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SHORT COMMUNICATION

Efficient thioacetalisation of carbonyl compounds

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The thioacetalisation of a variety of heterocyclic, aromatic, and aliphatic carbonyl compounds (1 mmol) with ethane-1,2-dithiol (1 mmol) using silica sulphuric acid (SSA) is presented as an efficient heterogeneous catalyst under mild and solvent-free conditions at 60 °C. The thioacetals were formed within a short reaction time (1–34 min) and isolated with 90–98 % yield following an extractive procedure and chromatography on silica gel. The competitive protection reaction between aldehyde and ketone with ethane-1,2-dithiol afforded the protected derivatives of benzaldehyde and acetophenone with 92 % and 8 % yields, respectively, indicating some selectivity.

Keywords: silica sulphuric acid (SSA), heterogeneous catalyst, thioacetalisation, chemoselectivity, carbonyl compounds, 1,2-ethanedithiol

The protection of carbonyl groups as dithioacetals is a common and popular practice in organic chemistry (Wuts & Greene, 2006; Kocienski, 1994), since they are quite stable under basic or acidic conditions. Among the different carbonyl-protecting groups, 1,3-dithianes, 1,3-oxathiolanes, and 1,3-dithiolanes have long been used as protective groups, and act as an acyl- anion equivalent in carbon–carbon bond-forming reactions (Eliel & Morris-Natschke, 1984; Gröbel & Seebach, 1977; Bulman Page et al., 1989). They are generally prepared by Brønsted or Lewis acid-catalysed condensation of carbonyl compounds with thiols or dithiols, in the presence of strong acid catalysts such as $AlCl_3$ (Ong, 1980), $LnCl_3$ (Garlaschelli & Vidari, 1990), $ZnCl_2$ (Evans et al., 1977), $TiCl_4$ (Kumar & Dev, 1983), WCl_6 (Firouzabadi et al., 1998), $InCl_3$ (Muthusamy et al., 2001), $In(OTf)_3$ (Muthusamy et al., 2002), $Sc(OTf)_3$ (Kamal & Chouhan, 2002a, 2003), $Bi(NO_3)_3$ (Komatsu et al., 1995), $VO(OTf)_2$ (De, 2005), and $Ce(OTf)_3$ (Kumar et al., 2010). A number of milder procedures employing lithium salts (Firouzabadi et al., 1999a, 1999b; Saraswathy & Sankararaman, 1994; Tietze et al., 2000; Yadav et al., 2001), $NiCl_2$ (Khan et al., 2003), $CoCl_2$ (De, 2004), NBS (Kamal & Chouhan, 2002b), silica gel-supported sulphamic acid (Aoyama et al., 2013), and I_2 (Samajdar et al., 2001) have also been reported for this purpose. Many of these protocols suffer from drawbacks such as requiring harsh reaction conditions and stoichiometric amounts of catalysts, the use of expensive reagents and/or chlorinated organic solvents and, in some instances, strong acidic reagents. Recently, a number of solid-supported reagents have also been used for the thioacetalisation of various types of carbonyl compounds, e.g. $ZrCl_4$–SiO_2 (Patney & Margan, 1996), $SOCl_2$–SiO_2 (Kamitori et al., 1986), $CoBr_2$–SiO_2 (Patney, 1994), $TaCl_5$–SiO_2 (Chandrasekhar et al., 1997), $Cu(OTf)_2$–SiO_2 (Anand et al., 1999), $NaHSO_4$–SiO_2 (Das et al., 2005), and I_2–natural phosphate (Zahouily, 2005). Interestingly, only a few of these methods have demonstrated chemoselective protection of aldehydes in the presence of ketones (Ong, 1980; Muthusamy et al., 2001; Kamal & Chouhan, 2002a, 2002b, 2003; Karimi & Seradj, 2000).

