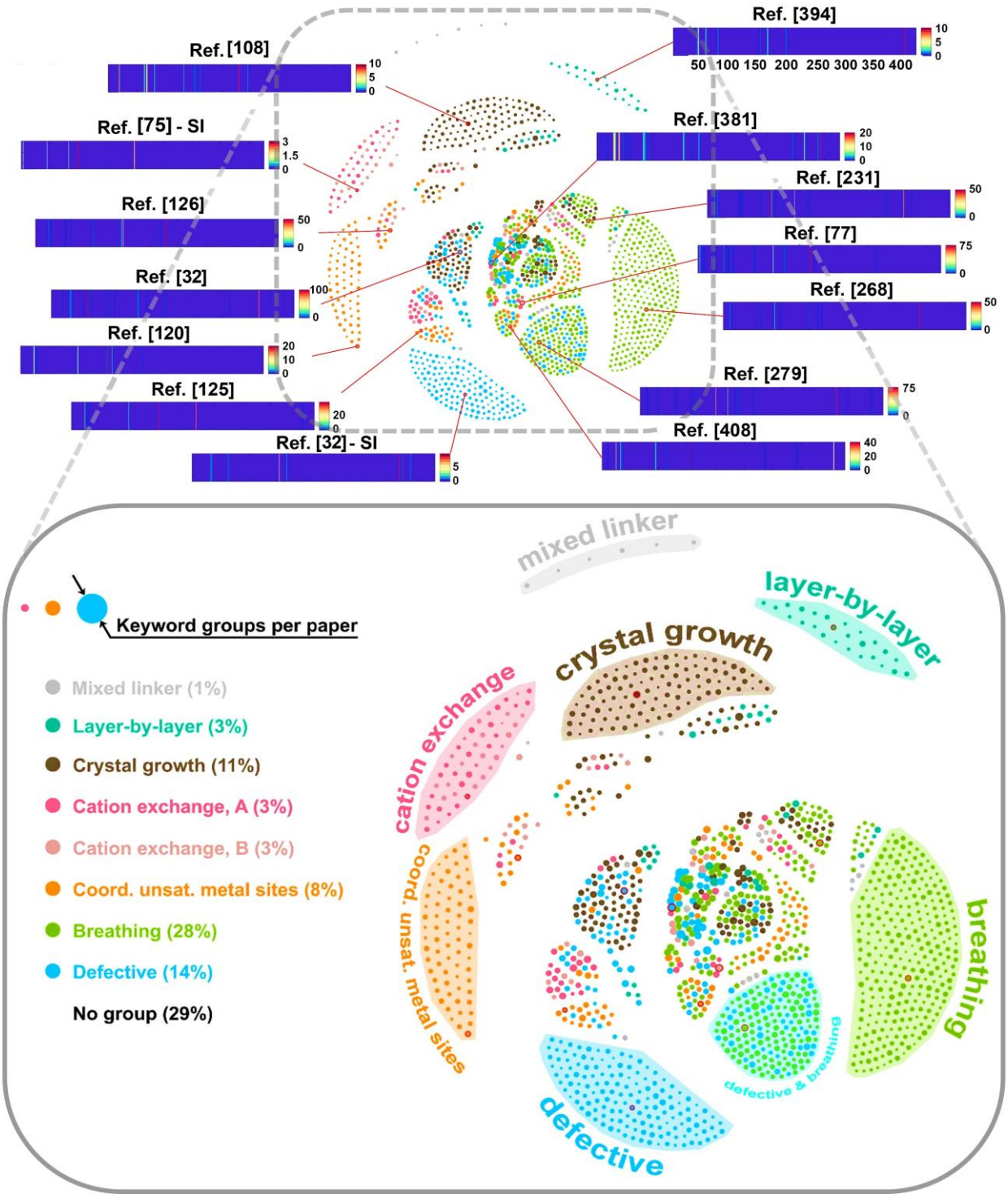

Fig. S1. Network of papers created by the bibliometric study correlating techniques and material properties mentioned in the full text of each paper (note that no correlation is established to a particular MOF topology). Each paper was scanned for the occurrence of 426 keywords pooled into 65 groups. Groups 1-8 (labelled A-H in Fig. 2) designated the phenomena mentioned, while groups 9-39 indicated the methods mentioned; groups 40-65 were used for MOF topologies. The network is formed by establishing weighted connections between papers that are members of the same group(s) designating phenomena and methods mentioned (groups 1-39), that is if they have a similar keyword DNA colour code in this keyword range (1-39). The layout is generated by applying a force directed graph drawing utilizing the Fruchterman-Reingold algorithm). The size of each dot represents the amount of keyword groups appearing in a particular paper. The selected dots highlight 14 relevant articles (references in brackets) and their "keyword fingerprint" – these papers are amongst others discussed in detail in the following sections. For more details about the network analysis we refer to the Supplementary Information (SI). *From the library under study, 29% of papers did not contain any of the keywords in the list identifying the features under study (groups 1-8 or A-H) and are therefore not plotted in this network.

