

**IN THE NAME OF GOD**

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Shiraz University  
Faculty of Sciences

**Ph.D. Dissertation in Organic Chemistry**

**NEW APPLICATIONS OF TRICHLOROTITANIUM(IV)  
TRIFLUOROMETHANESULFONATE,  $TiCl_3(OTf)$   
&  
PREPARATION AND APPLICATION OF SILICA BOUND  
 $Ti(IV)$ ,  $TiCl_2(OTf)-SiO_2$  AS A HETEROGENEOUS  
CATALYST IN ORGANIC TRANSFORMATIONS**

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دانشگاه شیراز  
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پایان نامه دکترا در رشته شیمی آلی

کاربردهای جدید تری کلرو تیتانیوم تریفلات  $TiCl_3(OTf)$  و تهیه و کاربردهای تیتانیوم پیوند شده بر سیلیکا ژل:  $TiCl_2(OTf)-SiO_2$  بعنوان یک کاتالیزور هتروژن در تبدیلات آلی

به وسیله ی:  
صغری فرهی

استاد راهنما:

پروفسور سید حبیب فیروزآبادی

۱۳۸۸ / ۴ / ۶

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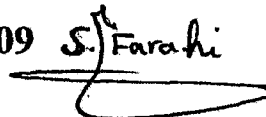
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## DECLARATION

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A handwritten signature in black ink, appearing to read 'S. Farahi', with a large, sweeping underline stroke.

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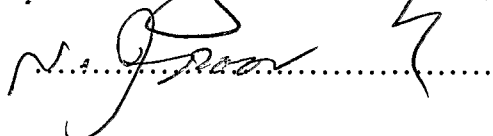

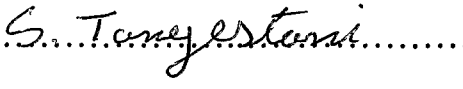
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IN

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EVALUATED AND APPROVED BY THE THESIS COMMITTEE AS: EXCELLENT

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APRIL 2009

**Dedicated to:**

*My Family Specially My Dear Mother*

*And*

*All My Teachers Specially*

*Professor Habib Firouzabadi, Professor Nasser Iranpoor*

*&*

*Professor Ali Reza Sardarian*

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## ABSTRACT

**NEW APPLICATIONS OF TRICHLOROTITANIUM(IV)  
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In this thesis, we have utilized two titanium (IV)-based compounds;  $TiCl_3(OTf)$  and  $TiCl_2(OTf)-SiO_2$  as catalysts for some organic reactions.

At first, catalytic applications of solid  $TiCl_3(OTf)$  was extensively investigated in esterification and transesterification reactions.  $TiCl_3(OTf)$  catalyzed acylation of alcohols, phenols, thiols and  $\alpha$ -hydroxyphosphonates with acid anhydrides in the absence of organic solvents at room temperature or at 70 and 80 °C. In the presence of  $TiCl_3(OTf)$ , formylation of alcohols and amines and acetylation of alcohols were achieved in refluxing ethyl formate and ethyl acetate. Direct esterification of different alcohols with different carboxylic acids was also experienced in the presence of this catalyst at 115 °C.



Protection of aldehydes with acetic anhydride was also achieved in the presence of  $\text{TiCl}_3(\text{OTf})$ . The generality of this method for the conversion of various aldehydes to their corresponding acylals has been shown.

$\text{TiCl}_3(\text{OTf})$  has also been applied for efficient silylation of  $-\text{OH}$  functional groups of  $\alpha$ -hydroxyphosphonates, alcohols and phenols with HMDS at room temperature under neat conditions. High chemo- and regioselectivity were observed between different substrates using  $\text{TiCl}_3(\text{OTf})$  as a catalyst.

We also prepared  $\text{TiCl}_2(\text{OTf})\text{-SiO}_2$ , which is a moisture tolerant Ti(IV) silica bound compound. Then, we investigated applications of this new compound as a catalyst in some organic reactions.

Preparation of  $\alpha$ -trimethylsiloxyphosphonates and silyl ethers using HMDS as silylating agent was achieved in the presence of  $\text{TiCl}_2(\text{OTf})\text{-SiO}_2$  as a catalyst under neat conditions. Here again, high chemo- and regioselectivity were observed between different substrates using this catalyst. The catalyst is separated from the reaction mixture by simple filtration and was reused for six consecutive runs without appreciable loss in its catalytic activity.

We also reported *N*-derivatization of  $\alpha$ -aminophosphonates *via* Michael addition reactions using  $\text{TiCl}_2(\text{OTf})\text{-SiO}_2$  as a catalyst for the first time. The generality of the catalyst for C-C and C-N bond formation reactions through 1,4-conjugate addition of structurally diverse amines, indoles and pyrrole to electron deficient C-C double bonds has been shown. Recyclability of the catalyst was also investigated in these reactions. The catalytic activity of  $\text{TiCl}_2(\text{OTf})\text{-SiO}_2$  is maintained during four consecutive runs.

Finally, we applied  $\text{TiCl}_2(\text{OTf})\text{-SiO}_2$  as an effective recyclable catalyst for cyanosilylation of aldehydes under neat conditions.

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## ABBREVIATIONS

TMSCl	Trimethylsilyl chloride
DPAT	Diphenyl ammonium triflate
CAN	Ceric (IV) ammonium nitrate
AcOH	Acetic acid
Ac <sub>2</sub> O	Acetic anhydride
AT	Ammonium triflate
DBSA	Dodecylbenzene sulfonic acid
CDBS	Copper dodecylbenzene sulfonate
DMAP	4-(Dimethylamino)pyridine
PPY	4-Pyrrolidinopyridine
Bu <sub>3</sub> P	Tributylphosphine
PMA	Phosphomolybdic acid
TBDMS	<i>t</i> -Butyl dimethyl silyl
DEAD	Diethyl azodicarboxylate
DMF	<i>N,N</i> -Dimethylformamide
HMDS	Hexamethyldisilazane
NBS	<i>N</i> -bromosuccinimide
SDS	Sodium dodecyl sulfate
TMSCN	Trimethylsilyl cyanide
MS	Molecular sieve
GC	Gas chromatography
TLC	Tin layer chromatography
EtOAc	Ethyl acetate
THF	Tetrahydrofuran

Bu

Butyl

$LD_{50}$  = The  $LD_{50}$  is a standardized measure for expressing and comparing the toxicity of chemicals.

The  $LD_{50}$  is the dose that kills half (50%) of the animals tested (LD = "lethal dose"). The animals are usually rats or mice, although rabbits, guinea pigs, hamsters, and so on are sometimes used.

TON = Turnover number; the number of moles of substrate that a mole of catalyst can convert before becoming inactivated.

TOF = Turnover frequency is used to refer to the turnover per unit time.