However attractive these reagents may be, to the best of our knowledge there is only one report on the application of silica sulphuric acid (SSA) in the thioac-

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Table 1. Thioacetalisation of carbonyl compounds in the presence of SSA

Entry	R^1	R^2	Time/min		Yield/%	
			A^a	B^b	A^a	B^b
1	Phenyl	H	5	3	95	96
2	4-Bromophenyl	H	2	–	98	–
3	4-Chlorophenyl	H	4	–	97	–
4	4-Nitrophenyl	H	3	14	98	74
5	3-Nitrophenyl	H	3	16	94	76
6	4-Methoxyphenyl	H	1	4	98	97
7	2-Methoxyphenyl	H	2	5	98	94
8	3-Bromophenyl	H	12	–	85	–
9	4-Methylphenyl	H	7	6	90	94
10	4-Hydroxyphenyl	H	1	5	95	94
11	4-Dimethylaminophenyl	H	3	–	90	–
12	4-Formylphenyl	H	3	–	70	–
13	1-Hydroxy-2,6-dimethoxyphenyl	H	3	–	96	–
14	Thiophen-2-yl	H	1	–	90	–
15	2-Furyl	H	3	17	70	98
16	3-Indolyl	H	12	–	90	–
17	2-Phenylethen-1-yl	H	3	4	98	95
18	Phenyl	CH_3	34	10	90	5
19	Benzyl	CH_3	20	–	98	–

a) Reaction conditions in present work (A): carbonyl compound (1.0 mmol), ethane-1,2-dithiol (1.0 mmol), SSA (0.1 g), 60 °C; *b*) reported (Pourmousavi & Kazemi, 2012) reaction conditions (B): carbonyl compound (2.0 mmol), ethane-1,2-dithiol (2.4 mmol), SSA (0.02 g), ambient temperature.

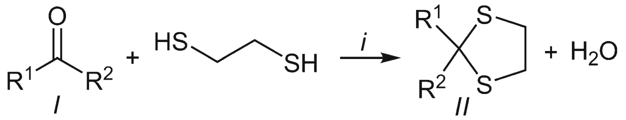

Fig. 1. Thioacetalisation of carbonyl compounds. Reaction conditions: *i*) SSA, 60 °C; for R^1 and R^2, see Table 1.

etalisation of carbonyl compounds (Pourmousavi & Kazemi, 2012). As a continuation of our studies on the application of SSA in organic synthesis (Habibi et al., 2013a, 2013b, 2013c), the utilisation of SSA as a heterogeneous acid catalyst is here reported for the highly chemoselective thioacetalisation of a variety of carbonyl compounds using ethane-1,2-dithiol under solvent-free conditions at 60 °C (Fig. 1). The results are compared with those obtained by Pourmousavi and Kazemi (2012) for analogous thioacetalisation of several identical carbonyl compounds at ambient temperature.

Solvents and reagents were obtained from commercial sources (Aldrich, Merck) and used without purification. Column chromatography was performed on silica gel (60–120 mesh). SSA was prepared according to the method previously reported (Zolfigol, 2001; Pourmousavi & Kazemi, 2012).

General procedure for synthesis of 2-R^1-2-R^2-1,3-dithiolanes (II)

SSA (0.1 g) was added to a mixture of corresponding carbonyl compound ($R^1R^2C{=}O$, *I*) (1.0 mmol) and ethane-1,2-dithiol (0.094 g, 1.0 mmol) and the reaction mixture was stirred at 60 °C under solvent-free conditions. After the appropriate time (disappearance of starting carbonyl compound was monitored by TLC), the reaction mixture was diluted with CH_2Cl_2 (DCM, 20 mL), filtered and the filtrate washed with water (15 mL). The organic layer was dried with anhydrous $MgSO_4$, filtered and concentrated under reduced pressure affording the crude product which was purified by chromatography on a short silica gel column using EtOAc/hexane ($\varphi_r = 1:4$) as the eluent to afford the corresponding thioacetal (*II*). The reaction was carried out with various aldehydes such as benzaldehyde (Table 1, entry 1), aromatic aldehydes containing electron-withdrawing and electron-donating substituents (entries 2–13), heterocyclic aldehydes (entries 14–16), α,β-unsaturated aldehydes (entry 17), and ketones (1-phenylethan-1-one (acetophenone), entry 18; 1-phenylpropan-2-one, entry 19). The products were characterised by their physical and spectral data and a comparison with authentic samples.

