"BABEŞ-BOLYAI" UNIVERSITY CLUJ-NAPOCA

FACULTY OF CHEMISTRY AND CHEMICAL ENGINEERING

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SYNTHESIS AND CHARACTERIZATION OF NEW STATIONARY PHASES USED IN LIQUID CHROMATOGRAPHY

Ph. D. Thesis Abstract

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Keywords: liquid chromatography, thin-layer chromatography, stationary phases, chemically modified stationary phases, FTIR spectroscopy, UV-VIS spectroscopy, silica gel, diatomaceous earth.

Chemistry literature is rich in recent data on the silica compounds (silica gel [41-46], diatomaceous earth [245], cellulose etc.) used more and more in liquid chromatography, especially in high performance liquid chromatography (HPLC) [133-134, 195-206], in high performance thin-layer chromatography (HPTLC) as chemically modified stationary phases, in order to perfect the separation process, obtaining both efficiency and selectivity. The synthesis of the organic layers, especially to the silica sub layers is achieved through the well-known reaction of organosilanization which consists in the reaction of the silanol groups of silica gel with an organosilane, forming the siloxanic bound Si-O-Si-C [41].

The main goal of this work was aimed at obtaining and characterization of new materials which can be used as stationary phases in liquid chromatography. The synthesis of the new stationary phases started from different inorganic hydroxilated supports, like Merck silica gel, HR silica gel (manufactured in Romania at the Chemistry Institute in Cluj-Napoca), diatomaceous earth from Miniş (Arad county), diatomaceous earth from Filia (Maramureş county) and sodium bentonite from Valea Chioarului.

1. Synthesis and characterization of chemically modified silica gel with 3-methacryloxypropyltrimethoxysilane (silane A 174)

The chemical modified silica gel was obtained through the 60H (Merck) silica gel and of HR silica gel reaction with the 3-methacryloxypropyltrimethoxysilane (silane A174) modifier. The preparation of the chemically modified silica gel can be ideally represented by the equation (fig. 1):

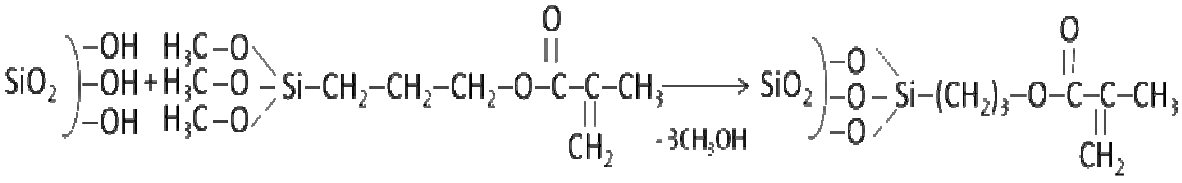

Fig.1. Silica gel chemically modified with 3-methacryloxypropyltrimethoxysilan (silane A 174)

The obtained chemically modified silica gel was characterized through elemental analysis (carbon, hydrogen), measurements of specific surface [226], FTIR spectroscopy, thermo analytical study and thin-layer chromatographic testing.

a)density of coverage

Table 1. Specific surface and density of coverage of silica gel chemically modified

Sample	Silica gel	% C	% H	$S_{BET}(m^2/g$	α (μmoli / m^2)
Sample 1 (silica gel Merck)	unmodified	-	-	500	-
	modified	12,35	1,533	335	4,63
Sample 2 (silica gel HR)	unmodified	-	-	296	-
	modified	6,271	1,043	188	3,096
Sample 3 (silica gel Merck)	unmodified	-	-	500	-
	modified	5,479	0,936	439	1,56

b)FTIR spectroscopy

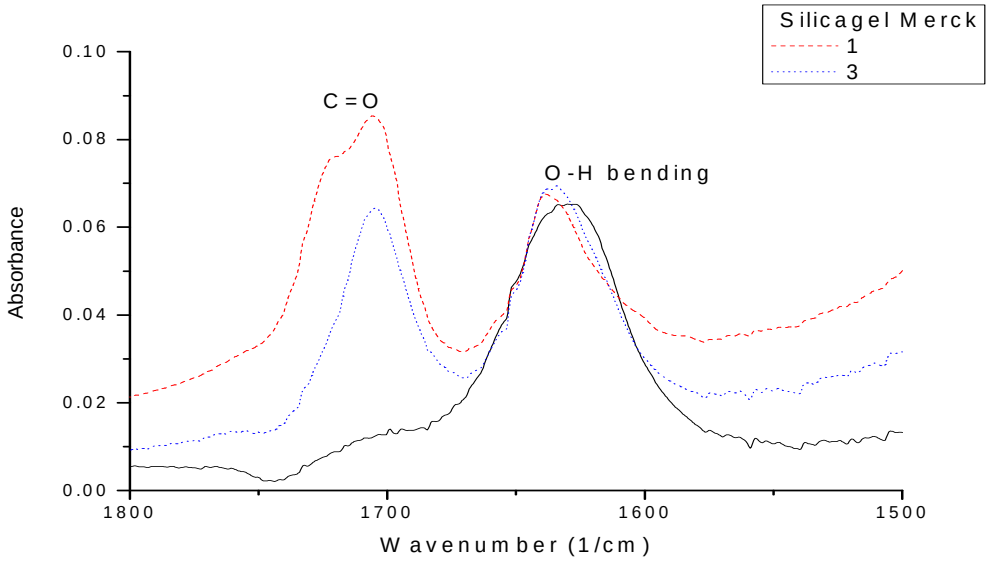

Fig. 2. FTIR spectra of unmodified 60 H Merck silica gel (black) and chemically modified with silane A 174 (red - sample 1 and blue - sample 3)

c) *thermo analytical study*

Table 2. Mass losses of unmodified Merck silica gel, chemically modified Merck silica gel with silane A 174 and chemically modified HR silica gel with silane A 174