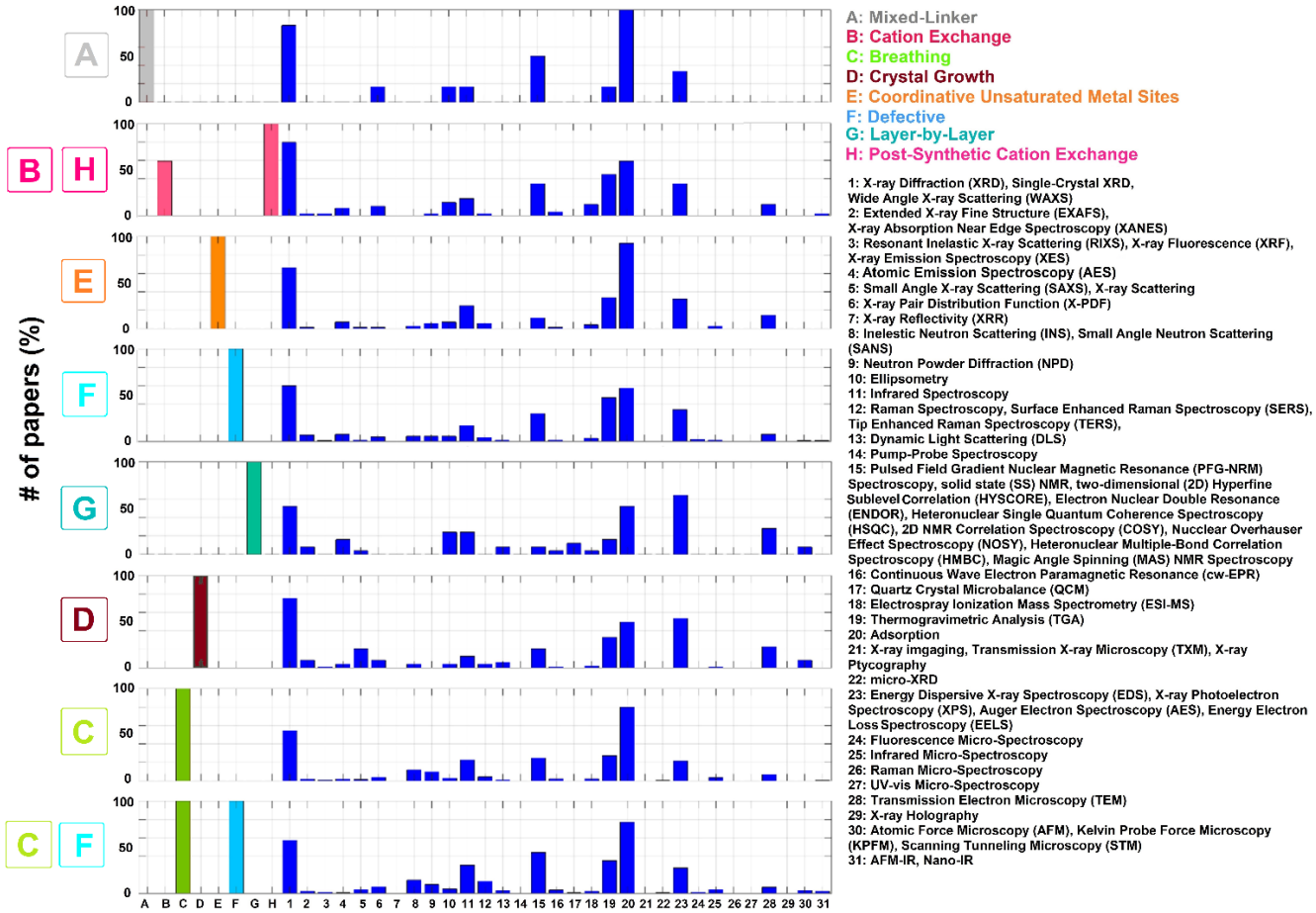

Fig. S2. Occurrence (in percent of all papers of the same cluster) of the different characterization tools (glossary on the right) mentioned in papers that also mention the specific material properties indicated by groups A-H (coloured). *Cation exchange and post-synthetic cation exchange were screened as two categories but are here reported in the same plot (pink). (See the Supporting Information (SI) section for more details.

This can be seen in the blue-green cloud containing those papers, indicating that they mention the same two features, (100% of all papers in this mixed group mention both, keywords from the group 'breathing' and the group 'defective', see Fig. S2) and thus, an apparent strong connection between studies of defects and breathing.

A data base of 2016 manuscripts (including supporting information documents that were treated as separate documents) put together by the authors of this review was analysed by searching the complete text of each document for the occurrence of a list 426 keywords defined by the authors of this review. For the complete set of keywords see Appendix A. To avoid problems with capitalization both keywords and all words in a document had been changed to lower case before the search.

Fig. S3 shows how the 426 individual keywords were grouped into 3 main groups and 65 sub-groups, each group identifying one search item. A search item here designates a specific topic, such as a material, a material property (in the following called 'field of study'), or a method of investigation ('technique') that can be described by several keywords. These three super-groups ('field of study', 'technique', and 'material') contained 8, 31, and 26 sub-groups, respectively (see Appendix A). The focus of this study was on the use of techniques utilized to study specific material properties (*i.e.* 'fields of study'), therefore the 31 groups of the super-group 'technique' were further pooled into classes ('bulk techniques',

'microscopies', and 'nanoscopies') and method clusters (X-rays, electrons, …) as illustrated schematically in Fig. S1.

