Preparation of New Nitrogen-Bridged Heterocycles 67.[1] Syntheses of α,α′-Bis[(thieno[3,4-*b*]indolizin-3-yl)thio]-*o*-, *m*-, and *p*-xylene Derivatives and Their Conformational Structures

Akikazu KAKEHI,*[,a] Hiroyuki SUGA,[a] Yukihisa OKUMURA,[a] Masatoshi SHINOHARA,[a] Tomonao KAKO,[a] Takeshi SEKIGUCHI,[a] and Motoo SHIRO[b]

[a] *Department of Chemistry and Material Engineering, Faculty of Engineering, Shinshu University; Wakasato, Nagano 380–8553, Japan: and* [b] *Rigaku X-Ray Research Laboratory, Rigaku Corporation; Matsubara-cho, Akishima, Tokyo 196–0003, Japan.* Recieved July 21, 2009; accepted September 4, 2009; published online September 14, 2009

The alkaline treatment and dehydrogenation of pyridinium salts, formed from the *S*-alkylations of 3-(1-pyridinio)thiophene-2-thiolates with α,α-dibromo-*o*-, *m*-, or *p*-xylene, provided the corresponding α,α′-bis[(thieno[3,4-*b*]indolizin-3-yl)thio]-*o*-, *m*-, and *p*-xylene derivatives in low to good yields. Both ^{1}H-NMR and UV–Vis spectra of these products supported distinctly the predominance of the gauche–gauche conformation in relation to the two sulfide linkages as the spacer in these molecules. On the other hand, the X-ray analyses indicated the expected gauche–gauche conformation for the *m*- and the *p*-xylene derivatives, but the anti–anti one for the *o*-xylene derivative.

Key words cyclization; arene–arene interaction; thieno[3,4-*b*]indolizine; sulfide linkage; X-ray analysis

Intramolecular and intermolecular attractive interactions such as arene–arene, arene–π, and cation–π interactions are important means for the conformational control of many organic molecules and have been extensively investigated in the fields of molecular recognition[2—5] and in the stereoselective or asymmetric syntheses.[2,6—8] Recently, we have reported facile and effective syntheses of 3-(arylmethylthio)-,[9—11] 3-(allylthio)-,[12] 3-(propargylthio)-[12] and 3-(acylmethylthio)-thieno[3,4-*b*]indolizine derivatives[13] and the presence of their intramolecular arene–arene or arene–π interaction. In addition we disclosed that the gauche conformation in the relation of the sulfide linkage in these molecules is more stable than the anti one, because the longer carbon–sulfur bond in comparison with a carbon–carbon bond does not only dramatically reduce the steric hindrance, but the favorable intramolecular arene–arene or arene–π interactions in their gauche forms are also possible. This was supported by their molecular orbital calculations using MOPAC PM3,[14] but the energy differences between the gauche and anti conformations were generally low (<1.5 kcal/mol).[11—13] As an extension of this work we are interested in the syntheses and the structure of the title compounds in which the gauche–gauche, gauche–anti, and anti–anti comformations are possible as shown in Fig. 1. For example, such molecules could be present as a gauche–gauche conformation if both thieno[3,4-*b*]indolizine rings are attracted by the electron-rich benzene ring and as a gauche–anti one if only one thieno[3,4-*b*]indolizine ring is interacted with it. In contrast, the increased steric hindrance between the central benzene ring and the two bulky thieno[3,4-*b*]indolizine rings might make these molecules to take the more strain-free anti–anti conformation. In this paper we report the preparation of the title compounds and discuss their conformations by their spectral and X-ray analyses.

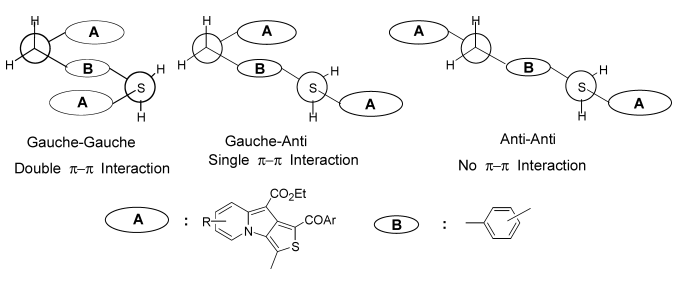


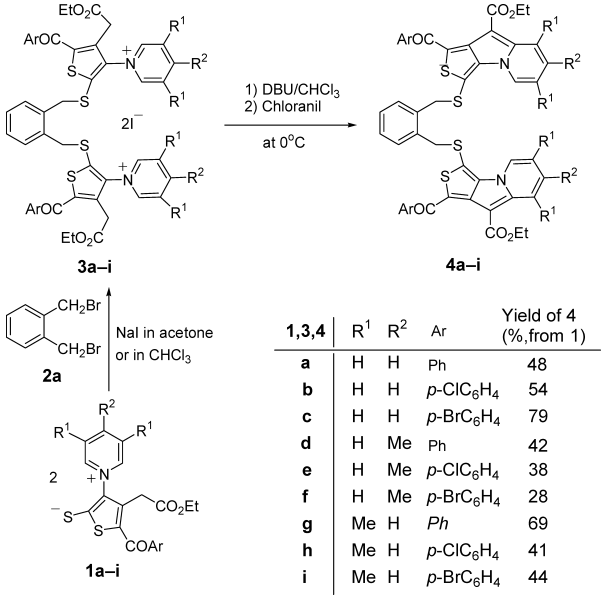
Fig. 1. Possible Three Conformations of α,α-Bis(thieno[3,4-*b*]indolizin-3-yl)-*o*-, *m*-, and *p*-Xylene Derivatives

Results and Discussion

Preparation of α,α′-Bis[(thieno[3,4-*b*]indolizin-3-yl)thio]-*o*-, *m*-, and *p*-xylene Derivatives The *S*-alkylations of 5-arylcarbonyl-4-ethoxycarbonylmethyl-3-(1-pyridinio)- (**1a**—**c**) and 3-[1-(4-methylpyridinio)]thiophene-2-thiolate (**1d**—**f**)[9,10] with a half equivalent of α,α′-dibromo-*o*-xylene (**2a**) in the presence of a large excess of sodium iodide in acetone, followed by the treatment of the resulting pyridinium salts **3a**—**f** with 1,8-diazabicyclo[5.4.0]undec-7-ene (DBU) and then chloranil at 0 °C in chloroform afforded the corresponding α,α′-bis[(1-arylcarbonyl-9-(ethoxycarbonyl)thieno[3,4-*b*]indolizin-3-yl)thio]-*o*-xylene (**4a**—**f**) in 28—79% yields. Similarly, the dehydrohalogenation and dehydrogenation of the corresponding pyridinium salts **3g**—**i**, obtained from the *S*-alkylations of 3-[1-(3,5-dimethylpyridinio)]thiophene-2-thiolate (**1g**—**i**) with **2a** in chloroform, gave α,α′-bis[(1-arylcarbonyl-9-ethoxycarbonyl-6,8-dimethylthieno[3,4-*b*]indolizin-3-yl)thio]-*o*-xylene (**4g**—**i**) in 69, 41, and 44% yields, respectively. These results are shown in Chart 1.