First, the solvent effect and catalytic activity of SSA for the thioacetalisation of 4-chlorobenzaldehyde with ethane-1,2-dithiol at 60 °C were investigated. It was found that the products under solvent-free conditions were very clean and the reactions were completed much more rapidly than reactions using solvents. The relevant results are summarised in Table 2. It can be seen that, under solvent-free reaction conditions, 4-chlorobenzaldehyde afforded 2-(4-chlorophenyl)-1,3-dithiolane (Table 2, entry 6) within 4 min with a 97 %

Table 2. Solvent effect on thioacetalisation of 4-chlorobenzaldehyde^{a}

Entry	Solvent	Time/min	Conversion/%
1	*n*-hexane	33	70
2	CH_3CN	15	90
3	CH_2Cl_2	7	90
4	$CHCl_3$	5	80
5	MeOH	5	65
6	no solvent	4	97

a) Reaction conditions: 4-chlorobenzaldehyde (1.0 mmol), ethane-1,2-dithiol (1.0 mmol), SSA (0.1 g), 60 ℃.

yield. In this respect, other starting aldehydes and ketones were allowed to react under the solvent-free conditions.

To examine the selectivity of thioacetalisation in the competitive protection of aldehyde and ketone, a mixture of benzaldehyde (1 mmol), acetophenone (1 mmol) and ethane-1,2-dithiol (1 mmol) in the presence of SSA (0.1 g) was allowed to react at 60 ℃ for 5 min. Examination of the isolated and purified reaction products revealed that 2-phenyl-1,3-dithiolane (protected benzaldehyde) and 2-methyl-2-phenyl-1,3-dithiolane (protected acetophenone) were formed with 92 % and 8 % yields, respectively. This observation indicates that this method is potentially applicable in the chemoselective conversion of aldehydes to the corresponding thioacetals in the presence of ketones.

It should also be noted that the thioacetalisation of a conjugated aldehyde takes place chemoselectively and the C=C bond remains intact during the reaction (Table 1, entry 17). In addition, ketones produce the corresponding 1,3-dithioacetals with very good to excellent yields but the reaction requires a longer time (Table 1, entries 18, 19, reaction conditions A) and higher temperature (Table 1, entry 18; 60 ℃ in A versus ambient temperature in B) than with aldehydes.

Some benefits of the thioacetalisation presented using SSA-like solvent-free versus solvent conditions (entries 2–4, 6, 9–11), short versus longer reaction time (entries 4, 6, 9-11), equimolar versus higher amounts of reactants (entries 2–11), no toxicity (entries 5, 8), availability, preparation, recycling, and easy storage of the catalyst compared with other methods are summarised in Table 3.

In conclusion, it was found that SSA efficiently catalyses the dithioacetalisation of a variety of carbonyl compounds under solvent-free conditions. The simplicity, mild reaction conditions and chemical selectivity represent several advantages over many existing methods.

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References

Anand, R. V., Saravanan, P., & Singh, V. K. (1999). Solvent free thioacetalization of carbonyl compounds catalyzed by $Cu(OTf)_2$-SiO_2. *Synlett*, *1999*, 415–416. DOI: 10.1055/s-1999-2635.

Aoyama, T., Suzuki, T., Nagaoka, T., Takido, T., & Kodomari, M. (2013). Silica-gel supported sulfamic acid (SA/SiO_2) as an efficient and reusable catalyst for conversion of ketones into oxathioacetals and dithioacetals. *Synthetic Communications*, *43*, 553–566. DOI: 10.1080/00397911.2011.604458.

Bulman Page, P. C., van Niel, M. B., & Prodger, J. C. (1989). Synthetic uses of the 1,3-dithiane grouping from 1977 to 1988. *Tetrahedron*, *45*, 7643–7677. DOI: 10.1016/s0040-4020(01)85784-7.

Chandrasekhar, S., Takhi, M., Reddy, Y. R., Mohapatra, S., Rao, C. R., & Reddy, K. V. (1997). $TaCl_5$-silicagel and $TaCl_5$ as new Lewis acid systems for selective tetrahydropyranylation of alcohols and thioacetalisation, trimerisation and aldolisation of aldehydes. *Tetrahedron*, *53*, 14997–15004. DOI: 10.1016/s0040-4020(97)01051-x.

Das, B., Ramu, R., Reddy, M. R., & Mahender, G. (2005). Simple, mild and efficient thioacetalization and transthioacetalization of carbonyl compounds and deprotection of thioacetals: Unique role of thiols in the selectivity of thioacetalization. *Synthesis*, *2005*, 250–254. DOI: 10.1055/s-2004-834934.

