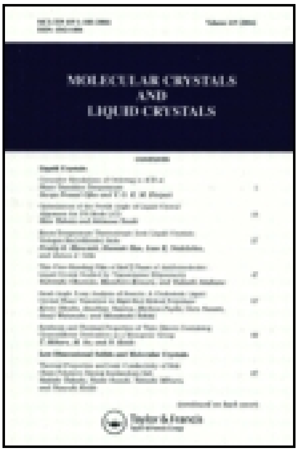


Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl19

Simple and Excellent Preparation of Polymorphic Crystals of 4,5-Bis(4-Methoxyphenyl)-2-(3-Nitrophenyl)-1H-Imidazole

Yoshiko Sakaino [a], Kyoko Kishi [a], Yoshinobu Inouye [b] & Takeshi Yamanobe [c]

[a] Department of Chemistry, Faculty of Education, Gunma University, Maebashi, 371, Japan

[b] Department of Chemistry, University of Tsukuba, Ibaraki, 305, Japan

[c] Department of Chemistry, Faculty of Engineering, Gunma University, Kiryu, 375

Version of record first published: 04 Oct 2006.

To cite this article: Yoshiko Sakaino, Kyoko Kishi, Yoshinobu Inouye & Takeshi Yamanobe (1996): Simple and Excellent Preparation of Polymorphic Crystals of 4,5-Bis(4-Methoxyphenyl)-2-(3-Nitrophenyl)-1H-Imidazole, Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals, 277:1, 259-269

To link to this article: http://dx.doi.org/10.1080/10587259608046030

Mol. Cryst. Liq. Cryst., 1996, Vol. 277, pp. 259–269
Reprints available directly from the publisher
Photocopying permitted by license only

SIMPLE AND EXCELLENT PREPARATION OF POLYMORPHIC CRYSTALS OF 4,5-BIS(4-METHOXYPHENYL)-2-(3-NITROPHENYL)-*1H*-IMIDAZOLE

Yoshiko Sakaino and Kyoko Kishi
Department of Chemistry, Faculty of Education, Gunma University, Maebashi , 371, Japan
Yoshinobu Inouye
Department of Chemistry, University of Tsukuba, Ibaraki, 305, J apan
Takeshi Yamanobe
Department of Chemistry, Faculty of Engineering, Gunma University, Kiryu, 375.

Abstract The title imidazole **1** forms inclusion complexes with ethyl acetate, tert-BuOH, and benzene. The complexes lost their guest molecule to give polymorphic crystals **A**, **B**, **C** and **D** in a pure state. **A** is red plates, **B** is yellow needles, **C** is pale yellow silky needles and **D** is light yellow cottony needles. The polymorphic crystal turns to the other one when the crystal contacts with organic vapor. The reactivity decreased with **B>D>C>A**. Structure and reactivity of the polymorphic crystals are discussed on the type of hydrogen bonding and on molecular arrangements in crystals.

INTRODUCTION

In previous paper we reported that 4,5-bis(4-methoxyphenyl)-2-(4-nirophenyl) *1H*-imidazole crystallized in various colored states by different crystallization conditions[1]. To expand this research, 4,5-bis(4-methoxyphenyl)-2-(3-nitrophenyl)-1H-imidazole **1** was prepared. The imidazole **1** also crystallized in various colored states, from yellow to red by changing crystallization solvents[1]. Among nine crystals obtained, three (**A**,**C**, and **D**)were polymorphisms of **1**, and other six were inclusion complexes with solvents. By heating of crystal **2** which is inclusion complex of **1** with ethyl acetate, polymorphic crystal **B** was obtained.. However, preparations of pure polymorphic crystals, **A**,**B**,**C**, and **D** were difficult because of small energy differences between them. Recently we found that some inclusion complexes of **1** lost the guest molecule in organic vapor to give pure polymorphic crystals. Proper combination of the inclusion complex and organic vapor gave pure polymorphic crystals rapidly. On the other hand, the polymorphic crystals turned to the other polymorphic crystal when the crystal contacts with organic vapor. This report describes preparation and properties of the polymorphic crystals by transformation of inclusion complexes in organic vapor.