Sample	Temperature interval °C / mass losses %		
Merck silica gel	25 - 210	210 - 420	420 - 1100
	3,2668	2,1816	1,1092
chemically modified Merck silica gel	25 - 230	230 - 460	460 - 1100
	3,6695	4,6598	3,4795
chemically modified HR silica gel	25 – 220	220 – 470	470 – 1100
	3,170	5,3412	3,9647

d)chromatographic behavior

Table 3. R_Fx100 values of β- blocker drugs separated on chromatographic plates

Nr.	β- blocker drugs	R_F x 100			
		chemically modified 60H Merck silica gel		chemically modified HR silica gel	
		standards	mixture	standards	mixture
1	Metoprolol	67	67	70	69
2	Sotalol	35	36	38	40
3	Carvedilol	0	0	0	0
4	Labetalol	21	21,5	25	26,5

Conclusion

The data obtained from this research show the chemical modification of the inorganic support surface (silica gel) and the formation of a new non polar chemically modified stationary phase, which can be use in liquid chromatography [227].

2.Synthesis and characterization of chemically modified diatomaceous earth with n-octyl

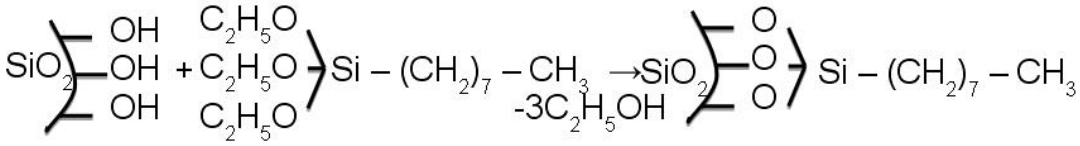

Fig. 3. Chemically modified diatomaceous earth with n-octyl

The obtained chemically modified diatomaceous earth was characterized through elemental analysis (carbon, hydrogen), measurements of specific surface, FTIR spectroscopy, thermo analytical study and thin-layer chromatographic testing.

a)density of coverage

Table 4. Specific surface and density of coverage of chemically modified diatomaceous earth

Sample	Carbon (%)	Hydrogen (%)	$S_{BET}[m^2g^{-1}]$	α (μmol/m^2)
diatomaceous earth from Miniș	-	-	146,3	-
chemically modified diatomaceous earth	4,28	2,52	73,2	6,94