Table 3. Comparison of catalytic effect of various catalysts and reaction conditions in thioacetalisation of benzaldehyde

Entry	Solvent	Catalyst/g	T/℃	Time/min	Yield/%	Mole ratio^{a}	Reference
1	–	SSA/0.1	60	5	95	1 : 1	Present work
2	DCM	$CoBr_2$–SiO_2/2	rt	10	99	10 : 12–30	Patney, 1994
3	DCM	$ZrCl_4$–SiO_2/1	rt	1	98	10 : 12–30	Patney & Margan, 1996
4	Benzene^{b}	$SOCl_2$–SiO_2/0.2	rt	300	100	1 : 1.1	Kamitori et al., 1986
5	–	I_2–natural phosphate/0.3	rt	3	90	2 : 2.1	Zahouily et al., 2005
6	Hexane	Sulphamic acid–SiO_2/0.3	rt	120	99	2 : 2.4	Aoyama et al., 2013
7	–^{c}	P_2O_5–Al_2O_3/0.2^{d}	rt	1	92	2 : 2.4	Zarei et al., 2009
8	–	H_2SO_4–silica/0.02	rt	3	96	2 : 2.4	Pourmousavi & Kazemi, 2012
9	DCM	SiO_2–$AlCl_3$/0.4^{d}	reflux	72	95	1 : 1.1–1.2	Tamami & Borujeny, 2003
10	DCM	Polystyrene–$AlCl_3$/0.25^{d}	reflux	210	98	1 : 1.1–1.2	Tamami & Borujeny, 2003
11	DCM	Polystyrene–$FeCl_3$/0.4^{d}	reflux	245	91	1 : 1.1–1.2	Tamami & Borujeny, 2003

a) Carbonyl compound/ethane-1,2-dithiol mole ratio; *b*) under nitrogen; *c*) under microwave irradiation (900 W); *d*) amount given in mmol; rt means ambient temperature.

De, S. K. (2004). Cobalt(II)chloride catalyzed chemoselective thioacetalization of aldehydes. *Tetrahedron Letters*, *45*, 1035–1036. DOI: 10.1016/j.tetlet.2003.11.082.

De, S. K. (2005). Vanadyl triflate as an efficient and recyclable catalyst for chemoselective thioacetalization of aldehydes. *Journal of Molecular Catalysis A: Chemical*, *226*, 77–79. DOI: 10.1016/j.molcata.2004.09.044.

Eliel, E. L., & Morris-Natschke, S. (1984). Asymmetric syntheses based on 1,3-oxathianes. 1. Scope of the reaction. *Journal of the American Chemical Society*, *106*, 2937–2942. DOI: 10.1021/ja00322a033.

Evans, D. A., Truesdale, L. K., Grimm, K. G., & Nesbitt, S. L. (1977). Thiosilanes, a promising class of reagents for selective carbonyl protection. *Journal of the American Chemical Society*, *99*, 5009–5017. DOI: 10.1021/ja00457a020.

Firouzabadi, H., Iranpoor, N., & Karimi, B. (1998). Tungsten hexachloride (WCl_6) as an efficient catalyst for chemoselective dithioacetalization of carbonyl compounds and transthioacetalization of acetals. *Synlett*, *1998*, 739–740. DOI: 10.1055/s-1998-1756.

Firouzabadi, H., Iranpoor, N., & Karimi, B. (1999a). Lithium bromide-catalyzed highly chemoselective and efficient dithioacetalization of α,β-unsaturated and aromatic aldehydes under solvent-free conditions. *Synthesis*, *1999*, 58–60. DOI: 10.1055/s-1999-3679.

Firouzabadi, H., Karimi, B., & Eslami, S. (1999b). Lithium trifluoromethanesulfonate (LiOTf) as a highly efficient catalyst for chemoselective dithioacetalization of carbonyl compounds under neutral and solvent-free conditions. *Tetrahedron Letters*, *40*, 4055–4058. DOI: 10.1016/s0040-4039(99)00647-4.