PREPARATION AND TRANSFORMATION OF CRYSTALS IN ORGANIC VAPOR

1 formed inclusion complexes with solvents[2]. TABLE I shows the inclusion complexes, their host-guest molar ratio and crystal color. At first we obtained the polymorphic crystals **A**, **C**, and **D** by changing recrystalization solvents. That is, **A** was obtained from EtOH as red plates. **C** was obtained from diluted dioxane-H_2O as pale yellow silky needles, and **D** was obtained from $CHCl_3$ as yellow cottony needles. However, crystals **C** and **D** were often contained small amount of the other polymorphic crystals or inclusion complexes. **B** was obtained by heating of **2** at 80°C under 2 Torr. Inspite of careful heating of **2**, **B** often contained small amount of **C** probably due to small energetic difference between **B** and **C**. Therefore, preparation of pure polymorphic crystals by the recrystallization was very difficult except for preparation of **A**.

Recently we found those inclusion complexes of **1** liberate the guest molecule in organic vapor to give pure polymorphic crystals. That is, crystal **3** that is inclusion complex with tert-BuOH, turned to **B** in ether vapor and **4** that is inclusion complex with benzene, changed to **C** in EtOH vapor. Then, **3** also changed to **D** in $CHCl_3$ vapor. TABLE I shows transformation of the inclusion complexes to polymorphic crystals accompanied color change in organic vapor. Elemental analyses of the crystals **A**,**B**,**C**, and **D** gave same analytical data corresponding to the formula of **1**, $C_{23}H_{19}N_3O_4$ and the same rf value, 0.53 on tlc chromatograms ($CHCl_3$: acetone = 15 : 1). However distinctly different DS C diagrams, IR and solid state CMR spectra were recorded.

Solid state absorption spectra of the polymorphic crystals showed very broad absorption in the visible region. To clarify the difference of the crystal color, two spectra were subtracted to give the difference spectra; absorption maxima, **A**-**C**, at 511 nm; **B**-**C**, at 485 nm; and **D**-**C**, at 492 nm. Absorption spectra of **2** in the solid state was almost same as that of **B** in the visible region. The result show that the guest molecule in **2** gives no effect on the coloration.

DSC DIAGRAMS

Thermal changes on DSC measurements of the polymorphs and the inclusion complexes are shown in TABLE II. **A** turns to **D** at 231°C and **B** changes to **C** near 111°C. **C** showed small endothermic change at 142°C that appeared reversibly by changing temperature in the range of 120° and 160°C. Small endothermic change at 227.4°C was estimated to be transformation of **C** to **D**. **D** did not transform into any other polymorphism during heating process up to the melting at 242.5°C. Thus **D** is the most stable in the four polymorphic crystals on elevated temperature. Inclusion complex **2** showed very complicated thermal change at near 110°C. Small two exothermic changes appeared at 102.1° and 106.3°C, and endothermic change was observed at 107.1°C. We assumed the thermal changes as release of guest molecule,

TABLE I Formation of Polymorphic Crystals in Organic Vapor

inclusion (guest)	molar ratio host:guest	crystal color	operated vapor	product (crystal color)
2 (AcOEt)	3 : 1	golden-yellow	EtOH	**A** (red)
3 (t-BuOH)	1 : 1	orange	Ether	**B** (yellow)
4 (Banzene)	2 : 1	yellow	EtOH	**C** (pale yellow)
3 (t-BuOH)	1 : 1	orange	$CHCl_3$	**D** (light yellow)

TABLE II. Enthalpy Changes Δ H(KJ mol^{-1}) and Transformation by the Heating, (-) : endo-, (+) : exo-thermic change

Cryst	removal of guest	°C (ΔH),KJmol^{-1}			melting, °C (ΔH)
A	-			231.1 (-9.0)	243.1 (-35.5)
B	-	111.4 (0.6)	138.3 (-1.1)		243.2 (-32.9)
C	-		142.0 (-7.8)	227.4 (-0.2)	243.3 (-31.7)
D	-				242.5 (-32.4)
2	102.1,106.3 (1.75)	107.1 (-3.8)	145.4 (-4.1)		242.8 (-31.0)
3	105.4 (-53.3)		145.6(-5.3)		242.8 (-27.6)
4	101.8 (-25.3)		147.5 (-2.2)		242.6 (-30.9)
5	84 84.5 (sh), (-64.3)		144.1 (-3.3)	220.4 (-1.91)	343.3 (-29.2)

formation of **B**, and transformation of **B** to **C** respectively. The other endothermic changes at 145.4°, and 242.8°C are due to transformed **C**. **3** released the guest molecule at 105°C to give **C**. **4** lost the guest molecule at 102°C to afford **C**. The transformation upon the heating was confirmed by IR measurements.