b)FTIR spectroscopy

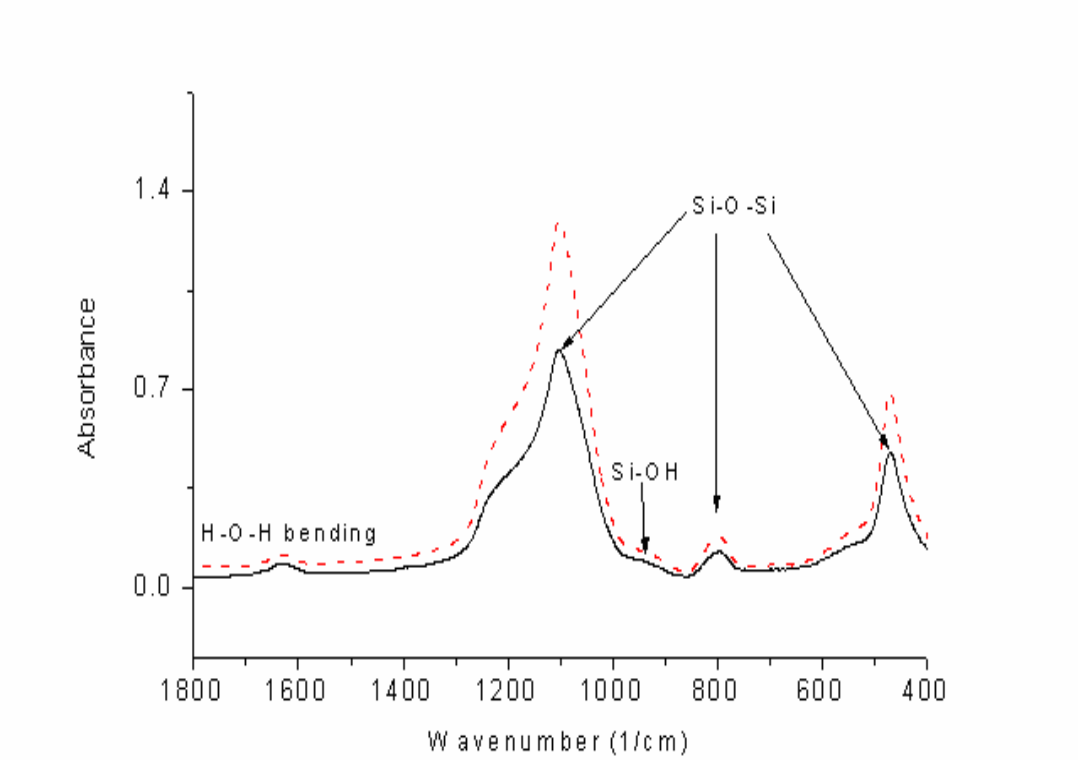

Fig. 4. FTIR spectra of unmodified diatomaceous earth (black) and chemically modified with n-octyl (red) [247]

c) *thermo analytical study*

Table 5. Mass losses of unmodified diatomaceous earth, chemically modified diatomaceous earth with n-octyl

Sample	Temperature interval °C / Mass losses %				
diatomaceous earth	25 - 250	250 - 390	390 - 1100		250 - 1100
	4.4485	0.6966	1.9668		2.6634
chemically modified diatomaceous earth	25 - 230	230 - 370	370 - 500	500 – 1100	230 - 1100
	4.3851	0.8107	1.4846	2.9003	5.1949

d)chromatographic behavior

The obtained chemically modified diatomaceous earth was thin-layer chromatographic testing [248, 329].

a)Nine food colorants were separated on C_8 chemically modified diatomaceous earth.

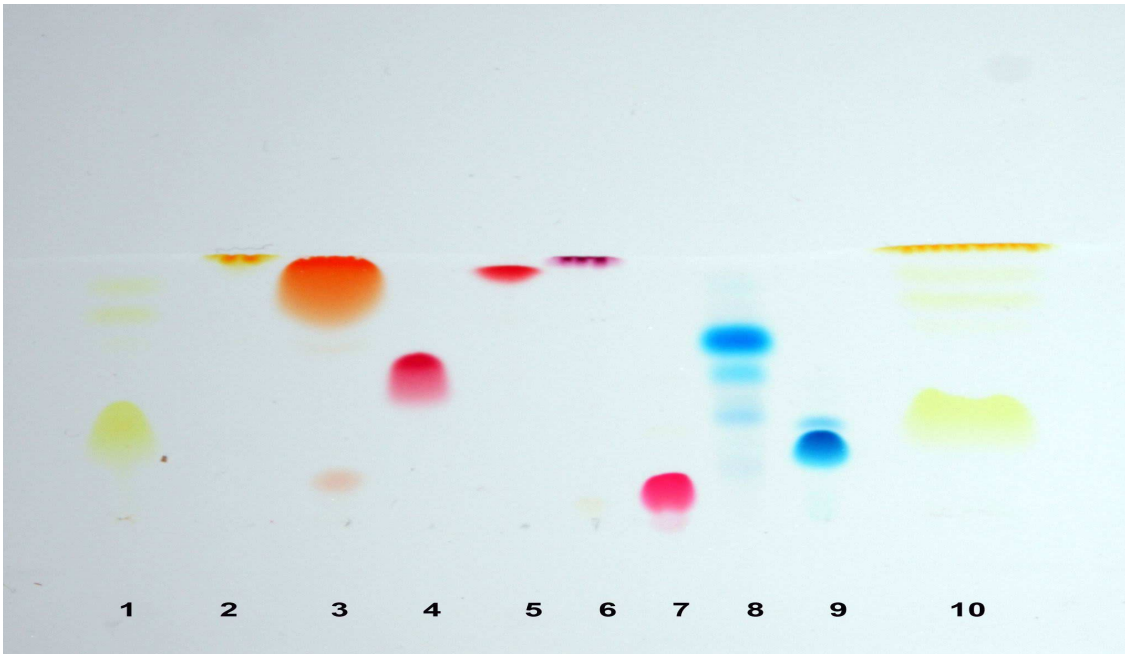

Fig.5. Chromatogram for: 1-quinoline yellow, 2-tartrazine, 3-sunset yellow FCF, 4-azorubine, 5-ponceau 4R, 6-erythrosine, 7-amaranth, 8-brilliant blue, 9-V patent blue, 10-extract of soft drinks. Stationary phase - C_8 chemically modified diatomaceous earth, mobile phase: absolute ethanol – K_2SO_4 1% in water (40:60, v/v) [313].

b)12 non-steroidal anti-inflammatory drugs was separated on plates with C_8 chemically modified diatomaceous earth.