Garlaschelli, L., & Vidari, G. (1990). Anhydrous lanthanum trichloride, a mild and convenient reagent for thioacetalization. *Tetrahedron Letters*, *31*, 5815–5816. DOI: 10.1016/s0040-4039(00)97967-x.

Gröbel, B. T., & Seebach, D. (1977). Umpolung of the reactivity of carbonyl compounds through sulfur-containing reagents. *Synthesis*, *1977*, 357–402. DOI: 10.1055/s-1977-24412.

Habibi, D., Nabavi, H., & Nasrollahzadeh, M. (2013a). Silica sulfuric acid as an efficient heterogeneous catalyst for the solvent-free synthesis of 1-substituted 1H-1,2,3,4-tetrazoles. *Journal of Chemistry*, *2013*, 645313. DOI: 10.1155/2013/645313.

Habibi, D., Rahmani, P., & Akbaripanah, Z. (2013b). *N*-Formylation of anilines with silica sulfuric acid under solvent-free conditions. *Journal of Chemistry*, *2013*, 972960. DOI: 10.1155/2013/972960.

Habibi, D., Rahmani, P., & Akbaripanah, Z. (2013c). Acetylation of phenols, anilines, and thiols using silica sulfuric acid under solvent-free conditions. *Journal of Chemistry*, *2013*, 268654. DOI: 10.1155/2013/268654.

Kamal, A., & Chouhan, G. (2002a). Scandium triflate as a recyclable catalyst for chemoselective thioacetalization. *Tetrahedron Letters*, *43*, 1347–1350. DOI: 10.1016/s0040-4039(01)02378-4.

Kamal, A., & Chouhan, G. (2002b). Mild and efficient chemoselective protection of aldehydes as dithioacetals employing *N*-bromosuccinimide. *Synlett*, *2002*, 474–476. DOI: 10.1055/s-2002-20469.

Kamal, A., & Chouhan, G. (2003). Chemoselective thioacetalization and transthioacetalization of carbonyl compounds catalyzed by immobilized scandium(III) triflate in ionic liquids. *Tetrahedron Letters*, *44*, 3337–3340. DOI: 10.1016/s0040-4039(03)00580-x.

Kamitori, Y., Hojo, M., Masuda, R., Kimura, T., & Yoshida, T. (1986). Selective protection of carbonyl compounds. Silica gel treated with thionyl chloride as an effective catalyst for thioacetalization. *The Journal of Organic Chemistry*, *51*, 1427–1431. DOI: 10.1021/jo00359a009.

Karimi, B., & Seradj, H. (2000). Zirconium tetrachloride ($ZrCl_4$) as an efficient and chemoselective catalyst for conversion of carbonyl compounds to 1,3-oxathiolanes. *Synlett*, *2000*, 805–806. DOI: 10.1055/s-2000-6692.

Khan, A. T., Mondal, E., Sahu, P. R., & Islam, S. (2003). Nickel(II) chloride as an efficient and useful catalyst for chemoselective thioacetalization of aldehydes. *Tetrahedron Letters*, *44*, 919–922. DOI: 10.1016/s0040-4039(02)02771-5.

Kocienski, P. J. (1994). *Protecting groups*. Stuttgart, Germany: Thieme.

Komatsu, N., Uda, M., & Suzuki, H. (1995). Bismuth(III) halides and sulfate as highly efficient catalyst for the sulfenylation of carbonyl and related compounds. *Synlett*, *1995*, 984–986. DOI: 10.1055/s-1995-5137.

Kumar, V., & Dev, S. (1983). Titanium tetrachloride, an efficient and convenient reagent for thioacetalization. *Tetrahedron Letters*, *24*, 1289–1292. DOI: 10.1016/s0040-4039(00)81637-8.

Kumar, A., Rao, M. S., & Rao, V. K. (2010). Cerium triflate: An efficient and recyclable catalyst for chemoselective thioacetalization of carbonyl compounds under solvent-free conditions. *Australian Journal of Chemistry*, *63*, 135–140. DOI: 10.1071/ch09296.

Muthusamy, S., Babu, S. A., & Gunanathan, C. (2001). Indium(III) chloride as an efficient, convenient catalyst for thioacetalization and its chemoselectivity. *Tetrahedron Letters*, *42*, 359–362. DOI: 10.1016/s0040-4039(00)01966-3.