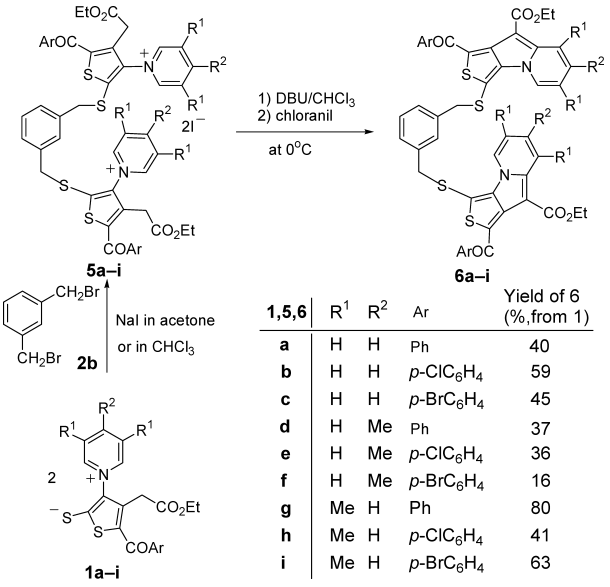
Similar reactions of pyridinium salts **5a**—**i** and **7a**—**i** which were prepared from the *S*-alkylations of 3-(1-pyridinio)thiophene-2-thiolate (**1a**—**i**) and α,α′-dibromo-*m*-xylene (**2b**) or α,α′-dibromo-*p*-xylene (**2c**) provided the corresponding α,α′-bis[(1-arylcarbonyl-9-(ethoxycarbonyl)-thieno[3,4-*b*]indolizin-3-yl)thio]-*m*-xylenes (**6a**—**i**) in 16—80% yields or α,α′-bis[(1-arylcarbonyl-9-(ethoxycarbonyl)-thieno[3,4-*b*]indolizin-3-yl)thio]-*p*-xylenes (**8a**—**i**) in 7—97% yields, as seen in Charts 2 and 3. The low yields for products **4d**—**f**, **h**, **i**, **6a**, **c**—**f**, **h**, and **8a**, **b**, **d**—**f** are mainly attributable to the sluggish *S*-alkylations of the 3-(1-pyridinio)thiophene-2-thiolates (**1a**—**i**) and most of these reactions did not complete even under more prolonged heating

* To whom correspondence should be addressed. e-mail: xkakehi@ shinshu-u.ac.jp



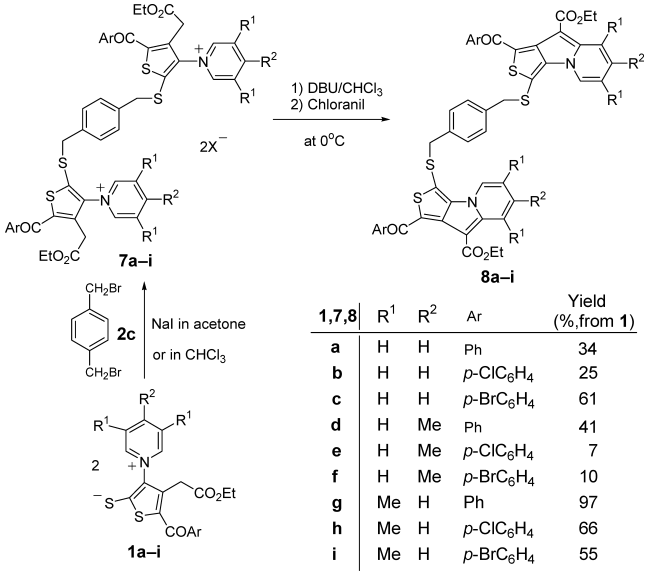
1,3,4	R^1	R^2	Ar	Yield of 4 (%,from 1)
a	H	H	Ph	48
b	H	H	*p*-ClC_6H_4	54
c	H	H	*p*-BrC_6H_4	79
d	H	Me	Ph	42
e	H	Me	*p*-ClC_6H_4	38
f	H	Me	*p*-BrC_6H_4	28
g	Me	H	*Ph*	69
h	Me	H	*p*-ClC_6H_4	41
i	Me	H	*p*-BrC_6H_4	44

Chart 1



1,5,6	R^1	R^2	Ar	Yield of 6 (%,from 1)
a	H	H	Ph	40
b	H	H	*p*-ClC_6H_4	59
c	H	H	*p*-BrC_6H_4	45
d	H	Me	Ph	37
e	H	Me	*p*-ClC_6H_4	36
f	H	Me	*p*-BrC_6H_4	16
g	Me	H	Ph	80
h	Me	H	*p*-ClC_6H_4	41
i	Me	H	*p*-BrC_6H_4	63

Chart 2



1,7,8	R^1	R^2	Ar	Yield (%,from **1**)
a	H	H	Ph	34
b	H	H	*p*-ClC_6H_4	25
c	H	H	*p*-BrC_6H_4	61
d	H	Me	Ph	41
e	H	Me	*p*-ClC_6H_4	7
f	H	Me	*p*-BrC_6H_4	10
g	Me	H	Ph	97
h	Me	H	*p*-ClC_6H_4	66
i	Me	H	*p*-BrC_6H_4	55

Chart 3

conditions over 2 weeks.

The elemental analyses of products **4a**—**i**, **6a**—**i**, and **8a**—**i** were in good accord with our proposed compositions and the IR spectra showed a characteristic α,β-unsaturated ester carbonyl band (1663—1721 cm^{-1}) and an arylcarbonyl one (1599—1638 cm^{-1}). The ^{1}H-NMR spectra of products **4a**—**i**, **6a**—**i**, and **8a**—**i** exhibited only one set of signals for the two thieno[3,4-*b*]indolizine rings in these molecules, and this fact indicated the presence of a symmetric element in these molecules. The chemical shifts for the protons and the methyl protons at the 5- and 6-positions on the thieno[3,4-*b*]indolizine ring were significantly shifted to higher magnetic regions (*ca.* δ 0.12—0.26) in comparison with those of ethyl 3-(methylthio)thieno[3,4-*b*]indolizine-9-carboxylates (**9a**—**c**),[15] and these values of the chemical shifts were almost comparable to those of ethyl 3-(benzylthio)thieno[3,4-*b*]indolizine-9-carboxylates (**10a**—**c**)[10] (see Table 1). Similar high-field shifts (*ca.* δ 0.10—0.36) for the phenylene protons were observed in comparison with the chemical shifts (δ 6.99—7.14) of the aromatic protons in *o*-, *m*-, and *p*-xylene. In addition, the interaction between the 5-proton on the thieno[3,4-*b*]indolizine ring and the methine protons α to the methylene groups in the α,α-disubstituted xylene moieties were indicated in the differential nuclear Overhauser effect (NOE) measurements for **4g**, **6g**, and **8g**. For example, when the signal of the 5-proton in **4g** was irradiated, the higher of the two aromatic signals (δ 6.87) survived, though its intensity was not high. On the other hand, the 2-proton in the α,α-disubstituted *m*-xylene moiety of **6g** and the all aromatic protons in the α,α-disubstituted *p*-xylene moiety of **8g** showed strong differential NOE on the irradiation of the 5-proton. The UV–Vis spectra of products **4a**—**i**, **6a**—**i**, and **8a**—**i** each showed absorption band (near 430 nm) characteristics of an arene–arene interaction in this kind of system,[9—13] though the molar extinction coefficients of *o*-xylene derivatives **4a**—**i** were considerably lower than those of *m*- **6a**—**i** and *p*-xylene derivatives **8a**—**i**. These facts strongly supported the hypothesis that the structures of products **4a**—**i**, **6a**—**i**, and **8a**—**i** must be the gauche–gauche conformations in the solution state.