CRYSTAL STRUCTURE of A, B, 2 AND 3

Molecular structure of polymorphic crystals **A** and **B**, inclusion complexes **2** and **3**, were determined by X-ray crystal analyses.

FIGURE 1 shows stereoscopic view of the crystals **A**, **B** and **3** and FIGURE 2 shows their hydrogen-bonding networks, which are represented as dotted lines.

In **A**, two independent molecules are present in an asymmetric unit and the oxygen atom of the niro group in one molecule bonds to the H-N of the imidazole ring in the other molecule. Two kinds of hydrogen-bond, which differ slightly in X---Y distances [3.199 and 3.138 Å] and X-H---Y angles [170 and 164°] were observed and these agree with the presence of two N-H absorptions at 3422 and 3384 cm^{-1} in solid IR spectra of **A**.(TABLE III). The hydrogen-bond of the nitro group agrees with the facts that one of the $\nu_s NO_2$ in IR shifts to lower than the other crystals and that one N-O bond of the nitro group in **A** lengthens to 1.24 Å as compared to the normal value (1.22Å) of nitro benzene. **A** packs as layer parallel along b-axis (FIGURE 1) and the nitro phenyl ring is faced with the imidazole ring in a next layer. The shortest interatomic distance between these rings was 3.479Å. The interlayer spacing is shorter than the Van der Waals distances(3.5Å) and thus weak π–π interaction can be considered. The red color of **A** can be estimated from the intermolecular C-T effect from imidazole ring to the nitrophenyl ring in addition to the planarity of the molecule.

B has another type of hydrogen-bondings. The N-H of the imidazole ring bonds to the -N= of the other imidazole ring. The host molecules are arranged in cross fashion as shown in FIGURE 2. The packing patterns in FIGURE 1 show the presence of holes like chimney. **2** lost the guest molecules without any change in the position of the host molecule to give **B**. Unmobile of the crystal structure of host molecule by removance of guest molecule was also confirmed by agreement of two solid state CMR spectra between **B** and **2** . The holes are represented as a circle with a diameter of 4.7Å in FIGURE 1. Preliminary crystal structure analysis of **2** in a capillary showed that the position of the host molecules were essentially similar with that in **B** but larger electron densities remained at positions in the holes though the molecular structure of ethyl acetate could not yet been clarified probably due to the disorder of this molecules.

In **3**, the oxygen atom of t-BuOH bonds to the H-N but the alcoholic hydrogen atom bonds to the -N= of another imidazole ring of ajacent molecule. Thus, two imidazole