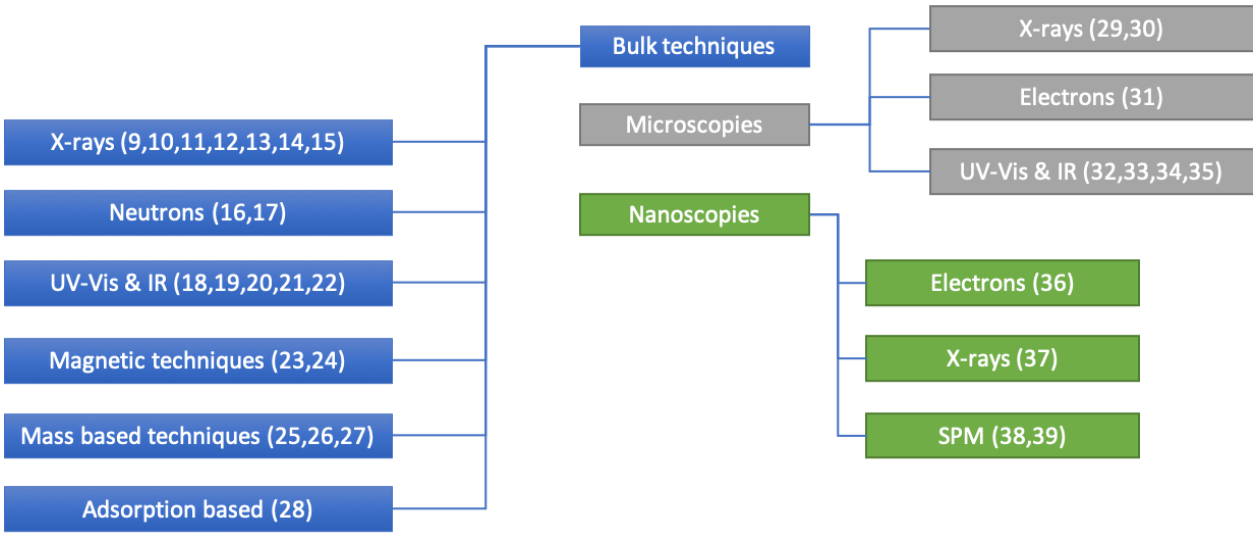

Fig. S3. Classification of the 31 sub-groups (9-39) of the super-group 'technique' containing 140 keywords. The numbers in brackets list the sub-group number (9-39) of each method cluster.

In Fig. S4 the numbers of documents found that contained at least one keyword of a sub-group are reported. Note that manuscripts will be counted multiple times, as one paper can contain keywords of multiple sub-groups, that is, the sum of papers plotted will by far exceed the 2016 manuscripts analysed.

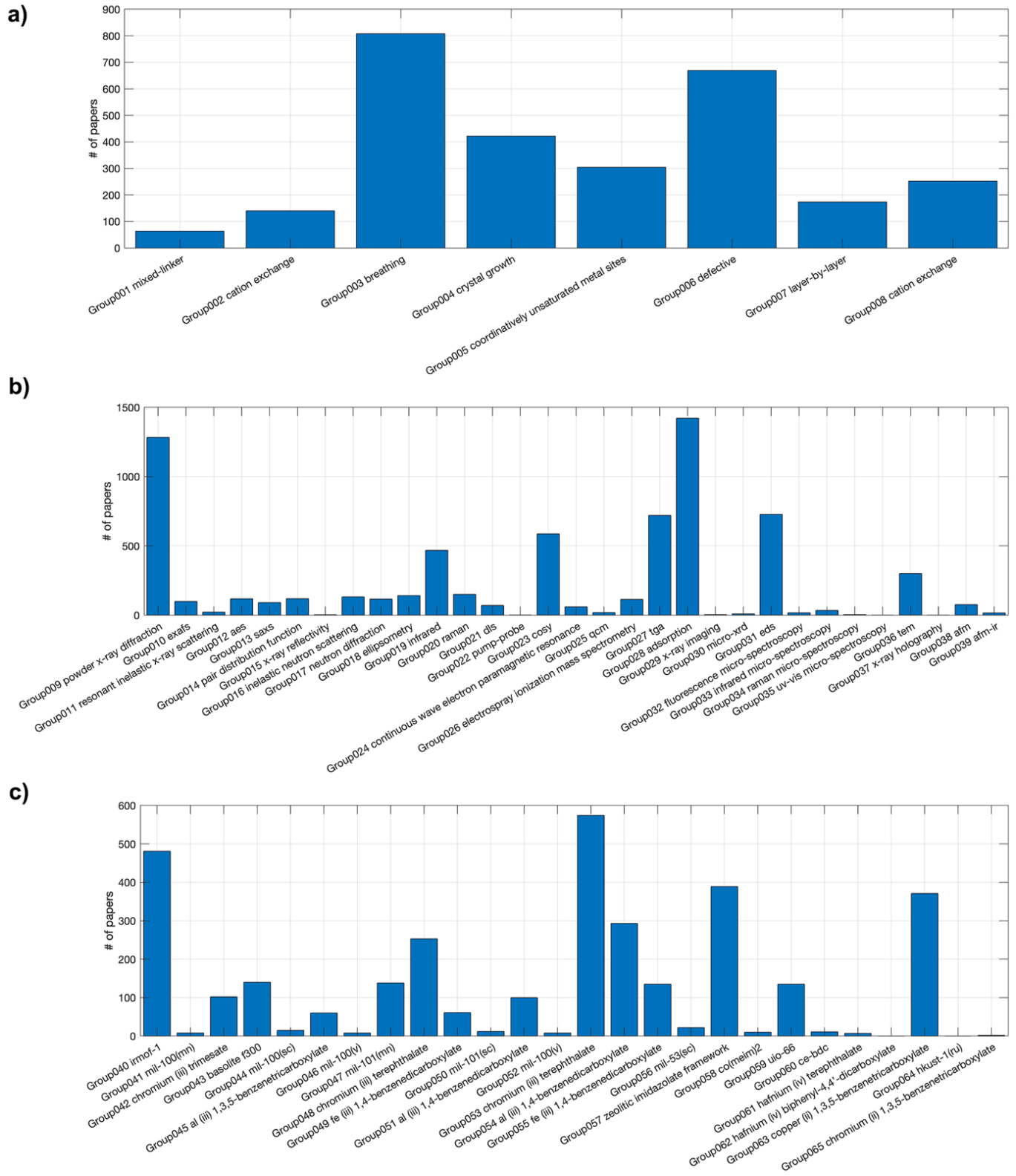

Fig. S4. Number of papers per keyword sub-group (1-65). The first keyword of each group (see Appendix A) is used together with the group number as a label.

In Fig. S5 the numbers of documents found that contained at least one keyword of the classes ('bulk techniques', 'microscopies', and 'nanoscopies', see Fig. S5) are reported. It becomes clear that the field is strongly dominated by bulk techniques.