To obtain further information for the conformation of these molecules we next investigated their X-ray analyses. Unfortunately parent **4a**—**c**, **6a**—**c**, and **8a**—**c** and 7-methyl derivatives **4d**—**f**, **6d**—**f**, and **8d**—**f** showed very low solubility for many solvents such as chloroform and ethanol and we could not prepare suitable single crystals for them. However, the 6,8-dimethyl compounds **4g**—**i**, **6g**—**i**, and **8g**—**i** had considerable solubility in chloroform and we could obtain single crystals for the three compounds **4i**, **6g**, and **8g**. The ORTEP drawings[16] for these molecules (**4i**, **6g**, **8g**) are exhibited in Figs. 2—4. As seen in these figures, the conformations of the *m*-**6g** and the *p*-derivative **8g** were the gauche–gauche ones as suggested in the ^{1}H-NMR and the UV–Vis spectral analyses, but that of the *o*-derivative **4i** was shown to be the anti–anti conformation. The torsion angles about the sulfide linkage for **4i**, **6g**, and **8g** were 179.7(2)°, 85.1(2)°,

Table 1. Main ^{1}H-NMR Spectral Data of **4a**—**i**, **6a**—**i**, **8a**—**i**, and **9a**—**c** and the Shielding Effect to the Pyridine Ring Protons

No.[a,b]	C-5	C-6	C-7	C-8	CH_2	Phenylene	$\delta_{5\text{-H}}$	$\delta_{6\text{-H}}$	$\delta_{7\text{-H}}$	$\delta_{8\text{-H}}$
9a	8.96	6.73	7.31	8.20	2.68[c]		0.00	0.00	0.00	0.00
4a	8.79	6.52	7.21	8.11	4.18	6.84, 6.92	0.17	0.21	0.10	0.09
4b	8.80	6.55	7.23	8.10	4.20	6.86, 6.94	0.16	0.18	0.08	0.10
4c	8.80	6.56	7.24	8.11	4.20	6.87, 6.94	0.16	0.17	0.07	0.09
6a	8.77	6.55	7.23	8.12	3.93	6.74, 6.89, 6.99	0.19	0.18	0.08	0.08
6b	8.78	6.58	7.26	8.12	3.94	6.76, 6.91, 7.00	0.18	0.15	0.05	0.08
6c	8.78	6.58	7.26	8.12	3.94	6.76, 6.91, 7.00	0.18	0.15	0.05	0.08
8a	8.79	6.56	7.24	8.15	4.00	6.93	0.17	0.17	0.07	0.05
8b	8.80	6.59	7.27	8.14	4.02	6.94	0.16	0.14	0.04	0.06
8c	8.79	6.59	7.26	8.13	4.01	6.94	0.17	0.14	0.05	0.07
10a	8.79	6.51	7.23	8.13	4.12	7.08, 7.11—7.18	0.17	0.22	0.08	0.07

	C-5	C-6	C-7	C-8	CH_2	Phenylene	$\delta_{5\text{-H}}$	$\delta_{6\text{-H}}$	$\delta_{7\text{-Me}}$	$\delta_{8\text{-H}}$
9b	8.84	6.58	2.40	8.00	2.67[c]		0.00	0.00	0.00	0.00
4d	8.66	6.36	2.32	7.90	4.18	6.88, 6.94	0.18	0.22	0.08	0.10
4e	8.68	6.40	2.35	7.90	4.20	6.90, 6.96	0.16	0.18	0.05	0.10
4f	8.68	6.40	2.35	7.90	4.20	6.91, 6.96	0.16	0.18	0.05	0.10
6d	8.64	6.40	2.35	7.91	3.93	6.77, 6.90, 7.00	0.20	0.18	0.05	0.09
6e	8.67	6.43	2.37	7.92	3.94	6.79, 6.93, 7.02	0.17	0.15	0.03	0.08
6f	8.67	6.44	2.37	7.92	3.95	6.79, 6.94, 7.02	0.17	0.14	0.03	0.08
8d	8.66	6.43	2.35	7.95	3.99	6.94	0.18	0.15	0.05	0.05
8e	8.69	6.46	2.37	7.96	4.01	6.96	0.15	0.12	0.03	0.04
8f	8.68	6.45	2.37	7.95	4.01	6.95	0.16	0.13	0.03	0.05
10b	8.68	6.37	2.36	7.94	4.11	7.09, 7.12—7.19	0.16	0.21	0.04	0.06

	C-5	C-6	C-7	C-8	CH_2	Phenylene	$\delta_{5\text{-H}}$	$\delta_{6\text{-Me}}$	$\delta_{7\text{-H}}$	$\delta_{8\text{-Me}}$
9c	8.59	2.29	6.86	2.49	2.65[c]		0.00	0.00	0.00	0.00
4g	8.39	2.03	6.72	2.44	4.18	6.87, 6.97	0.20	0.26	0.14	0.05
4h	8.40	2.06	6.75	2.45	4.19	6.88, 6.98	0.19	0.23	0.11	0.04
4i	8.40	2.06	6.75	2.45	4.19	6.88, 6.99	0.19	0.23	0.11	0.04
6g	8.37	2.13	6.75	2.44	3.89	6.64, 6.88, 7.00	0.22	0.16	0.11	0.05
6h	8.38	2.14	6.77	2.44	3.90	6.62, 6.89, 7.01	0.21	0.15	0.09	0.05
6i	8.39	2.14	6.77	2.45	3.90	6.63, 6.90, 7.01	0.20	0.15	0.09	0.04
8g	8.41	2.15	6.77	2.46	3.98	6.94	0.18	0.14	0.09	0.03
8h	8.43	2.17	6.79	2.46	4.00	6.96	0.16	0.12	0.07	0.03
8i	8.43	2.17	6.79	2.46	4.00	6.96	0.16	0.12	0.07	0.03
10c	8.38	2.13	6.76	2.46	4.09	7.08, 7.12—7.23	0.21	0.16	0.10	0.03

a) The coupling constants are as follows: $J_{5,6}=J_{6,7}=6.8$—7.1 Hz, $J_{7,8}=9.0$—9.2 Hz, $J_{5,7}=1.2$—1.5 Hz, $J_{6,8}=1.0$—1.3 Mz. *b*) The ethoxycarbonyl signals (δ 0.93—1.20 (3H, t, J=6.9—7.2 Hz) and 3.62—4.02 (2H, q, J=6.9—7.2 Hz) and the arylcarbonyl signals (δ 7.20—8.00 (4H or 5H, m) were also appeared. *c*) Methyl group.

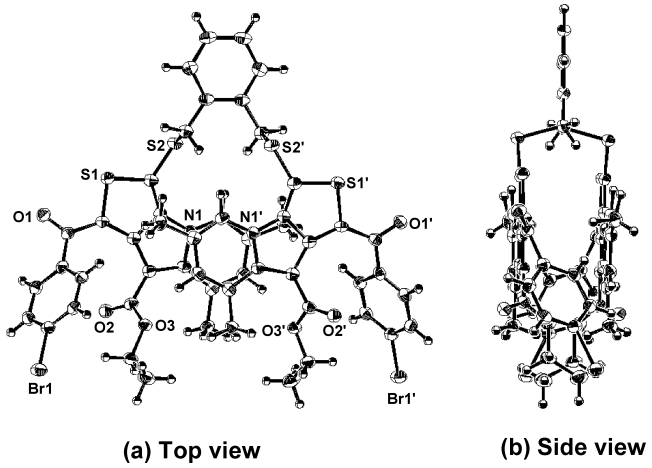


Fig. 2. ORTEP Drawing of the *o*-Xylene Derivative **4i**

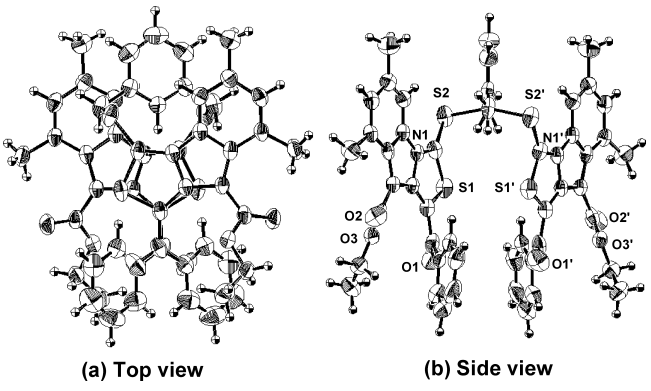


Fig. 3. ORTEP Drawing of *m*-Xylene Derivative **6g**

and 75.5(3)°, respectively. In the crystal structure of **4i** the two pyridine rings were the closest and the distance between them was in the range of 3.477—3.990 Å, while the distance between the 5-carbon on the thieno[3,4-*b*]indolizine ring and the aromatic carbons on the α,α-disubstituted *m*- (**6g**) or *p*-