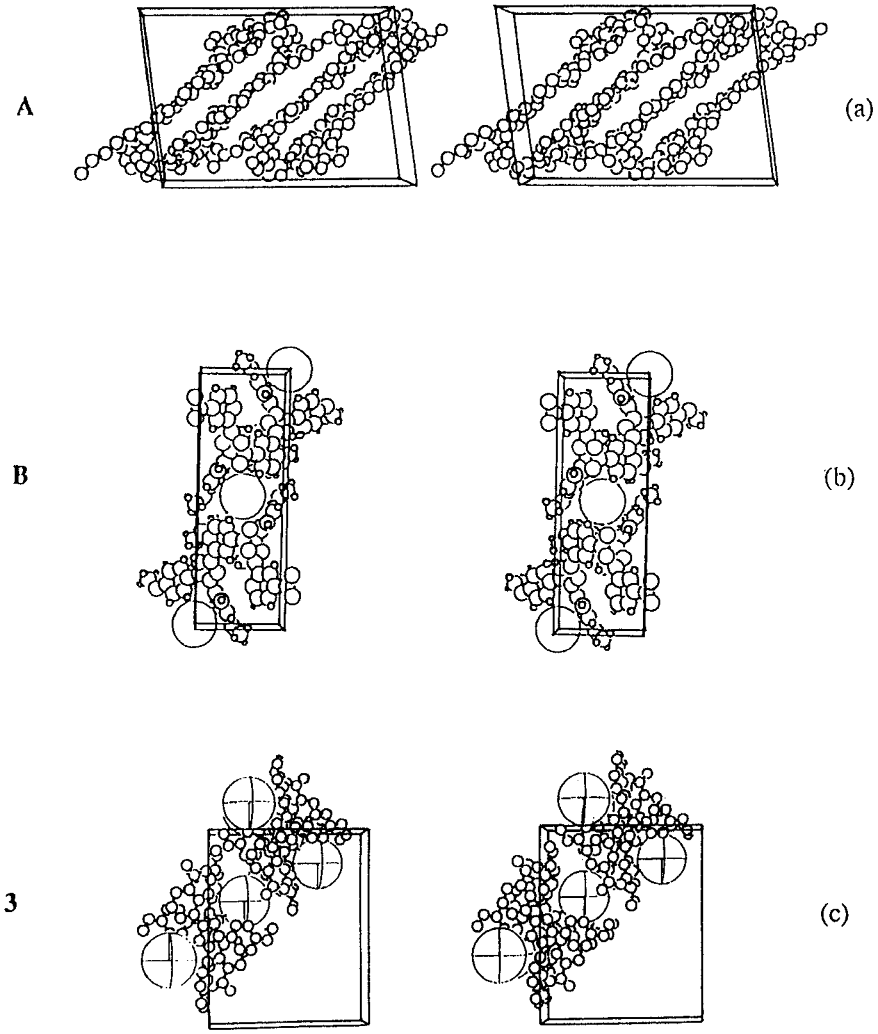


FIGURE 1. Sereoscopic view (a) : **A**, (b) : **B**, (c) : **3**.