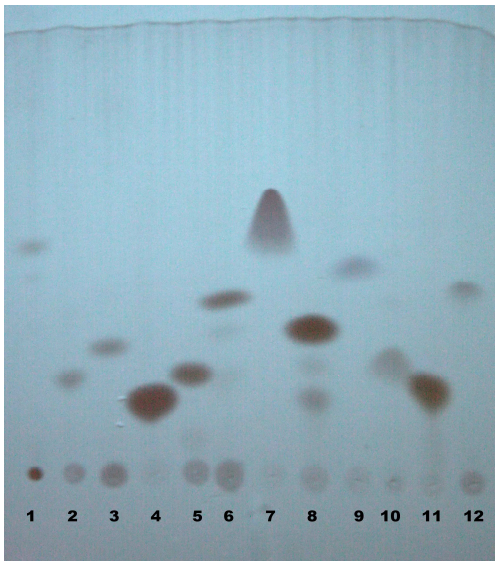

Fig.6. Chromatogram at λ=254 nm for: 1-tenoxicam; 2-nimesulid; 3-meloxicam; 4-celecoxib; 5-indometacin; 6-ketorolac; 7-etoricoxib; 8-ketoprofen; 9-aspirin; 10-ibuprofen; 11-sodium diclofenac; 12-piroxicam. Stationary phase: C_8 chemically modified R diatomaceous earth; mobile phase: acetonitrile - water - H_3PO_4 85% (50: 50:1, v/v) [356].

Conclusion

The data obtained from this research show the modification of the inorganic support surface and the formation of a new non polar chemically modified stationary phase [340a, 340b].

3.Synthesis and characterization of chemically modified diatomaceous earth with n-octadecyl

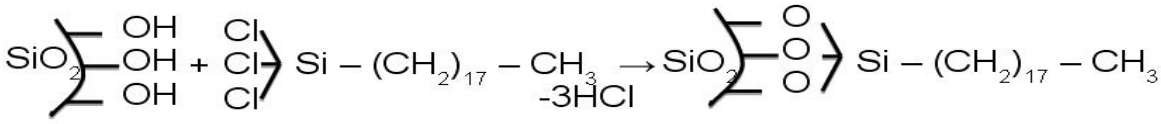

Fig. 7. Chemically modified diatomaceous earth with n-octadecyl

The obtained chemically modified diatomaceous earth was characterized through elemental analysis (carbon, hydrogen), measurements of specific surface, FTIR spectroscopy, thermo analytical study and thin-layer chromatographic testing [372, 396, 418].

a)density of coverage

Table 6. Specific surface and density of coverage of chemically modified diatomaceous earth

Sample	C (%)	H (%)	$S_{BET}[m^2g^{-1}]$	α (μmol/m^2)
diatomaceous earth from Miniş	-	-	146,1	-
chemically modified diatomaceous earth	9,63	2,63	50,2	3,69

b)FTIR spectroscopy

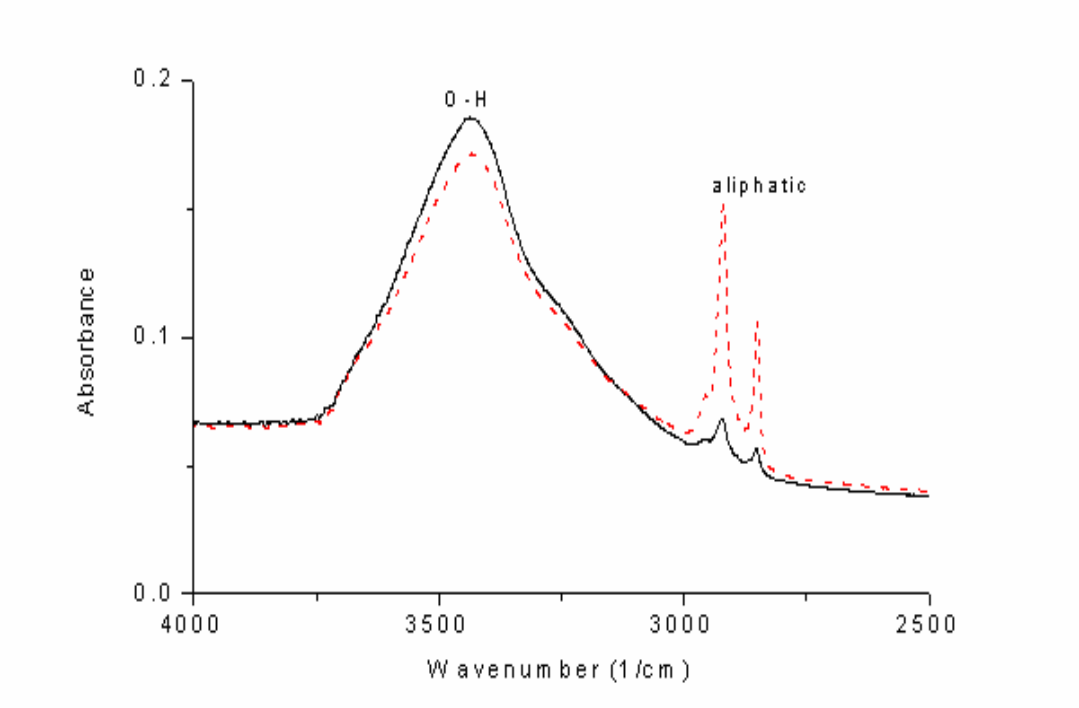

Fig.8. FTIR spectra of unmodified diatomaceous earth (black) and chemically modified diatomaceous earth with n-octadecyl (red), for 4000-2500 cm^{-1} spectra range

c) *thermo analytical study*

Table.7.Mass losses of unmodified diatomaceous earth, chemically modified diatomaceous earth with n-octadecyl