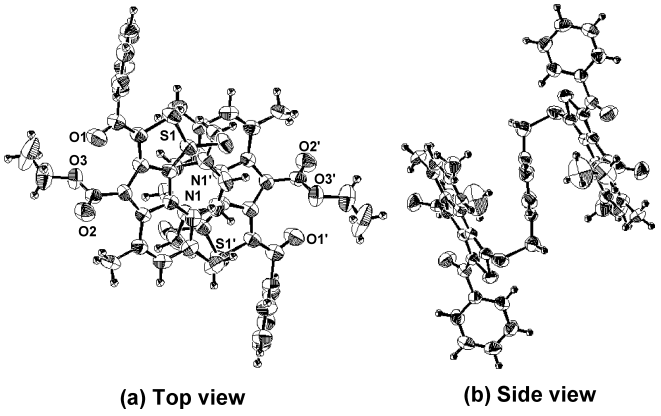


Fig. 4. ORTEP Drawing of *p*-Xylene Derivative **8g**

xylene (**8g**) were in the range of 3.506—4.264 or 3.547—3.824 Å, respectively.

In conclusion, we first prepared some compounds in which two thieno[3,4-*b*]indolizine nuclei were combined with the spacers involving an *o*-, *m*-, and *p*-phenylene moieties at the 3-position and investigated their conformations. All of the compounds indicated the predominance of the gauche–gauche conformation in the solution state as shown in their NMR and UV–Vis spectral indications, but only the *o*-xylene derivative **8g** appeared as the anti–anti conformation in the solid state.

Experimental

Melting points were measured on a Yamagimoto micro melting point apparatus and were not corrected. IR spectra were measured on a JASCO FT/IR-5300 IR spectrophotometer from samples as KBr pellets and UV–Vis spectra on a Shimadzu UV-2450 spectrophotometer. NMR spectra were measured on a JEOL JNM-GX400 (400 MHz for ^{1}H and 67.8 MHz for ^{13}C) in deuteriochloroform solutions. Tetramethylsilane was used as the internal standard and *J* values were given in Hz. Elemental analyses were performed on a Perkin-Elmer 2400 elemental analyzer.

Preparation of 5-Arylcarbonyl-3-(1-pyridinio)-4-(ethoxycarbonylmethyl)thiophene-2-thiolates (1a—i) The starting 5-arylcarbonyl-4-(ethoxycarbonylmethyl)-3-(1-pyridinio)thiophene-2-thiolates **1a**—**c** and 3-(4-methyl-1-pyridinio)thiophene-2-thiolates **1d**—**f** were prepared according to the procedure described in our previous paper.[10] However, the corresponding 3-(3,5-dimethyl-1-pyridinio)thiophene-2-thiolates (**1g**—**i**) could not be obtained by this procedure. So, we prepared them by the following method.

General Method: A solution of 3,5-lutidine (1.284 g, 12 mmol) and ethyl 4-chloroacetoacetate (1.645 g, 10 mmol) in chloroform (60 ml) was stirred at room temperature until the disappearance of ethyl 4-chloroacetoacetate was confirmed by tlc monitoring (5—7 d). To the reaction solution, carbon disulfide (1.140 g, 15 mmol), phenacyl bromide (10 mmol), and triethylamine (2.020 g, 20 mmol) were added under cooling, and the resulting mixture was then stirred in an ice bath for 12 h. The solution was moved in a separatory funnel and washed two times with cold water (each 50 ml) to remove triethylamine hydrochloride. After the $CHCl_3$ layer was dried over anhydrous sodium sulfate, it was concentrated at reduced pressure. Recrystallization of the residue from ethanol afforded the corresponding 3,5-dimethylpyridinium betaines **1g**—**i**. Some data for the new compounds **1g**—**i** are shown below.

5-Benzoyl-3-(3,5-dimethyl-1-pyridinio)-4-(ethoxycarbonylmethyl)thiophene-2-thiolate (**1g**): 59%; orange prisms (from ethanol); mp 167—168 °C. IR (KBr) cm^{-1}: 1715, 1628. ^{1}H-NMR ($CDCl_3$) δ: 1.25 (3H, t, J=7.1 Hz, $OCH_2C\underline{H}_3$), 2.59 (6H, s, 3,5-diMe), 3.75 (2H, s, CH_2), 4.15 (2H, q, J=7.1 Hz, $OC\underline{H}_2CH_3$), 7.43 (2H, m, Ph-H), 7.51 (1H, m, Ph-H), 7.83 (2H, m, Ph-H), 8.04 (1H, br s, 4-H), 8.47 (2H, br s, 2,6-H). *Anal.* Calcd for $C_{22}H_{21}NO_3S_2$: C, 64.21; H, 5.14; N, 3.40%; Found C, 64.29; H, 5.07; N, 3.36%.

5-(4-Chlorobenzoyl-3-(3,5-dimethyl-1-pyridinio)-4-(ethoxycarbonylmethyl)thiophene-2-thiolate (**1h**): 42%; orange prisms (from ethanol); mp 177—178 °C. IR (KBr) cm^{-1}: 1728, 1624. ^{1}H-NMR ($CDCl_3$) δ: 1.25 (3H, t, J=7.1 Hz, $OCH_2C\underline{H}_3$), 2.60 (6H, s, 3,5-diMe), 3.72 (2H, s, CH_2), 4.16 (2H, q, J=7.1 Hz, $OC\underline{H}_2CH_3$), 7.41 (2H, m, Ph-H), 7.78 (2H, m, Ph-H), 8.04 (1H, br s, 4-H), 8.46 (2H, s, 2,6-H). *Anal.* Calcd for $C_{22}H_{20}ClNO_3S_2$: C, 59.25; H, 4.52; N, 3.14%; Found C, 59.44; H, 4.52; N, 2.95%.

5-(4-Bromobenzoyl-3-(3,5-dimethyl-1-pyridinio)-4-(ethoxycarbonylmethyl)thiophene-2-thiolate (**1i**): 55%; orange prisms (from ethanol); mp 174—175 °C. IR (KBr) cm^{-1}: 1730, 1624. ^{1}H-NMR ($CDCl_3$) δ: 1.25 (3H, t, J=7.1 Hz, $OCH_2C\underline{H}_3$), 2.60 (6H, s, 3,5-diMe), 3.72 (2H, s, CH_2), 4.16 (2H, q, J=7.1 Hz, $OC\underline{H}_2CH_3$), 7.57 (2H, m, Ph-H), 7.71 (2H, m, Ph-H), 8.04 (1H, br s, 4-H), 8.45 (2H, br s, 2,6-H). *Anal.* Calcd for $C_{22}H_{20}BrNO_3S_2$: C, 53.88; H, 4.11; N, 2.86%; Found C, 54.11; H, 4.07; N, 2.67%.