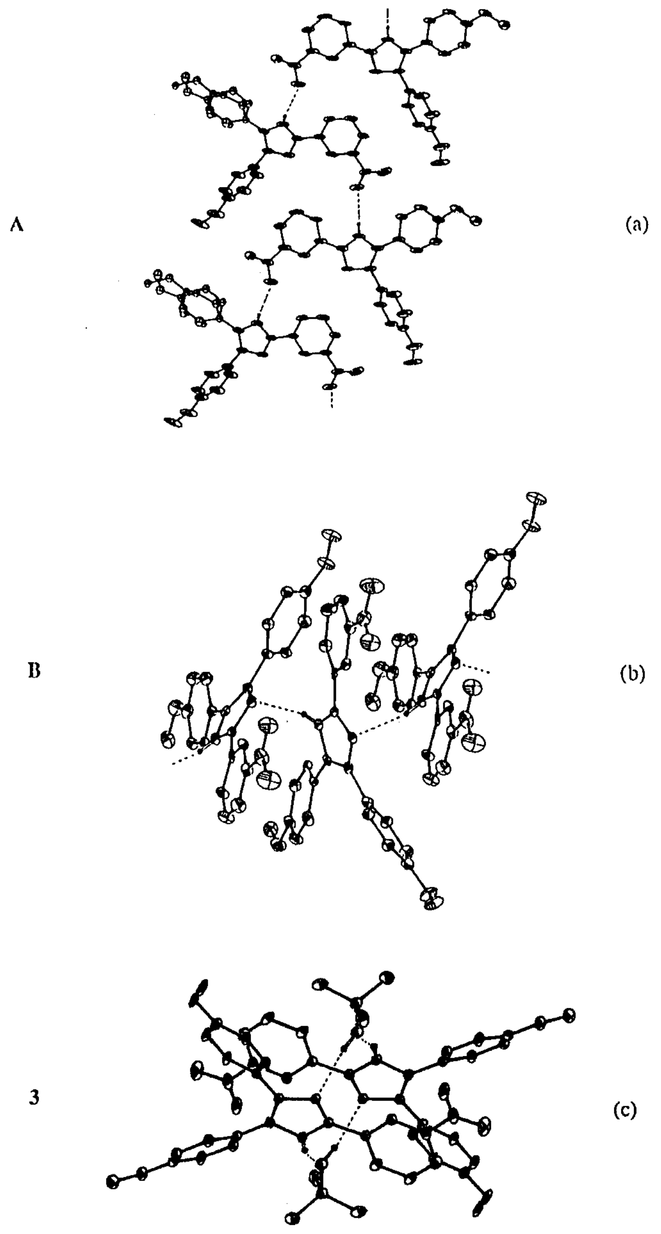


FIGURE 2 ORTEP drawing of the molecules and hydrogen-bonding networks. Non-hydrogen atoms are represented by thermal ellipsoids at 20% probability level and those in the disordered part by isotropic circles. Hydrogen-bonds are represented by a dotted line, (a):**A**, (b):**B**, (c):**3**.

TABLE III Characteristic IR Absorptions

	in C4Cl6 (cm^{-1})	in Nujol (cm^{-1})		
	νNH	$\nu_{as}NO_2$	$\nu_{s}NO_2$	δCH (out ofplane)*
A	3422(m) 3384(m)	1525(s) 1515(s)	1351(s) 1341(s)	836(m-s) 830(s)
B	3350-2450 (br,m)	1527(s) 1517(s)	1348(s)	838(m-s) 830(s)
C	3300-2500 (br,m)	1529(s) 1520(s)	1350(s)	832(s)
D	3350-2400 (br,m)	1530(s) 1517(m-s)	1351(s)	833(s)

sh:shoulder, br:broad, s:strong, m:medium, w:weak, *:$MeOC_6H_4$-

TABLE IV IR Spectral Change by Heating up to 150°C

	B(26° C)	C(26°C)	**C**(150 °C)	**D**(26 °C)
das Me	1469(m) 1465(m)	1470(m) 1465(sh)	1463(m)	1465(m)
drocking, Me	1183(s) 1175(m-s)	1185(m) 1180(m) 1173(s)	1174(s)	1173(m-s)
ν_{as}=C-O-C	1247(br,s)	1253(s)	1251(s)	1251(s)
ν_{s}=C-O-C	1034(s)	1036(m) 1025(m)	1034(m)	1036(m-s)

TABLE V Transformation of **A**,**B**,**C**, and **D** in organic vapor for 1 hour, no: no reaction, ( ) : content, %

organic vapor	**A**	**B**	**C**	**D**
MeOH	no	**A**(80.5)	no	**A**(13.8),**C**(74.7)
MeCHO	no	no	**B**(100)	no
MeCOMe	no	**D**(100)	**D**(100)	no
AcOEt	no	**2**(100)	**B**(22)	**2**(89.0)
$CHCl_3$	no	**D**(100)	**D**(4)	no

molecule lie one upon another by connecting with two t-BuOH to have a center of symmety at a point between two imidazole ring.

IR SPECTRA

C and **D** did not give suitable crystals for X-ray analysis. Therefore, molecular structures of these crystals were discussed by IR and solid state CMR spectra. TABLE III shows characteristic IR absorptions of these crystals and TABLE IV shows IR spectral change of **C** and **D** by heating up to 150°C.

IR spectra of **C** showed broad ν_{NH} absorption between 3300-2500 cm^{-1}. The ν_{NH} absorption shows formation of hydrogen bonding of the type -NH---N=, the NH of one molecule bonds to the nitrogen -N= on the imidazole ring of the other molecule[3]. **C** showed splitted $\nu_{as}NO_2$ absorptions at 1529(s) and 1520(s) but one ν_sNO_2 at normal position, 1350(s) cm^{-1}. Isolated δCH due to m-nitrophenyl group also appeared at normal position. The results show that neither an intermolecular CT complex formation betwen imidazole ring and m-nitrophenyl ring nor hydrogen bonding between NH hydrogen and nitro oxygen that **A** formed.[3,4] **C** showed splitted absorptions in (δ_{as}Me), (δMe rocking), (ν_{as}=C-O-C), and (ν_s=C-O-C) bands at room temperature. On elevation of temperature up to 150°C, these absorptions combined into one but reverted to the original absorptions on cooling. The splitting shows unequivalence of methoxyl groups of the p-methoxyphenyl groups. One of the two OMe groups may considerably be twisted from the methoxyphenyl plane. On the other hand, δCH(out of plane) due to p-methoxyphenyl groups and ν_{as}=C-O-C absorptions were not splitted The twist of methoxyl groups may be resulted by molecular arrangement of the imidazole that are fixed by the hydrogen bonding. When the hydrogen bonding is broken on elevation of the temperature, molecules are released from the restriction and move to form more planar structure. On cooling, the hydrogen bond is again formed, and the mehoxyl groups are twisted again by formation of original structure. Subtraction of the IR spectrum of the initial state from the recooled one, showd no absorption in that region. Reversible endothermic change near 141°C observed in DSC measurement is attributable to break of the hydrogen bonds and conformational change of the methoxyl group on p-methoxyphenyl groups. At higher temperature above 227°C, **C** turned to **D**.