Sample	Temperature interval °C /mass losses %				
diatomaceous earth	25 - 280	280 - 365	365 - 560	560-690	280 - 1100
	3,6893	0.3182	0,9561	0,968	2,2423
C_{18} chemicall modified diatomaceous earth	25 - 240	240 - 619	619-1100	240-1100	25- 1100
	3,0199	7,8097	1,6975	9,5072	12,5244

d)chromatographic behavior

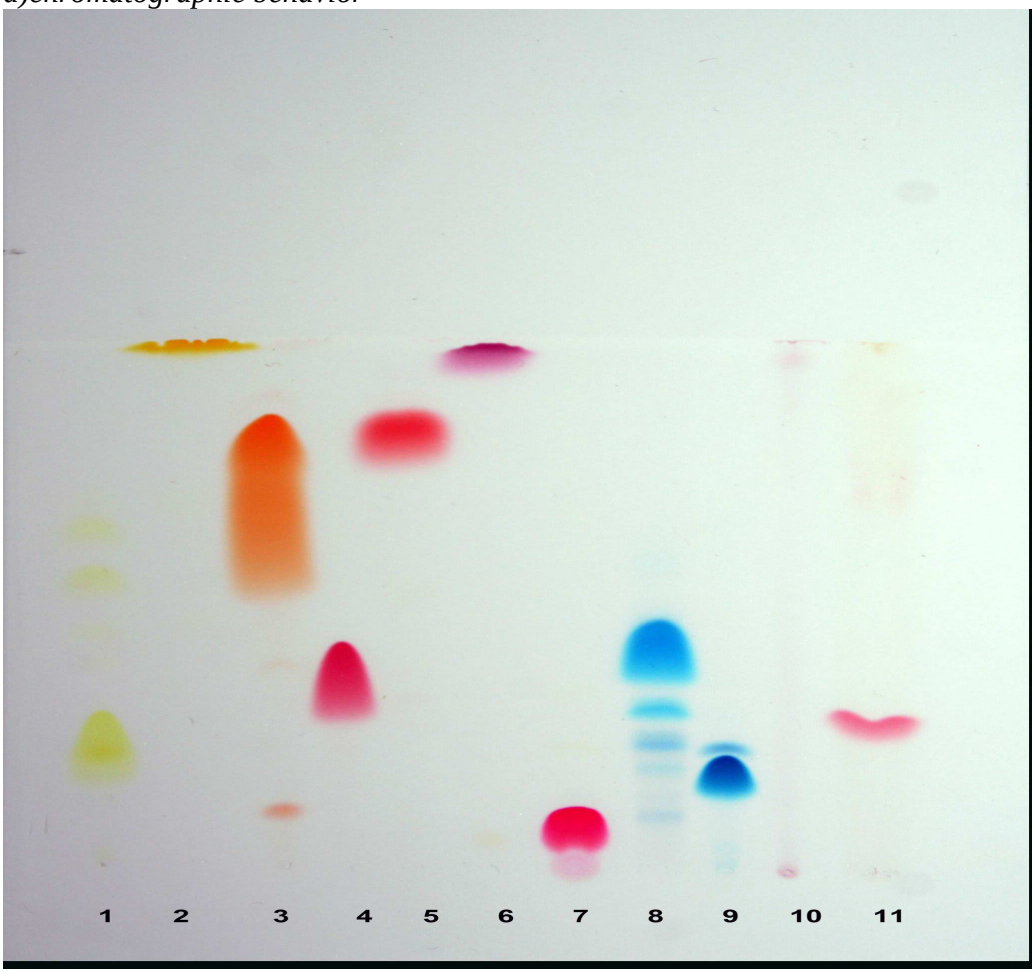

Fig.9. Chromatogram for: 1-quinoline yellow, 2-tartrazine, 3-sunset yellow FCF, 4-azorubine, 5-ponceau 4R, 6-erythrosine, 7-amaranth, 8-brilliant blue, 9-V patent blue, 10-carmine, 11-extract of soft drinks. Stationary phase – C_{18} chemically modified diatomaceous earth, mobile phase: absolute ethanol – K_2SO_4 0,5% in water (40:60, v/v) [313].

Conclusion

The data obtained from this research show the modification of the inorganic support surface and the formation of a new non polar chemically modified stationary phase, which can be use in liquid chromatography.

4.Synthesis and characterization of some chemically modified stationary phases with ethylphenyl

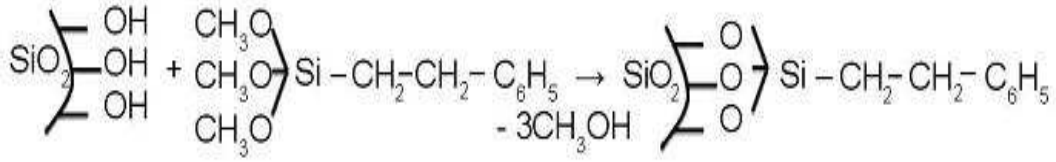

Fig.10 . Chemically modified stationary phases with ethylphenyl

The obtained chemically modified stationary phases were characterized through elemental analysis (carbon, hydrogen), measurements of specific surface, FTIR spectroscopy, thermo analytical study and thin-layer chromatographic testing.