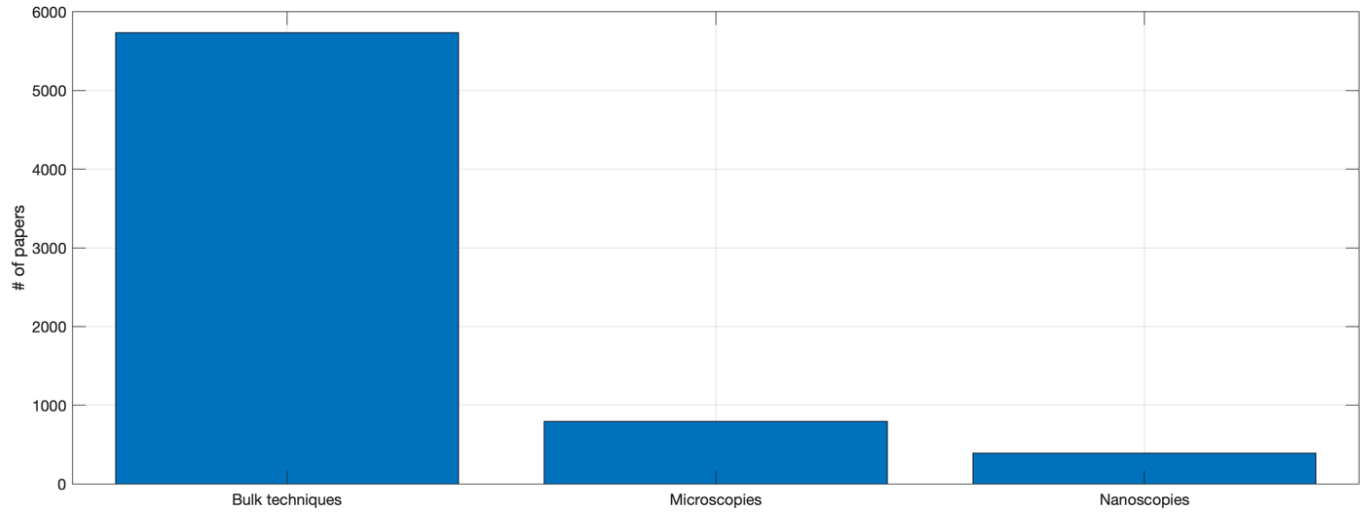

Fig. S5. Number of papers mentioning keywords that are members of one of the three classes 'bulk techniques', 'microscopies', and 'nanoscopies' (see Fig. S1).

As an example, Fig. S6 reports the number of papers that mentioned each individual keyword that belongs to one of the sub-groups 1-8 ('Field of study'), exemplifying how the bibliometric analysis was performed at the individual keyword level.

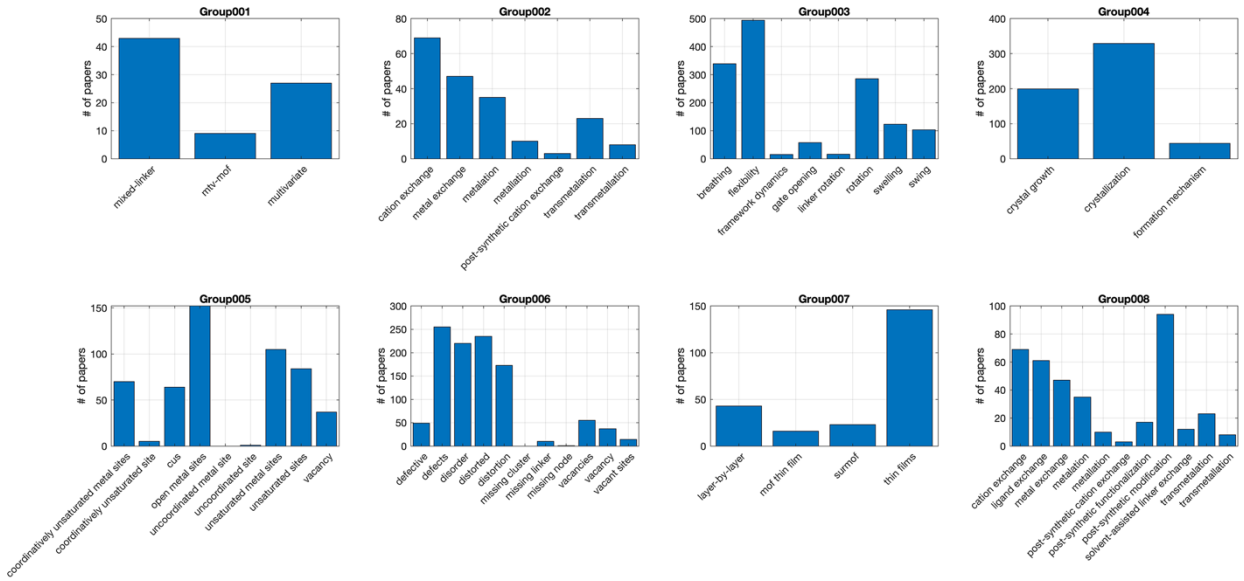

Fig. S6. Occurrence of individual keywords of subgroups 1-8 ('Field of study') in all papers scanned.

Fig. S6 reports the same information as displayed in Fig. S5 but for all sub-groups and plotted as stacked bars. It becomes obvious that certain keywords dominate a sub-group; as example is sub-group 27 ('tga') where 'tga' (keyword ID 152) is used more often than 'thermogravimetric analysis' (keyword ID 153). This is not surprising as abbreviations are typically used more often after introducing them at the first use in a manuscript. The color scheme used in the stacked bar plot corresponds to the order of keywords as listed in Appendix A.