IR spectrum of **D** is very resemble to that of **C**. That is, **D** showed broad ν_{NH} absorption between 3350-2400 cm^{-1}, splitting of $\nu_{as}NO_2$ at 1529(s) and 1517(m-s), normal position of isolated δCH due to m-nitrophenyl group at 906 cm^{-1}, no splitting of δCH (out of plane) due to p-methoxyphenyl groups at 833 cm^{-1} in IR spectra. However, δ_{as}Me, $\delta_{rocking}$, Me and ν_s=C-O-C absorptions in **D** did not splitted. The results show that **D** forms hydrogen bonding the type of NH---N=, and that two p-methoxyphenyl groups are rotating similar extent to the imidazole plane. The methoxyl groups on p-methoxyphenyl ring may not twist toward the aromatic ring contrast to **C**.

SOLID STATE CMR

2 gave same CMR spectrum as that of **B** except for the signal due to ethyl acetate. The result shows that host molecule in **2** forms almost same molecular structure as that of **B**. The methoxyl carbons in all polymorphic crystals appeared at different chemical shifts. But **C** showed the methoxyl signals at δ55.05 and 52.90 ppm and the latter signal is situated at higher field than that of the other polymorphs. On elevation of temperature up to 140°C, the signal combined into one, which appeared at 55.63 ppm. The signal reverted to original on cooling. The results may show that at least one of the methoxyl groups in **C** considerably restricted because more packed structure of the crystal is forced by the hydrogen bonding. On elevation of temperature above 140°C, the hydroen bonding were broken to form more flexible structure. This is the same conclusion as that derives from IR. From these results we asumed the molecular structure of **C** as shown in SHEMA 2.

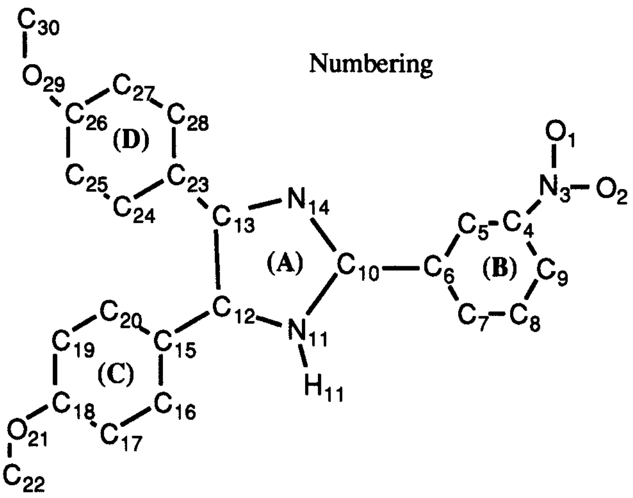
The methoxyl carbons in **D** showed very small splitting at δ55.34 and 54.85 ppm. The latter signal is situated at lower field than that of **C**. From the result we assumed OMe groups in **D** may not so restricted that contrast to **C**. Therefore, we assumed the molecular structure of **D** as written in SHEMA 2. Details on CMR spectra of the crystals will be reported in another paper.[5]