a)density of coverage

Table 8. Specific surface and density of coverage of chemically modified stationary phases

Sample	**% C**	**%H**	**S_{BET}(m^2/g)**	**α(μmol/m^2)**
unmodified HR silica gel	-	-	320	
chemically modified silica gel	8,35	2,11	165	6,56
diatomaceous earth from Filia	-	-	33,5	
chemically modified diatomaceous earth	4,28	1,9	15,3	3,00

b)FTIR spectroscopy

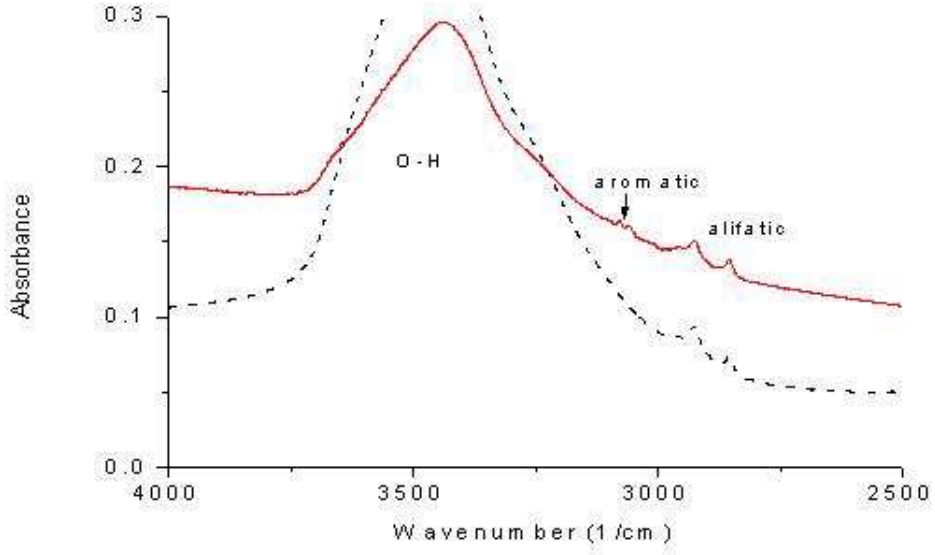

Fig.11. FTIR spectra of unmodified HR silica gel (black) and chemically modified silicagel with ethylphenyl (red), for 4000-2500 cm^{-1} spectra range

c) *thermo analytical study*

Table 9. Mass losses of different stationary phases unmodified and chemically modified with ethylphenyl

Sample	Temperature interval °C / mass losses %				
diatomaceous earth	25 - 260	260 - 360	360 - 560	560 - 1100	260 - 1100
	2.1518	0.4322	1.0787	0.8914	2.4023
chemically modified diatomaceous earth	25 - 270	270 - 560		560 - 1100	270 - 1100
	3.6443	3.4698		1.6795	5.1493
unmodified silica gel	25 - 200		200 - 600	600 - 1100	200 - 1100
	3.2668		2.1816	1.1092	3.2908
chemically modified silica gel	25 - 105	105 - 205	205 - 710	710 – 1100	205 - 1100
	1.1513	0.7335	8.5024	3.3940	11.8964

d)chromatographic behavior

Table 10. R_Fx100 values of aromatic polycyclic compounds separated on chromatographic plates

Compounds	R_F x 100		
	ethylphenyl chemically modified diatomaceous earth	ethylphenyl chemically modified silica gel	C_8 Merck silica gel
Benzo[a]piren-7-hydroxyl	44	42	41.5
Benzo[a]piren-8-hydroxy	35	33	33,5
Benzo[a]pirene	70	64	63,5
Dibenz[a,h]antracen	72	69	68
Crisen	75	74	78

Conclusion

The data obtained from this research show the formation of some new non polar chemically modified stationary phases, which can be use in liquid chromatography [276].

5.Synthesis and characterization of chemically modified diatomaceous earth with n-thiol

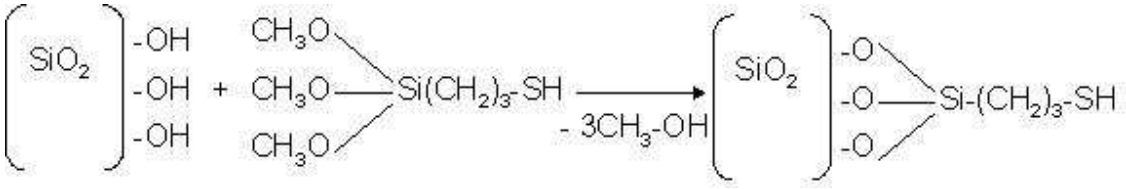

Fig.12. Chemically modified diatomaceous earth with n-thiol

The obtained chemically modified diatomaceous earth was characterized through elemental analysis (carbon, hydrogen), measurements of specific surface, FTIR spectroscopy, thermo analytical study and thin-layer chromatographic testing.

a)density of coverage

Table 11. Specific surface and density of coverage of chemically modified diatomaceous earth