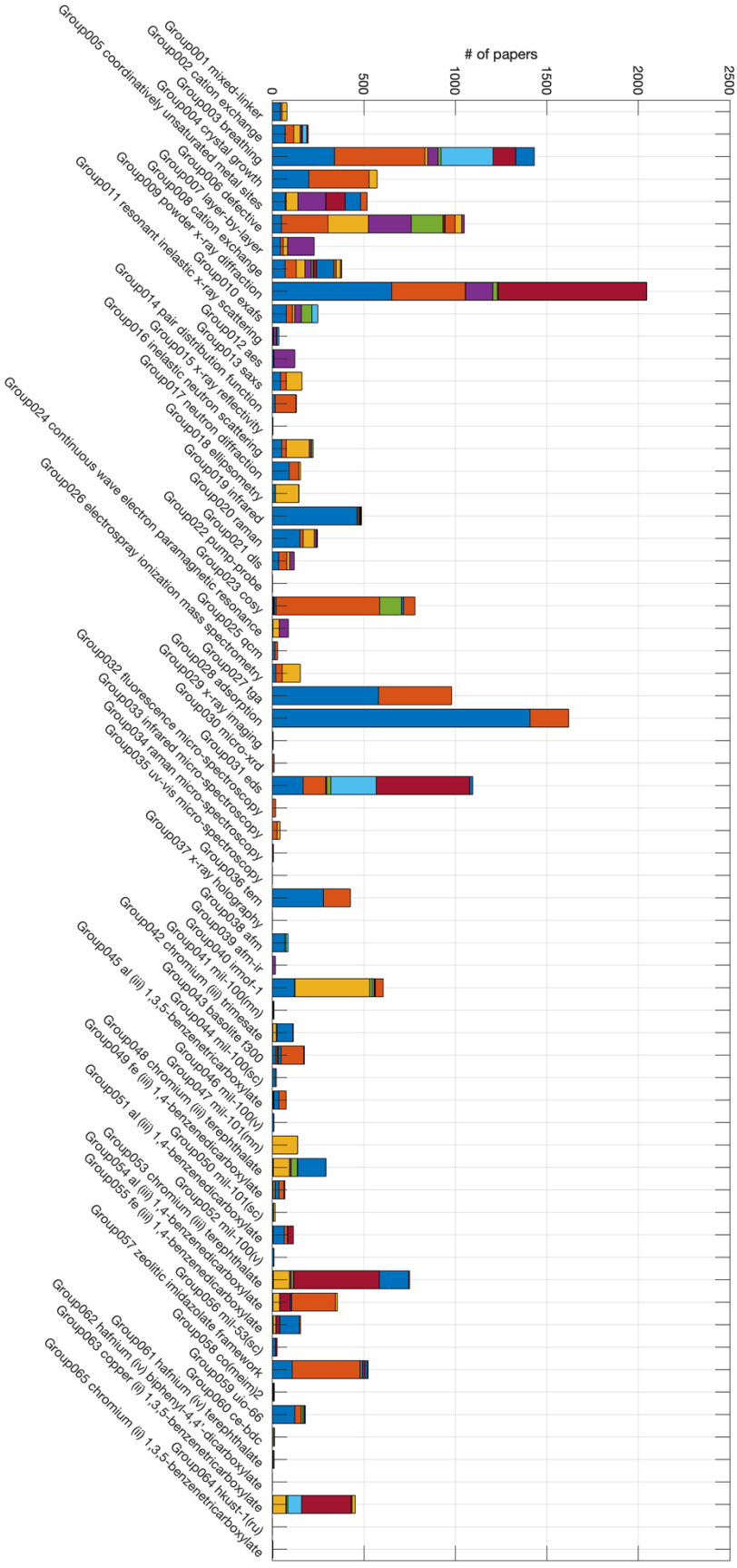

Fig. S7. Occurrence of individual keywords of all sub-groups (1-65) in all documents scanned. The numbers of papers mentioning a specific keyword of a sub-group are plotted as stacked bars using a different color for each keyword of a subgroup. (Compare to Fig. S6 for subgroups 1-8). The color scheme used in the stacked bar plot corresponds to the order of keywords as listed in Appendix A.

Finally, we studied the correlation between the field of study mentioned in a manuscript and the methods mentioned in the same paper, assuming that is most cases these techniques have actually been used to study the respective material property (or at least suggest by the authors of the paper). The result is reported in Fig. S8, plotting the number of papers that mention both a specific field of study (y-axis) and technique (x-axis). The number of papers is both listed and represented by a circle with a diameter and color that corresponds to the number listed.