Muthusamy, S., Babu, S. A., & Gunanathan, C. (2002). Indium triflate: a mild Lewis acid catalyst for thioacetalization and transthioacetalization. *Tetrahedron*, *58*, 7897–7901. DOI: 10.1016/s0040-4020(02)00897-9.

Ong, B. S. (1980). A simple and efficient method of thioacetal- and ketalization. *Tetrahedron Letters*, *21*, 4225–4228. DOI: 10.1016/s0040-4039(00)92868-5.

Patney, H. K. (1994). Anhydrous cobalt(II) bromide dispersed on silica gel: A mild and efficient reagent for thioacetalisation of carbonyl compounds. *Tetrahedron Letters*, *35*, 5717–5718. DOI: 10.1016/s0040-4039(00)77287-x.

Patney, H. K., & Margan, S. (1996). Zirconium(IV) chloride-silica catalysed thioacetalisation of carbonyl compounds. *Tetrahedron Letters*, *37*, 4621–4622. DOI: 10.1016/0040-4039(96)00892-1.

Pourmousavi, S. A., & Kazemi, S. S. (2012). Highly efficient and chemoselective method for the thioacetalization of aldehydes and transthioacetalization of acetals and acylals catalyzed by H_2SO_4-silica under solvent-free conditions. *Monatshefte für Chemie - Chemical Monthly*, *143*, 917–923. DOI: 10.1007/s00706-011-0664-6.

Samajdar, S., Basu, M. K., Becker, F. F., & Banik, B. K. (2001). A new molecular iodine-catalyzed thioketalization of carbonyl compounds: selectivity and scope. *Tetrahedron Letters*, *42*, 4425–4427. DOI: 10.1016/s0040-4039(01)00752-3.

Saraswathy, V. G., & Sankararaman, S. (1994). Chemoselective protection of aldehydes as dithioacetals in lithium perchlorate-diethylether medium. Evidence for the formation of oxocarbenium ion intermediate from acetals. *The Journal of Organic Chemistry*, *59*, 4665–4670. DOI: 10.1021/jo00095a049.

Tamami, B., & Borujeny, K. P. (2003). Chemoselective protection of carbonyl compounds as dithioacetals using polystyrene and silica gel supported $AlCl_3$ and $FeCl_3$. *Iranian Polymer Journal (English Edition)*, *12*, 507–513.

Tietze, L. F., Weigand, B., & Wulff, C. (2000). A mild and efficient method for the preparation of 1,3-dithianes from aldehydes and ketones. *Synthesis*, *2000*, 69–71. DOI: 10.1055/s-2000-6226.

Wuts, P. G. M., & Greene, T. W. (2006). *Greene's protective groups in organic synthesis* (4th ed., Chapter 4, pp. 431–532).

Hoboken, NJ, USA: Wiley. DOI: 10.1002/9780470053485.ch4.

Yadav, J. S., Reddy, B. V. S., & Pandey, S. K. (2001). $LiBF_4$ catalyzed chemoselective conversion of aldehydes to 1,3-oxathiolanes and 1,3-dithianes. *Synlett*, *2001*, 238–239. DOI: 10.1055/s-2001-10780.

Zahouily, M., Mezdar, A., Rakik, J., Elmakssoudi, A., Rayadh, A., & Sebti, S. (2005). A mild and efficient method for the protection of carbonyl compounds as dithioacetals, dithiolanes and dithianes catalysed by iodine supported on natural phosphate. *Journal of Molecular Catalysis A: Chemical*, *233*, 43–47. DOI: 10.1016/j.molcata.2005.01.043.

Zarei, A., Hajipour, A. R., Khazdooz, L., Mirjalili, B. F., & Zahmatkesh, S. (2009). Fast, efficient and chemoselective method for thioacetalization and transthioacetalization using catalytic amount of P_2O_5/Al_2O_3 under microwave irradiation. *Journal of Molecular Catalysis A: Chemical*, *301*, 39–46. DOI: 10.1016/j.molcata.2008.11.005.

Zolfigol, M. A. (2001). Silica sulfuric acid/$NaNO_2$ as a novel heterogeneous system for production of thionitrites and disulfides under mild conditions. *Tetrahedron*, *57*, 9509–9511. DOI: 10.1016/s0040-4020(01)00960-7.