Sample	**C %**	**H %**	**S %**	**$S_{BET}(m^2/g)$**
diatomaceous earth from Filia	-	-	-	33,2
chemically modified diatomaceous earth	4,02	1,59	2,99	23,0

b) *thermo analytical study*

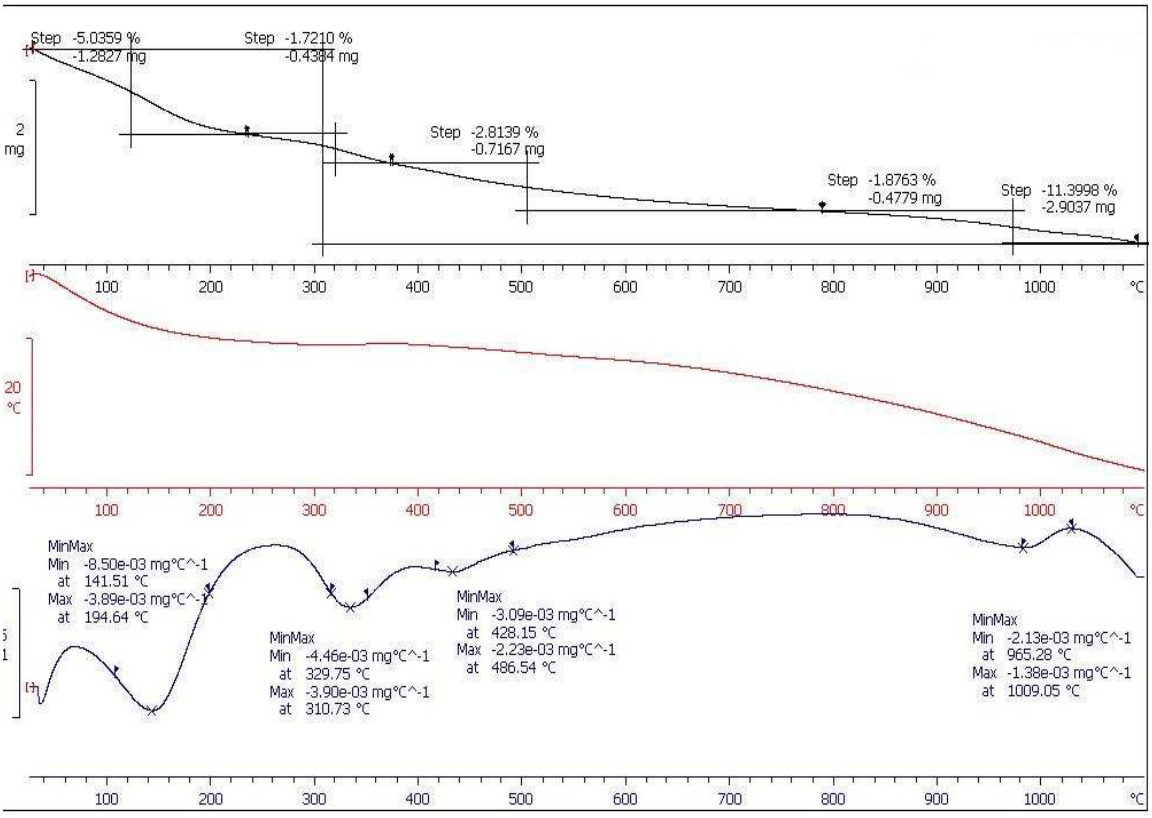

Fig.13. Thermo-gravimetric curves of the diatomaceous earth sample

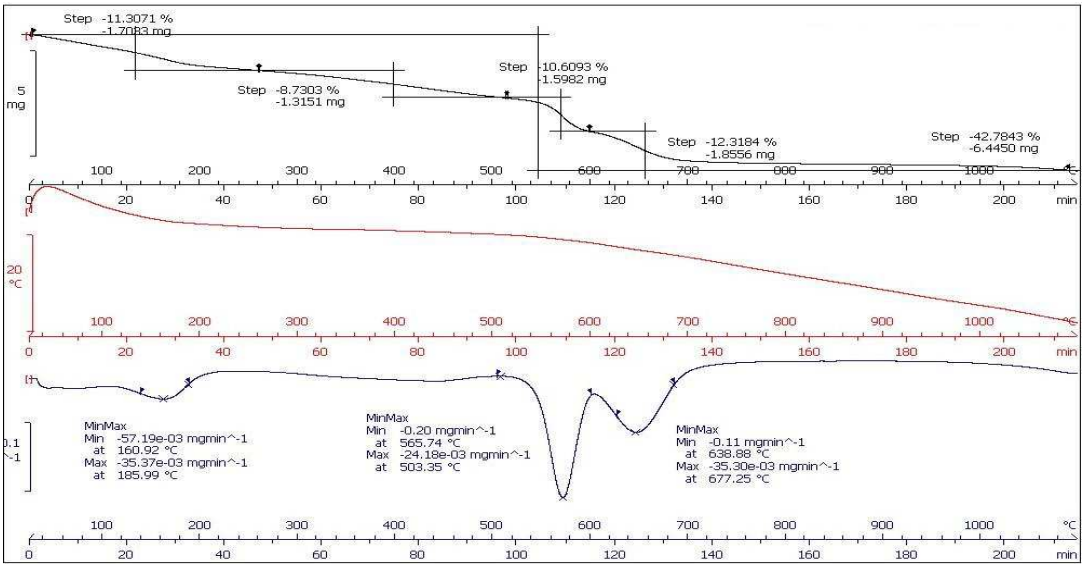

Fig.14. Thermo-gravimetric curves of the chemically modified diatomaceous earth sample