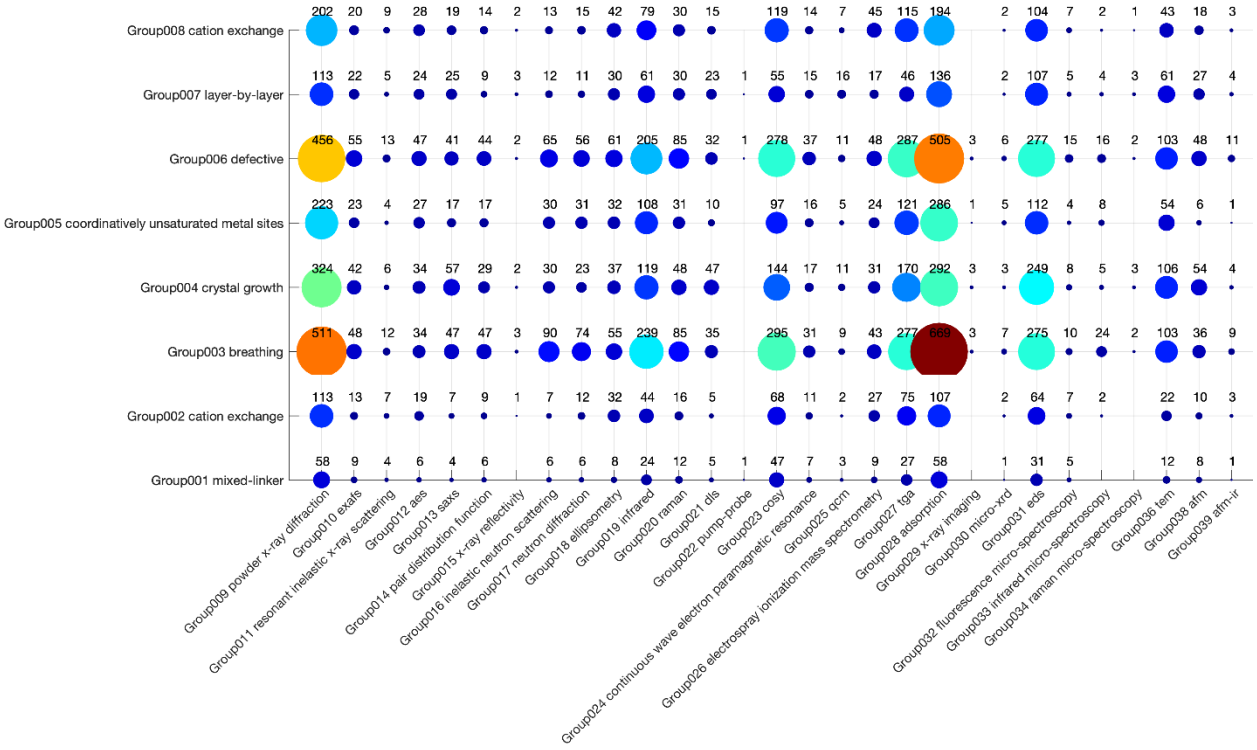

Fig. S8. Correlation between field of study and techniques used. On the x-axis we list techniques and on the y-axis the field of study is listed. The number of papers that mention both a specific field of study and technique are reported as labels of circles with a diameter and color that corresponds to this number.

Network analysis

As explained in the main text a paper network was generated by establishing a connection (network edge) between two papers that were members of the same super-group 'Fields of study' (sub-groups 1-8, labeled A-H in the main text). This connection was then weighted by the total number of groups two papers had in common (groups 1-8 and 9-39). The total number of groups a paper was found to be a member of was further used as the diameter of the circle representing the paper in the network. Next, a force directed graph drawing was used to visualize the network (see Fig. 1 in main text). The force directed graph drawing (Fruchterman-Reingold algorithm) was performed in the software package Gephi [1]. All other processing was done using self-developed code in Matlab© R2018.

References

[1] Bastian M., Heymann S., Jacomy M., *Gephi: an open source software for exploring and manipulating networks.* International AAAI Conference on Weblogs and Social Media (**2009**). http://www.aaai.org/ocs/index.php/ICWSM/09/paper/view/154

Appendix A

Complete list of keywords (426); the 65 sub-groups are separated by an empty line.

1 Field of study:

8 sub-groups,
sub-groups 1-8,
keywords 1-56

1. 'mixed-linker'
2. 'mtv-mof'
3. 'multivariate'

4. 'cation exchange'
5. 'metal exchange'
6. 'metalation'
7. 'metallation'
8. 'post-synthetic cation exchange'
9. 'transmetalation'
10. 'transmetallation'

11. 'breathing'
12. 'flexibility'
13. 'framework dynamics'
14. 'gate opening'
15. 'linker rotation'
16. 'rotation'
17. 'swelling'
18. 'swing'

19. 'crystal growth'
20. 'crystallization'
21. 'formation mechanism'

22. 'coordinatively unsaturated metal sites'
23. 'coordinatively unsaturated site'
24. 'cus'
25. 'open metal sites'
26. 'uncoordinated metal site'
27. 'uncoordinated site'
28. 'unsaturated metal sites'
29. 'unsaturated sites'
30. 'vacancy'

31. 'defective'
32. 'defects'
33. 'disorder'
34. 'distorted'
35. 'distortion '
36. 'missing cluster'
37. 'missing linker'
38. 'missing node'
39. 'vacancies'
40. 'vacancy'
41. 'vacant sites'

42. 'layer-by-layer'
43. 'mof thin film'
44. 'surmof'
45. 'thin films'

46. 'cation exchange'
47. 'ligand exchange'
48. 'metal exchange'
49. 'metalation'
50. 'metallation'
51. 'post-synthetic cation exchange'
52. 'post-synthetic functionalization'
53. 'post-synthetic modification'
54. 'solvent-assisted linker exchange'
55. 'transmetalation'
56. 'transmetallation'

2 Technique:

31 sub-groups,
sub-groups 9-39,
keywords 57-196

57. 'powder x-ray diffraction'
58. 'pxrd'
59. 'sc-xrd'
60. 'single-crystal x-ray diffraction'
61. 'waxs'
62. 'wide angle x-ray scattering'
63. 'xrd'

64. 'exafs'
65. 'extended x-ray absorption fine structure '
66. 'x-ray absorption near-edge structure'
67. 'x-ray absorption spectroscopy'
68. 'xanes'
69. 'xas'

70. 'resonant inelastic x-ray scattering'
71. 'rixs'
72. 'x-ray emission spectroscopy'
73. 'x-ray fluorescence'
74. 'xes'
75. 'xrf'

76. 'aes'
77. 'auger electron spectroscopy'
78. 'x-ray photo-electron spectroscopy'
79. 'xps'

80. 'saxs'
81. 'small-angle x-ray scattering'
82. 'x-ray scattering'

83. 'pair distribution function'
84. 'pdf'
85. 'x-pdf'
86. 'x-ray pair distribution function'

87. 'x-ray reflectivity'
88. 'xrr'

89. 'inelastic neutron scattering'
90. 'ins'
91. 'neutron scattering'
92. 'sans'
93. 'small-angle neutron scattering'

94. 'neutron diffraction'
95. 'neutron powder diffraction'
96. 'npd'

97. 'ellipsometry'
98. 'uv visible'
99. 'uv-vis'
100. 'visible absorption'

101. 'infrared'
102. 'infrared reflection absorption spectroscopy'
103. 'irras'
104. 'probe-molecule infrared'
105. 'probe-molecule ir'
106. 'rairs'
107. 'reflection absorption infrared spectroscpy'
108. 'sfg'

109. 'sfg spectroscopy'
110. 'sum frequency generation'
111. 'sum frequency generation spectroscopy'

112. 'raman'
113. 'raman scattering'
114. 'raman spectroscopy'
115. 'sers'
116. 'surface enhanced raman scattering'
117. 'uv raman spectroscopy'

118. 'dls'
119. 'dynamic light scattering'
120. 'sls'
121. 'static light scattering'

122. 'pump-probe'
123. 'pump-probe spectroscopy'
124. 'ultrafast spectroscopy'