Preparation of α,α′-Bis(thieno[3,4-*b*]indolizin-3-yl)-*o*- (4a—i), *m*- (6a—i), and *p*-xylene Derivatives (8a—i). General Method 1: An acetone suspension (20 ml) of 3-(1-pyridinio)thiophene-2-thiolates (**1a**—**f**) (2.0 mmol), α,α-dibromo-*o*- (**2a**), *m*- (**2b**), or *p*-xylene (**2c**) (0.264 g, 1 mmol), and sodium iodide (2 g, 13.3 mmol) was heated at 50 °C in a water bath until the disappearance of **1** was confirmed by thin layer chromatographic (TLC) monitoring (5—10 d). The reaction mixture was concentrated at reduced pressure and the resulting residue was washed 3 times with ether (each 10 ml) to remove the unaltered halide. The residue was dissolved in chloroform (30 ml) and then 1,8-diazabicyclo[5.4.0]undec-7-ene (0.364 g, 2.4 mmol) was added at 0 °C in an ice bath. After 15 min, chloranil (0.492 g, 2 mmol) was added at that temperature and stirred for a further 4 h. The reaction mixture was filtered by suction, and the chloroform solution was concentrated at reduced pressure. Chromatographic separation on alumina of the residues using chloroform as an eluent followed by the recrystallization from chloroform gave the corresponding products **4a**—**f**, **6a**—**f** and **8a**—**f**.

General Method 2: 3-(3,5-Dimethyl-1-pyridinio)thiophene-2-thiolates (**1g**—**i**) (2.0 mmol) were allowed to react with α,α-dibromo-*o*-, *m*-, or *p*-xylene (**2**) (0.264 g, 1 mmol) in chloroform (20 ml) at room temperature until the disappearance of **1** was confirmed by tlc monitoring (12 h—3 d). The reaction mixture was concentrated at reduced pressure and the resulting residue was washed 3 times with ether (each 10 ml) to remove the unaltered halide. Similar treatment of the residue as described above and the recrystallization from chloroform–hexane afforded the corresponding products **4g**—**i**, **6g**—**i**, and **8g**—**i**.

^{1}H-NMR spectral data for **4a**—**i** and **6a**—**i**, and **8a**—**i** are shown in Table 1 and some other data are described below.

α,α′-Bis[(1-benzoyl-9-ethoxycarbonylthieno[3,4-*b*]indolizin-3-yl)thio]-*o*-xylene (**4a**): From **1a** and **2a**; 48%; red prisms (from $CHCl_3$); mp 142—143 °C. IR (KBr) cm^{-1}: 1680, 1613. UV–Vis (nm (log ε), $CHCl_3$): 330 (shoulder), 432 (3.89), 497 (3.86). ^{13}C-NMR ($CDCl_3$) δ: 14.3, 41.6, 59.0, 93.2, 110.6, 114.9, 119.8, 125.4, 126.4, 128.1, 128.2, 129.3, 130.0, 130.6, 132.4, 134.2, 134.5, 137.0, 138.7, 149.6, 163.7, 187.8. *Anal.* Calcd for $C_{48}H_{36}N_2O_6S_4$: C, 66.64; H, 4.19; N, 3.24%; Found C, 66.71; H, 4.15; N, 3.21%.

α,α3′-Bis[(1-(4-chlorobenzoyl)-9-ethoxycarbonylthieno[3,4-*b*]indolizin-3-yl)thio]-*o*-xylene (**4b**): From **1b** and **2a**; 54%; red prisms (from $CHCl_3$); mp 202—203 °C. IR (KBr) cm^{-1}: 1684, 1616. UV–Vis (nm (log ε), $CHCl_3$): 331 (shoulder), 432 (3.84), 498 (3.81). *Anal.* Calcd for $C_{48}H_{34}Cl_2N_2O_6S_4$: C, 61.73; H, 3.67; N, 3.00%; Found C, 61.97; H, 3.59; N, 2.84%.

α,α′-Bis[(1-(4-bromobenzoyl)-9-ethoxycarbonylthieno[3,4-*b*]indolizin-3-yl)thio]-*o*-xylene (**4c**): From **1c** and **2a**; 79%; red prisms (from $CHCl_3$); mp 205—206 °C. IR (KBr) cm^{-1}: 1682, 1618. UV–Vis (nm (log ε), $CHCl_3$): 329 (shoulder), 432 (3.85), 499 (3.82). *Anal.* Calcd for $C_{48}H_{34}Br_2N_2O_6S_4$: C, 56.36; H, 3.35; N, 2.74%; Found C, 56.55; H, 3.30; N, 2.59%.

α,α′-Bis[(1-benzoyl-9-ethoxycarbonyl-7-methylthieno[3,4-*b*]indolizin-3-yl)thio]-*o*-xylene (**4d**): From **1d** and **2a**; 42%; red prisms (from $CHCl_3$); mp 144—145 °C. IR (KBr) cm^{-1}: 1676, 1638. UV–Vis (nm (log ε), $CHCl_3$): 329 (shoulder), 441 (3.95), 488 (3.87). ^{13}C-NMR ($CDCl_3$) δ: 14.3, 22.1, 41.6, 58.9, 92.2, 113.5, 114.9, 118.1, 124.9, 125.9, 128.3, 128.4, 129.4, 130.7, 132.5, 134.3, 135.0, 137.0, 138.9, 142.4, 150.5, 164.1, 188.1. *Anal.* Calcd for $C_{50}H_{40}N_2O_6S_4$: C, 67.24; H, 4.51; N, 3.14%; Found C, 67.52; H, 4.46; N, 2.87%.

α,α′-Bis[(1-(4-chlorobenzoyl)-9-ethoxycarbonyl-7-methylthieno[3,4-*b*]indolizin-3-yl)thio]-*o*-xylene (**4e**): From **1e** and **2a**; 38%; red prisms (from $CHCl_3$); mp 142—143 °C. IR (KBr) cm^{-1}: 1680, 1638. UV–Vis (nm (log ε), $CHCl_3$): 328 (shoulder), 440 (3.98), 495 (3.88). *Anal.* Calcd for $C_{50}H_{36}Cl_2N_2O_6S_4+H_2O$: C, 61.28; H, 4.11; N, 2.86%; Found C, 61.28; H, 4.16; N, 2.81%.

α,α′-Bis[(1-(4-bromobenzoyl)-9-ethoxycarbonyl-7-methylthieno[3,4-*b*]indolizin-3-yl)thio]-*o*-xylene (**4f**): From **1f** and **2a**; 28%; red prisms (from $CHCl_3$); mp 138—139 °C. IR (KBr) cm^{-1}: 1680, 1638. UV–Vis (nm (log ε), $CHCl_3$): 331 (shoulder), 441 (3.95), 496 (3.87). *Anal.* Calcd for

$C_{50}H_{38}Br_2N_2O_6S_4$: C, 57.14; H, 3.64; N, 2.67%; Found C, 57.41; H, 3.53; N, 2.51%.