BEHAVIOR IN ORGANIC VAPOR OF THE CRYSTALS

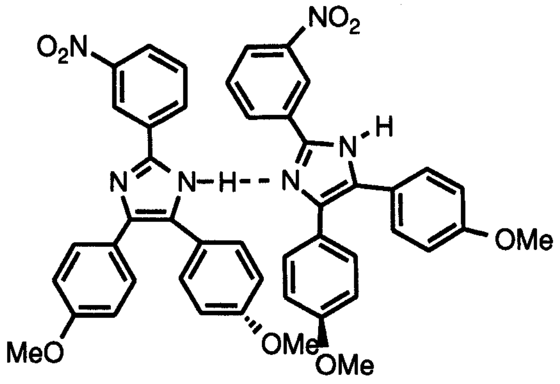
When **B** was put in n-alcohol vapor, the crystal changed to red. IR spectra and DSC diagrams showed that the color change is due to transformation of **B** to **A**. **B** was the most reactive to EtOH vapor among four polymorphic crystals. For example, about 90% of **B**, 11% of **D** were changed to **A** in EtOH vapor for 1 hr but **C** did not transform to **A** even though the crystal was put in saturated EtOH vapor for 2 weeks. Transformation of **B** to **A** was also observed in other n-alcohol vapor. Rates of the transformation decreased in the order, MeOH>EtOH>n-PrOH>n-BuOH. **B** colored to red at once when it was put in MeOH vapor but if the crystal was put in the vapor for 1 hour, about 20% of inclusion complex **5** (molar ratio, **1**:MeOH= 1:2) was contaminated. **C** did not transform in EtOH vapor. **C** never transformed to **A** in t-BuOH vapor but gradually turned to **3**.

2 rapidly changed to **A** in EtOH vapor but **A** never changed to **2** in ethyl acetate vapor. **3** rapidly changed to **B** in ether vapor, and **4** changed to **C** in EtOH vapor. TABLE V shows transformation of the polymophic crystals in other organic vapor.

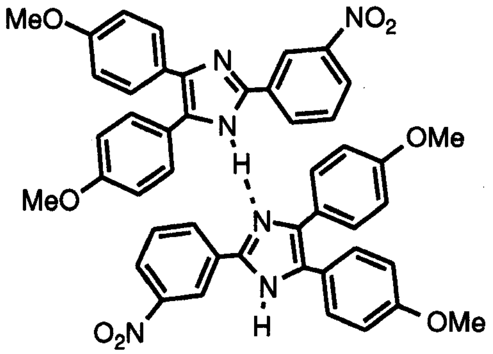
SHEMA 1



SHEMA 2



C



D

The crystal structure of **A** clarified the presence of no cavity in the crystal where any alcohol vapor could enter. On the other hand, **B** has holes like chimney along c axis. The inclusion complex **3** holds guest but the space for t-BuOH does not form straight column. Both of wide and narrow part exist in the column (see FIGURE 1). The narrow part diminishes the exchange of gest in **3**. Ether molecule pulls out t-BuOH molecule from host but can not pass through the cavity. in the crystal. Moreover, it can not form stable hydrogen bonding with the host because of high volatility.

From the result we concluded that when an alcohol vapor is passed through the cavity of the crystals, transformation of the polymophic crystal takes place. On the other hand, if molecules of the vapor can not easily pass through the cavity, or if the molecule of vapor can form stable hydrogen bond with the host, and if the vapor molecule can form CT complex with the host, inclusion complex is formed.

REFERENCES

1. Y.Sakaino, R.Fujii, and T.Fujiwara, J.Chem.Soc.,Perkin Trans. 1, 2852 (1990).
2. Y.Sakaino, Y.Inouye, H.Kakisawa, and T.Takizawa, Proc.VIII, ICCOSS; Mol. Cryst. Liq.Cryst. Inc. Nonlin. Opt., 161, 255 (1988).
3. a.D.M.White and J.Sonnenberg, J.Org.Chem., 29, 1928(1964).
   b.M.R.Grimmt, Advances in Imidazole Chemistry; A.R.Katritzky, A.J.Boulton, Eds.; Advances in Heterocyclic Chemistry Series No.12, (Academic Press: New York and London, 1970), p.144.
4. Y.Sakaino, T.Takizawa, Y.Inouye, and H.Kakisawa, J.Chem.Soc., Perkin Trans.2, 1623 (1986).
5. Y.Yamanobe, T.Komoto and Y.Sakaino, This Proceeding, XII, ICCOSS, (1995).