125. 'cosy'
126. 'endor'
127. 'heteronuclear multiple-bond correlation spectroscopy'
128. 'heteronuclear single quantum coherence spectroscopy'
129. 'hmbc'
130. 'magic angle spinning nuclear magnetic resonance'
131. 'mas-nrm'
132. 'mössbauer spectroscopy'
133. 'nmr'
134. 'nmr nuclear overhauser effect spectroscopy'
135. 'nosy'
136. 'nuclear magnetic resonance'
137. 'pfg-nrm'
138. 'probe molecule nmr'
139. 'pulsed field gradient nmr'
140. 'solid state nmr'
141. 'two-dimensional hyperfine sublevel correlation'

142. 'continuous wave electron paramagnetic resonance'
143. 'cw-epr'
144. 'electron paramagnetic resonance'
145. 'epr'
146. 'probe-molecule epr'

147. 'qcm'
148. 'quartz crystal microbalance'

149. 'electrospray ionization mass spectrometry'
150. 'esi-ms'
151. 'mass spectrometry'

152. 'tga'
153. 'thermogravimetric analysis'

154. 'adsorption'
155. 'physisorption'

156. 'x-ray imaging'
157. 'x-ray microscopy'
158. 'xrm'

159. 'micro-xrd'
160. 'x-ray microdiffraction'

161. 'eds'
162. 'edx'
163. 'eels'
164. 'electron energy loss spectroscopy'
165. 'energy dispersive x-ray spectroscopy'
166. 'scanning electron microscopy'
167. 'sem'
168. 'sem-edx'

169. 'fluorescence micro-spectroscopy'
170. 'fluorescence microscopy'
171. 'single-molecule fluorescence microscopy'

172. 'infrared micro-spectroscopy'
173. 'infrared microscopy'
174. 'interference microscopy'

175. 'raman micro-spectroscopy'
176. 'raman microscopy'

177. 'uv-vis micro-spectroscopy'
178. 'uv-vis microscopy'

179. 'tem'
180. 'transmission electron microscopy'

181. 'x-ray holography'
182. 'x-ray holotomography'
183. 'x-ray nano-tomography'
184. 'x-ray nanotomography'
185. 'x-ray ptychography'

186. 'afm'
187. 'atomic-force microscopy'
188. 'kelvin probe force microscopy'
189. 'kpfm'
190. 'scanning tunnelling microscopy'
191. 'stm'

192. 'afm-ir'
193. 'nano-infrared'
194. 'nano-ir'
195. 'ters'
196. 'tip-enhanced raman scattering'

3 Material:

26 sub-groups,
sub-groups 40-65,
keywords 197-426

197. 'irmof-1'
198. 'mil-100/101'
199. 'mof-5'
200. 'zinc (ii) terephthalate'
201. 'zn terephthalate'
202. 'zn(bdc)'
203. 'zn-bdc'
204. 'zn-terephthalate'
205. 'zn4o(bdc)3'

206. 'mil-100(mn)'
207. 'mil-100-mn'
208. 'mil-100/101'
209. 'mn-btc'

210. 'mn-mil-100'
211. 'mn-trimesate'

212. 'chromium (iii) trimesate'
213. 'chromium 1,3,5-benzenetricarboxylate'
214. 'chromium trimesate'
215. 'cr-btc'
216. 'cr-mil-100'
217. 'cr-trimesate'
218. 'cr3o(h2o)2x[c9h3o6]·nh2o'
219. 'mil-100(cr)'
220. 'mil-100-cr'

221. 'basolite f300'
222. 'fe-btc'
223. 'fe-mil-100'
224. 'fe3o(h2o)2x[c9h3o6]·nh2o'
225. 'iron (iii) 1,3,5-benzenetricarboxylate'
226. 'iron (iii) trimesate'
227. 'iron 1,3,5-benzenetricarboxylate'
228. 'iron trimesate'
229. 'mil-100(fe)'
230. 'mil-100-fe'

231. 'mil-100(sc)'
232. 'mil-100-sc'
233. 'sc-btc'
234. 'sc-mil-100'
235. 'sc3o(h2o)2x[c9h3o6]·nh2o'
236. 'scandium trimesate'

237. 'al (iii) 1,3,5-benzenetricarboxylate'
238. 'al-btc'
239. 'al-mil-100'
240. 'al3o(h2o)2x[c9h3o6]·nh2o'
241. 'aluminum (iii) 1,3,5-benzenetricarboxylate'
242. 'aluminum (iii) trimesate'
243. 'aluminum 1,3,5-benzenetricarboxylate'
244. 'aluminum trimesate'
245. 'mil-100(al)'
246. 'mil-100-al'

247. 'mil-100(v)'
248. 'mil-100-v'
249. 'v-mil-100'
250. 'v3o(h2o)2x[c9h3o6]·nh2o'
251. 'vanadium (iii) trimesate'

252. 'mil-101(mn)'
253. 'mil-101-mn'
254. 'mil101'
255. 'mn-bdc'
256. 'mn-mil-101'
257. 'mn-terephthalate'

258. 'chromium (iii) terephthalate'
259. 'chromium 1,4-benzenedicarboxylate'
260. 'chromium terephthalate'
261. 'cr-bdc'
262. 'cr-mil-101'
263. 'cr-terephthalate'
264. 'cr3o(h2o)2x[c8h4o4]·nh2o'
265. 'mil-101(cr)'
266. 'mil-101-cr'

267. 'fe (iii) 1,4-benzenedicarboxylate'
268. 'fe-bdc'
269. 'fe-mil-101'
270. 'fe-terephthalate'
271. 'fe3o(h2o)2x[c8h4o4]·nh2o'
272. 'iron (iii) 1,4-benzenedicarboxylate'
273. 'iron (iii) terephthalate'
274. 'iron terephthalate'
275. 'mil-101(fe)'
276. 'mil-101-fe'
277. 'nh2-mil-101(fe)'