α,α′-Bis[(1-benzoyl-9-ethoxycarbonyl-6,8-dimethylthieno[3,4-*b*]indolizin-3-yl)thio]-*o*-xylene (**4g**): From **1g** and **2a**; 69%; red prisms (from $CHCl_3$–hexane); mp 206—208 °C. IR (KBr) cm^{-1}: 1703, 1612. UV–Vis (nm (log ε), $CHCl_3$): 332 (shoulder), 439 (shoulder), 522 (4.00). ^{13}C-NMR ($CDCl_3$) δ: 14.3, 17.8, 20.6, 42.0, 60.4, 96.4, 115.8, 118.9, 121.2, 122.4, 128.3, 128.4, 129.0, 130.6, 131.9, 132.2, 134.2, 136.3, 136.7, 139.1, 145.3, 165.9, 186.0 (one carbon is overlapping). *Anal.* Calcd for $C_{52}H_{44}N_2O_6S_4$: C, 67.80; H, 4.81; N, 3.04%; Found C, 68.08; H, 4.78; N, 2.80%.

α,α′-Bis[(1-(4-chlorobenzoyl)-9-ethoxycarbonyl-6,8-dimethylthieno[3,4-*b*]indolizin-3-yl)thio]-*o*-xylene (**4h**): From **1h** and **2a**; 41%; red prisms (from $CHCl_3$–hexane); mp 198—199 °C. IR (KBr) cm^{-1}: 1701, 1616. UV–Vis (nm (log ε), $CHCl_3$): 330 (shoulder), 431 (shoulder), 525 (4.07). *Anal.* Calcd for $C_{52}H_{42}Cl_2N_2O_6S_4$: C, 63.08; H, 4.28; N, 2.83%; Found C, 63.22; H, 4.24; N, 2.73%.

α,α′-Bis[(1-(4-bromobenzoyl)-9-ethoxycarbonyl-6,8-dimethylthieno[3,4-*b*]indolizin-3-yl)thio]-*o*-xylene (**4i**): From **1i** and **2a**; 44%; red prisms (from $CHCl_3$–hexane); mp 196—198 °C. IR (KBr) cm^{-1}: 1701, 1599. UV–Vis (nm (log ε), $CHCl_3$): 335 (shoulder), 436 (shoulder), 528 (4.02). *Anal.* Calcd for $C_{52}H_{42}Br_2N_2O_6S_4$: C, 57.88; H, 3.92; N, 2.60%; Found C, 57.85; H, 3.96; N, 2.60%.

α,α′-Bis[(1-benzoyl-9-ethoxycarbonylthieno[3,4-*b*]indolizin-3-yl)thio]-*m*-xylene (**6a**): From **1a** and **2b**; 40%; red prisms (from $CHCl_3$); mp 181—183 °C. IR (KBr) cm^{-1}: 1682, 1615. UV–Vis (nm (log ε), $CHCl_3$): 330 (shoulder), 437 (4.07), 474 (4.03). ^{13}C-NMR ($CDCl_3$) δ: 14.3, 44.2, 59.0, 93.3, 110.5, 115.8, 119.8, 125.0, 126.8, 128.1, 128.2, 128.9, 129.0, 129.3, 130.1, 132.4, 134.5, 136.6, 137.0, 138.8, 149.7, 163.8, 187.8. *Anal.* Calcd for $C_{48}H_{36}N_2O_6S_4$: C, 66.64; H, 4.19; N, 3.24%; Found C, 66.55; H, 4.18; N, 3.04%.

α,α′-Bis[(1-(4-chlorobenzoyl)-9-ethoxycarbonylthieno[3,4-*b*]indolizin-3-yl)thio]-*m*-xylene (**6b**): From **1b** and **2b**; 59%; red prisms (from $CHCl_3$); mp 181—182 °C. IR (KBr) cm^{-1}: 1672, 1624. UV–Vis (nm (log ε), $CHCl_3$): 329 (shoulder), 438 (4.10), 472 (4.03). *Anal.* Calcd for $C_{48}H_{34}Cl_2N_2O_6S_4$: C, 61.73; H, 3.67; N, 3.00%; Found C, 61.74; H, 3.69; N, 2.97%.

α,α′-Bis[(1-(4-bromobenzoyl)-9-ethoxycarbonylthieno[3,4-*b*]indolizin-3-yl)thio]-*m*-xylene (**6c**): From **1c** and **2b**; 45%; red prisms (from $CHCl_3$); mp 179—180 °C. IR (KBr) cm^{-1}: 1676, 1624. UV–Vis (nm (log ε), $CHCl_3$): 330 (shoulder), 437 (4.10), 475 (4.04). *Anal.* Calcd for $C_{48}H_{34}Br_2N_2O_6S_4$: C, 56.36; H, 3.35; N, 2.74%; Found C, 56.63; H, 3.26; N, 2.56%.

α,α′-Bis[(1-benzoyl-9-ethoxycarbonyl-7-methylthieno[3,4-*b*]indolizin-3-yl)thio]-*m*-xylene (**6d**): From **1d** and **2b**; 37%; red prisms (from $CHCl_3$); mp 214—216 °C. IR (KBr) cm^{-1}: 1682, 1615. UV–Vis (nm (log ε), $CHCl_3$): 327 (shoulder), 439 (4.12), 475 (shoulder). ^{13}C-NMR ($CDCl_3$) δ: 14.3, 22.1, 44.0, 58.8, 92.2, 113.4, 115.8, 118.0, 124.5, 126.2, 128.2, 128.3, 129.0, 129.1, 129.3, 132.4, 135.0, 136.7, 137.0, 139.0, 142.4, 150.5, 164.1, 188.0. *Anal.* Calcd for $C_{50}H_{40}N_2O_6S_4$: C, 67.24; H, 4.51; N, 3.14%; Found C, 67.53; H, 4.40; N, 2.96%.

α,α′-Bis[(1-(4-chlorobenzoyl)-9-ethoxycarbonyl-7-methylthieno[3,4-*b*]indolizin-3-yl)thio]-*m*-xylene (**6e**): From **1e** and **2b**; 36%; red prisms (from $CHCl_3$); mp 227—228 °C. IR (KBr) cm^{-1}: 1665, 1616. UV–Vis (nm (log ε), $CHCl_3$): 330 (shoulder), 4410 (4.16), 475 (shoulder). *Anal.* Calcd for $C_{50}H_{36}Cl_2N_2O_6S_4$: C, 62.43; H, 3.98; N, 2.91%; Found C, 62.68; H, 3.87; N, 2.77%.

α,α′-Bis[(1-(4-bromobenzoyl)-9-ethoxycarbonyl-7-methylthieno[3,4-*b*]indolizin-3-yl)thio]-*m*-xylene (**6f**): From **1f** and **2b**; 16%; red prisms (from $CHCl_3$); mp 232—233 °C; IR (KBr) cm^{-1}: 1663, 1613. UV–Vis (nm (log ε), $CHCl_3$): 331 (shoulder), 441 (4.10), 475 (shoulder). *Anal.* Calcd for $C_{50}H_{38}Br_2N_2O_6S_4$: C, 57.14; H, 3.64; N, 2.67%; Found C, 57.29; H, 3.52; N, 2.49%.

α,α′-Bis[(1-benzoyl-9-ethoxycarbonyl-6,8-dimethylthieno[3,4-*b*]indolizin-3-yl)thio]-*m*-xylene (**6g**): From **1g** and **2b**; 80%; red prisms (from $CHCl_3$–hexane); mp 206—208 °C. IR (KBr) cm^{-1}: 1711, 1620. UV–Vis (nm (log ε), $CHCl_3$): 330 (shoulder), 447 (shoulder), 515 (4.05). ^{13}C- NMR ($CDCl_3$) δ: 14.3, 18.0, 20.6, 44.3, 60.5, 96.4, 107.6, 117.0, 118.7, 121.6, 121.8, 128.3, 128.4, 129.0, 129.0, 131.8, 132.1, 135.8, 136.1, 136.7, 139.3, 145.3, 166.0, 186.0 (one carbon is overlapping). *Anal.* Calcd for $C_{52}H_{44}N_2O_6S_4$: C, 67.80; H, 4.81; N, 3.04%; Found C, 67.83; H, 4.85; N, 2.98%.