278. 'mil-101(sc)'
279. 'mil-101-sc'
280. 'sc (iii) 1,4-benzenedicarboxylate'
281. 'sc-bdc'
282. 'sc-mil-101'
283. 'sc-terephthalate'
284. 'sc3o(h2o)2x[c8h4o4]·nh2o'
285. 'scandium (iii) 1,4-benzenedicarboxylate'
286. 'scandium (iii) terephthalate'
287. 'scandium terephthalate'

288. 'al (iii) 1,4-benzenedicarboxylate'
289. 'al-bdc'
290. 'al-mil-101'
291. 'al3o(h2o)2x[c8h4o4]·nh2o'
292. 'aluminum (iii) 1,4-benzenedicarboxylate'
293. 'aluminum (iii) terephthalate'

294. 'aluminum 1,4-benzenedicarboxylate'
295. 'aluminum terephthalate'
296. 'mil-101(al)'
297. 'mil-101(al)-nh2'
298. 'mil-101-al'
299. 'mil-101-al-nh2'
300. 'nh2-al-mil-101'
301. 'nh2-mil-101(al)'
302. 'nh2-mil-101-al'

303. 'mil-100(v)'
304. 'mil-100-v'
305. 'v-mil-100'
306. 'v3o(h2o)2x[c9h3o6]·nh2o'
307. 'vanadium (iii) trimesate'

308. 'chromium (iii) terephthalate'
309. 'chromium 1,4-benzenedicarboxylate'
310. 'chromium terephthalate'
311. 'cr-bdc'
312. 'cr-mil-53'
313. 'cr-terephthalate'
314. 'mil-53'
315. 'mil-53(cr)'
316. 'mil-53-cr'

317. 'al (iii) 1,4-benzenedicarboxylate'
318. 'al-bdc'
319. 'al-mil-53'
320. 'aluminum (iii) 1,4-benzenedicarboxylate'
321. 'aluminum (iii) terephthalate'
322. 'aluminum 1,4-benzenedicarboxylate'
323. 'aluminum terephthalate'
324. 'basolite a100'
325. 'mil-53(al)'
326. 'mil-53-al'
327. 'nh2-al-mil-53'

328. 'fe (iii) 1,4-benzenedicarboxylate'
329. 'fe-bdc'
330. 'fe-mil-53'
331. 'iron (iii) 1,4-benzenedicarboxylate'
332. 'iron (iii) terephthalate'
333. 'iron 1,4-benzenedicarboxylate'
334. 'iron terephthalate'
335. 'mil-53(fe)'
336. 'mil-53-fe'

337. 'mil-53(sc)'
338. 'sc (iii) 1,4-benzenedicarboxylate'
339. 'sc-bdc'
340. 'sc-terephthalate'
341. 'scandium (iii) 1,4-benzenedicarboxylate'
342. 'scandium (iii) terephthalate'
343. 'scandium terephthalate'

344. 'zeolitic imidazolate framework'
345. 'zif-8'
346. 'zif-8(zn)'
347. 'zif-8-zn'
348. 'zinc (ii) imidazolate'
349. 'zinc imidazolate'
350. 'zn(meim)2'
351. 'zn(mim)2'
352. 'zn-(meim)'
353. 'zn-(meim)2'
354. 'zn-imidazolate'
355. 'zn-zif-8'

356. 'co(meim)2'
357. 'co(mim)2'
358. 'co-(meim)2'
359. 'co-imidazolate'
360. 'co-zif-67'
361. 'cobalt (ii) imidazolate'
362. 'cobalt imidazolate'
363. 'zif-67(co)'
364. 'zif-67-co'

365. 'uio-66'
366. 'uio-66(zr)'
367. 'uio-66-zr'
368. 'zirconium (iv) terephthalate'
369. 'zirconium terephthalate'
370. 'zr-bdc'
371. 'zr-uio-66'
372. 'zr6o4(oh)4(bdc)12'

373. 'ce-bdc'
374. 'ce-uio-66'
375. 'ce6o4(oh)4(bdc)12'
376. 'cerium (iv) terephthalate'
377. 'cerium terephthalate'
378. 'uio-66(ce)'
379. 'uio-66-ce'
380. 'uio-67(zr)'
381. 'uio-67-zr'

382. 'zirconium (iv) biphenyl-4,4'-dicarboxylate'
383. 'zirconium biphenyl-4,4'-dicarboxylate'
384. 'zr-bdc'
385. 'zr-uio-67'
386. 'zr6o4(oh)4(bpdc)12'

387. 'hafnium (iv) terephthalate'
388. 'hafnium terephthalate'
389. 'hf-bdc'
390. 'hf-uio-66'
391. 'hf6o4(oh)4(bdc)12'
392. 'uio-66(hf)'
393. 'uio-66-hf'

394. 'hafnium (iv) biphenyl-4,4'-dicarboxylate'
395. 'hafnium biphenyl-4,4'-dicarboxylate'
396. 'hf-bdc'
397. 'hf-uio-67'
398. 'hf6o4(oh)4(bpdc)12'
399. 'uio-67(hf)'
400. 'uio-67-hf'

401. 'copper (ii) 1,3,5-benzenetricarboxylate'
402. 'copper 1,3,5-benzenetricarboxylate'
403. 'cu-btc'
404. 'cu-hkust-1'
405. 'cu3btc2'
406. 'cubtc'
407. 'hkust-1'
408. 'hkust-1(cu)'
409. 'hkust-1-cu'
410. 'mof-199'

411. 'hkust-1(ru)'
412. 'hkust-1-ru'
413. 'ru-btc'
414. 'ru-hkust-1'
415. 'ru3btc2'
416. 'rubtc'
417. 'ruthenium (ii) 1,3,5-benzenetricarboxylate'
418. 'ruthenium 1,3,5-benzenetricarboxylate'

419. 'chromium (ii) 1,3,5-benzenetricarboxylate'
420. 'chromium 1,3,5-benzenetricarboxylate'
421. 'cr-btc'
422. 'cr-hkust-1'
423. 'cr3btc2'
424. 'crbtc'
425. 'hkust-1(cr)'
426. 'hkust-1-cr'