α,α′-Bis[(1-(4-chlorobenzoyl)-9-ethoxycarbonyl-6,8-dimethylthieno[3,4-*b*]indolizin-3-yl)thio]-*m*-xylene (**6h**): From **1h** and **2b**; 41%; red prisms (from $CHCl_3$–hexane); mp 108—111 °C. IR (KBr) cm^{-1}: 1721, 1620. UV–Vis (nm (log ε), $CHCl_3$): 333 (shoulder), 441 (shoulder), 519 (3.99). *Anal.* Calcd for $C_{52}H_{42}Cl_2N_2O_6S_4$: C, 63.08; H, 4.28; N, 2.83%; Found C, 63.24; H, 4.24; N, 2.71%.

α,α′-Bis[(1-(4-bromobenzoyl)-9-ethoxycarbonyl-6,8-dimethylthieno[3,4-*b*]indolizin-3-yl)thio]-*m*-xylene (**6i**): From **1i** and **2b**; 63%; red prisms (from $CHCl_3$–hexane); mp 111—113 °C. IR (KBr) cm^{-1}: 1709, 1615. UV–Vis (nm (log ε), $CHCl_3$): 335 (shoulder), 518 (4.10). *Anal.* Calcd for $C_{52}H_{42}Br_2N_2O_6S_4$: C, 57.88; H, 3.92; N, 2.60%; Found C, 57.87; H, 4.20; N, 2.34%.

α,α′-Bis[(1-benzoyl-9-ethoxycarbonylthieno[3,4-*b*]indolizin-3-yl)thio]-*p*-xylene (**8a**): From **1a** and **2c**; 34%; red prisms (from $CHCl_3$–EtOH); mp 207—209 °C. IR (KBr) cm^{-1}: 1678, 1628. UV–Vis (nm (log ε), $CHCl_3$): 326 (shoulder), 433 (4.13), 473 (4.03). ^{13}C-NMR ($CDCl_3$) δ: 14.4, 44.1, 59.0, 93.3, 110.5, 116.0, 119.8, 124.9, 126.8, 128.2, 129.0, 129.3, 130.1, 132.4, 134.5, 135.8, 136.9, 138.9, 149.7, 163.8, 187.8. *Anal.* Calcd for $C_{48}H_{36}N_2O_6S_4$+EtOH: C, 65.91; H, 4.65; N, 3.07%; Found C, 65.97; H, 4.78; N, 2.89%.

α,α′-Bis[(1-(4-chlorobenzoyl)-9-ethoxycarbonylthieno[3,4-*b*]indolizin-3-yl)thio]-*p*-xylene (**8b**): From **1b** and **2c**; 25%; red prisms (from $CHCl_3$); mp 199—201 °C. IR (KBr) cm^{-1}: 1678, 1624. UV–Vis (nm (log ε), $CHCl_3$): 328 (shoulder), 434 (4.11), 476 (4.02). *Anal.* Calcd for $C_{48}H_{34}Cl_2N_2O_6S_4$: C, 61.73; H, 3.67; N, 3.00%; Found C, 61.84; H, 3.62; N, 2.92%.

α,α′-Bis[(1-(4-bromobenzoyl)-9-ethoxycarbonylthieno[3,4-*b*]indolizin-3-yl)thio]-*p*-xylene (**8c**): From **1c** and **2c**; 61%; red prisms (from $CHCl_3$); mp 215—216 °C. IR (KBr) cm^{-1}: 1678, 1620. UV–Vis (nm (log ε), $CHCl_3$): 327 (shoulder), 435 (4.00), 477 (3.92). *Anal.* Calcd for $C_{48}H_{34}Br_2N_2O_6S_4$: C, 56.36; H, 3.35; N, 2.74%; Found C, 56.50; H, 3.42; N, 2.61%.

α,α′-Bis[(1-benzoyl-9-ethoxycarbonyl-7-methylthieno[3,4-*b*]indolizin-3-yl)thio]-*p*-xylene (**8d**): From **1d** and **2c**; 41%; red prisms (from $CHCl_3$); mp 232 °C. IR (KBr) cm^{-1}: 1672, 1622. UV–Vis (nm (log ε), $CHCl_3$): 326 (shoulder), 441 (4.17), 475 (shoulder). ^{13}C-NMR ($CDCl_3$) δ: 14.3, 22.2, 44.1, 58.9, 92.2, 113.5, 116.0, 118.1, 124.5, 126.1, 128.3, 129.1, 129.4, 132.5, 135.0, 136.0, 136.9, 139.0, 142.4, 150.5, 164.2, 188.1. *Anal.* Calcd for $C_{50}H_{40}N_2O_6S_4$: C, 67.24; H, 4.51; N, 3.14%; Found C, 67.26; H, 4.48; N, 3.15%.

α,α′-Bis[(1-(4-chlorobenzoyl)-9-ethoxycarbonyl-7-methylthieno[3,4-*b*]indolizin-3-yl)thio]-*p*-xylene (**8e**): From **1e** and **2c**; 7%; red prisms (from $CHCl_3$); mp 251—252 °C. IR (KBr) cm^{-1}: 1663, 1636. UV–Vis (nm (log ε), $CHCl_3$): 328 (shoulder), 439 (4.13), 478 (shoulder). *Anal.* Calcd for $C_{50}H_{36}Cl_2N_2O_6S_4$: C, 62.43; H, 3.98; N, 2.91%; Found C, 61.70; H, 3.86; N, 2.76%.

α,α′-Bis[(1-(4-bromobenzoyl)-9-ethoxycarbonyl-7-methylthieno[3,4-*b*]indolizin-3-yl)thio]-*p*-xylene (**8f**): From **1f** and **2c**; 10%; red prisms (from $CHCl_3$); mp 261—263 °C. IR (KBr) cm^{-1}: 1663, 1636. UV–Vis (nm (log ε), $CHCl_3$): 326 (shoulder), 438 (4.15), 478 (shoulder). *Anal.* Calcd for $C_{50}H_{38}Br_2N_2O_6S_4$: C, 57.14; H, 3.64; N, 2.67%; Found C, 57.24; H, 3.62; N, 2.60%.

α,α′-Bis[(1-benzoyl-9-ethoxycarbonyl-6,8-dimethylthieno[3,4-*b*]indolizin-3-yl)thio]-*p*-xylene (**8g**): From **1g** and **2c**; 97%; red prisms (from $CHCl_3$–hexane); mp 206—207 °C. IR (KBr) cm^{-1}: 1712, 1620. UV–Vis (nm (log ε), $CHCl_3$): 333 (shoulder), 441 (3.90), 512 (4.09). ^{13}C-NMR ($CDCl_3$) δ: 14.3, 18.0, 20.6, 44.2, 60.5, 96.4, 117.0, 118.8, 121.6, 121.8, 128.3, 128.4, 129.0, 129.0, 131.8, 132.1, 135.8, 136.1, 136.7, 145.3, 166.0, 186.0 (one carbon is overlapping). *Anal.* Calcd for $C_{52}H_{44}N_2O_6S_4$: C, 67.80; H, 4.81; N, 3.04%; Found C, 68.02; H, 4.82; N, 2.82%.

α,α′-Bis[(1-(4-chlorobenzoyl)-9-ethoxycarbonyl-6,8-dimethylthieno[3,4-*b*]indolizin-3-yl)thio]-*p*-xylene (**8h**): From **1h** and **2c**; 66%; red prisms (from $CHCl_3$–hexane); mp 240—242 °C. IR (KBr) cm^{-1}: 1701, 1614. UV–Vis (nm (log ε), $CHCl_3$): 334 (shoulder), 436 (shoulder), 516 (4.04). *Anal.* Calcd for $C_{52}H_{42}Cl_2N_2O_6S_4$: C, 63.08; H, 4.28; N, 2.83%; Found C, 63.07; H, 4.32; N, 2.80%.

α,α′-Bis[(1-(4-bromobenzoyl)-9-ethoxycarbonyl-6,8-dimethylthieno[3,4-*b*]indolizin-3-yl)thio]-*p*-xylene (**8i**): From **1i** and **2c**; 55%; red prisms (from $CHCl_3$–hexane); mp 238—240 °C. IR (KBr) cm^{-1}: 1701, 1616. UV–Vis (nm (log ε), $CHCl_3$): 336 (shoulder), 435 (shoulder), 517 (4.00). *Anal.* Calcd for $C_{52}H_{42}Br_2N_2O_6S_4$: C, 57.88; H, 3.92; N, 2.60%; Found C, 57.87; H, 3.97; N, 2.56%.

Crystallography of α,α′-Bis[(1-(4-benzoyl)-9-ethoxycarbonylthieno[3,4-*b*]indolizin-3-yl)thio]-*o*-xylene (4i) A single crystal (0.20×0.10×0.10 mm) grown from $CHCl_3$–hexane was used for the unit-cell determinations and the data collection by a Rigaku RAXIS RAPID imaging plate area detector with graphite-monochromated Cu*Kα* radiation (λ=1.54187 Å). Crystal data of these compounds are as follows: **4i**: $C_{52}H_{42}Br_2N_2O_6S_4$; M=1078.96; monoclinic, space group $C2/c$ (#15), Z=4 with α=11.5689(2) Å, β=23.6937(4) Å, c=17.0393(3) Å, β=102.7864° (7); V=4554.83(14) Å^3, and $D_{calc.}$=1.573 g/cm^3. All calculations were performed using CrystalStructure.[17] The structure was solved by a direct method (SIR).[18] The non-hydro-

gen atoms were refined anisotropically, and the hydrogen atoms were attached at the idealized position and not refined. The final R- and R_{w2}-factors after full-matrix least-squares refinements were 0.0496 for ($I>2.00\sigma(I)$) and 0.1338 for all observed reflections (4147).

Crystallography of α,α′-Bis[(1-benzoyl-9-ethoxycarbonylthieno[3,4-*b*]indolizin-3-yl)thio]-*m*-xylene (6a) A single crystal (0.88×0.42×1.00 mm) grown from $CHCl_3$–hexane was used for the unit-cell determinations and the data collection by a Rigaku AFC5S four-circle diffractometer with graphite-monochromated Mo$K\alpha$ radiation ($\lambda=0.71069$ Å). Crystal data of these compounds are as follows: **6a**: $C_{52}H_{44}N_2O_6S_4$; $M=921.17$; monoclinic, space group $C2/c$ (#15), $Z=4$ with $a=17.093(13)$ Å, $b=14.05(2)$ Å, $c=19.623(13)$ Å, $\beta=102.33(6)°$; $V=4602.5(80)$ Å^3, and $D_{calc.}=1.329$ g/cm^3. All calculations were performed using CrystalStructure.[17] The structure was solved by a direct method (SIR).[18] The non-hydrogen atoms were refined anisotropically, and the hydrogen atoms were attached at the idealized position and not refined. The final R- and R_w-factors after full-matrix least-squares refinements were 0.068 and 0.055 respectively for 3152 ($I>2.00\sigma(I)$) observed reflections.

Crystallography of α,α′-Bis[(1-benzoyl-9-ethoxycarbonylthieno[3,4-*b*]indolizin-3-yl)thio]-*p*-xylene (8a) A single crystal (0.88×0.42×0.18 mm) grown from $CHCl_3$–hexane was used for the unit-cell determinations and the data collections by Rigaku AFC5S four-circle diffractometer with graphite-monochromated Mo$K\alpha$ radiation ($\lambda=0.71069$ Å). Crystal data of **8a**: $C_{52}H_{44}N_2O_6S_4$; $M=921.17$; triclinic, space group P-1 (#2), $Z=2$ with $a=10.66(3)$ Å, $b=13.32(4)$ Å, $c=9.71(2)$ Å, $\alpha=104.9°$ (3), $\beta=113.1°$ (2), $\gamma=66.7°$ (2); $V=1155.8(53)$ Å^3, and $D_{calc.}=1.323$ g/cm^3. All calculations were performed using the CrystalStructure.[17] The structure was solved by a direct method (SIR).[18] The non-hydrogen atoms were refined anisotropically, and the hydrogen atoms were attached at the idealized position and not refined. The final R- and R_w-factors after full-matrix least-squares refinements were 0.063 and 0.040 for 2386 ($I>2.00\sigma(I)$) observed reflections, respectively.

References and Notes

1) For part 66 of this series, see Abe T., Okumura Y., Suga H., Kakehi A., *Heterocycles*, in press.
2) Jones G. B., *Tetrahedron*, **57**, 7999—8016 (2001).
3) Meyer E. A., Castellano R. K., Diederich F., *Angew. Chem. Int. Ed.*, **42**, 1210—1250 (2003).
4) Yamada S., *Yuki Gosei Kagaku Kyokaishi*, **63**, 339—350 (2003).
5) Carroll W. R., Pellechia P., Shimizu K. D., *Org. Lett.*, **10**, 3547—3550 (2008).
6) Kishikawa K., Naruse M., Kohmoto S., Yamamoto M., Yamaguchi K., *J. Chem. Soc.*, *Perkin Trans 1*, **2001**, 462—468 (2001).
7) Yamada S., Imoue M., *Org. Lett.*, **9**, 1477—1480 (2007).
8) Yamada S., Yamamoto J., Ohta E., *Tetrahedron Lett.*, **48**, 855—858 (2007).
9) Kakehi A., Ito S., Suga H., Miwa T., Mori T., Kobayashi T., *Heterocycles*, **57**, 17—20 (2002).
10) Kakehi A., Ito S., Suga H., Miwa T., Mori T., Fujii T., Tanaka N., Kobayashi T., *Chem. Pharm. Bull.*, **51**, 75—84 (2003).
11) Kakehi A., Suga H., Kako T., Fujii T., Tanaka N., Kobayashi T., *Chem. Pharm. Bull.*, **51**, 1246—1252 (2003).
12) Kakehi A., Suga H., Kaneko Y., Fujii T., Tanaka N., *Chem. Pharm. Bull.*, **53**, 1430—1238 (2005).
13) Kakehi A., Suga H., Isogai H., *Chem. Pharm. Bull.*, **55**, 95—101 (2007).
14) "WinMOPAC (Version 2.0)," Fujitsu Corporation.
15) Kakehi A., Ito S., Suga H., Yasuraoka K., *Heterocycles*, **54**, 185—200 (2001).
16) Johnson C. K., "ORTEO II, Report ORNL-5138," Oak Ridge National Laboratory, Oak Ridge, Tennessee, 1976.
17) "CrystalStructure 3.8," Crystal Structure Analysis Package, Regaku and Regaku/Molecular Structure Corporation (2000—2005), 9009 New Trails Dr., The Woodlands, TX 77381, U.S.A.
18) Altomare A., Cascarano G., Giacovazzo C., Guagliardi A., *J. Appl. Cryst.*, **26**, 343—350 (1993).