c)chromatographic behavior

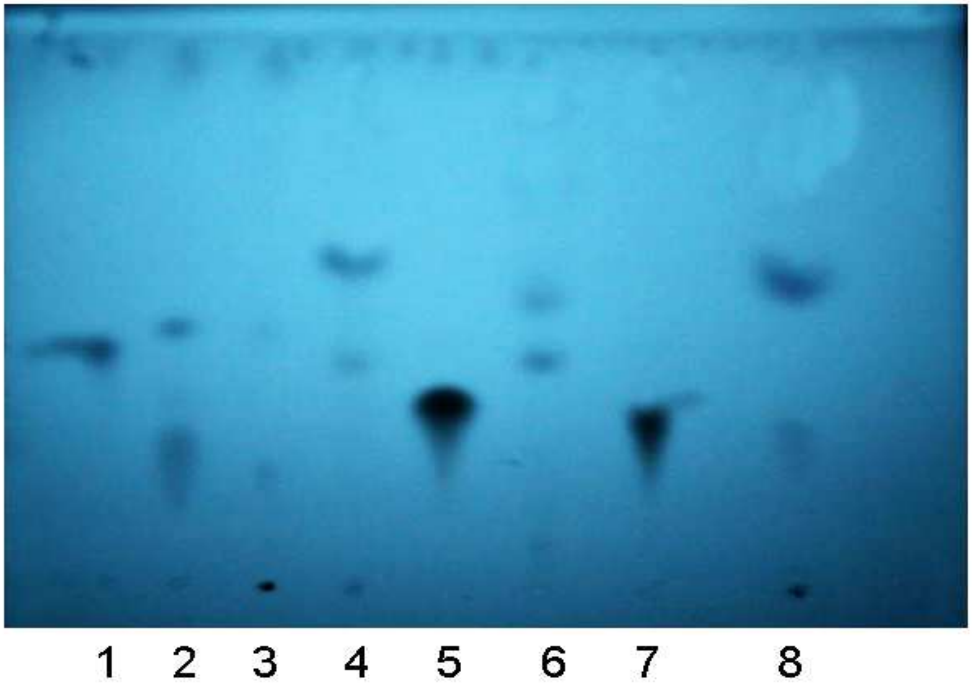

Fig.15. Chromatogram at λ=254 nm for: 1-Diazepam, 2-Nitrazepam, 3-Lorazepam, 4-Bromazepam, 5-Medazepam, 6-Tetrazepam, 7- Autilon, 8-Zopiclone. Stationary phase – diatomaceous earth chemically modified with n-thiol, mobile phase: methanol - water (30:20, v/v)

Conclusion

The data obtained from this research show the chemical modification of the surface support and the formation of a new polar chemically modified stationary phase, which can be use in liquid chromatography.

6.Synthesis and characterization of bentonite chemically modified with γ-aminopropyltriethoxysilane

Bentonite are rocks formed from a mineral resulted by the devitrification and chemical alteration of erruptive glass material, normally volcanic tuf and ash.[284]
The percent composition of sodium bentonite from the Chioarului valley is: SiO_2 - 78,22%; Al_2O_3 - 14,42%; Fe_2O_3 - 1,70%; CaO - 0,60%; Na_2O - 1,60%; MgO - 1,60%; K_2O - 1,55%; TiO_2 – 0,50%; MnO - 0,03%.

Sinthesis of the stationary phase:

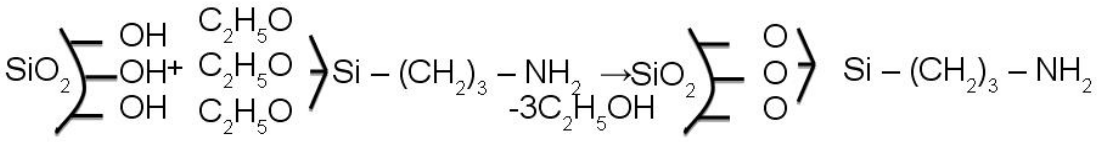

Fig. 16. Chemically modified bentonite with n-tyol

The obtained chemically modified bentonite was characterized through elemental analysis (carbon, hydrogen), measurements of specific surface, FTIR spectroscopy, thermo analytical study and thin-layer chromatographic testing.

a)density of coverage

Table 12. Specific surface and density of coverage of chemically modified bentonite

Sample	**Carbon (%)**	**Hydrogen (%)**	**Nitrogen (%)**	**S_{BET} [m^2g^{-1}]**	**α (µmol/m^2)**	**Vp (cm^3/g)**
Sodium bentonite	-	-	-	111.6	-	0.10
–NH_2 modified bentonite	3.99	1.52	1.56	30	3.64	0.05

b) FTIR spectroscopy

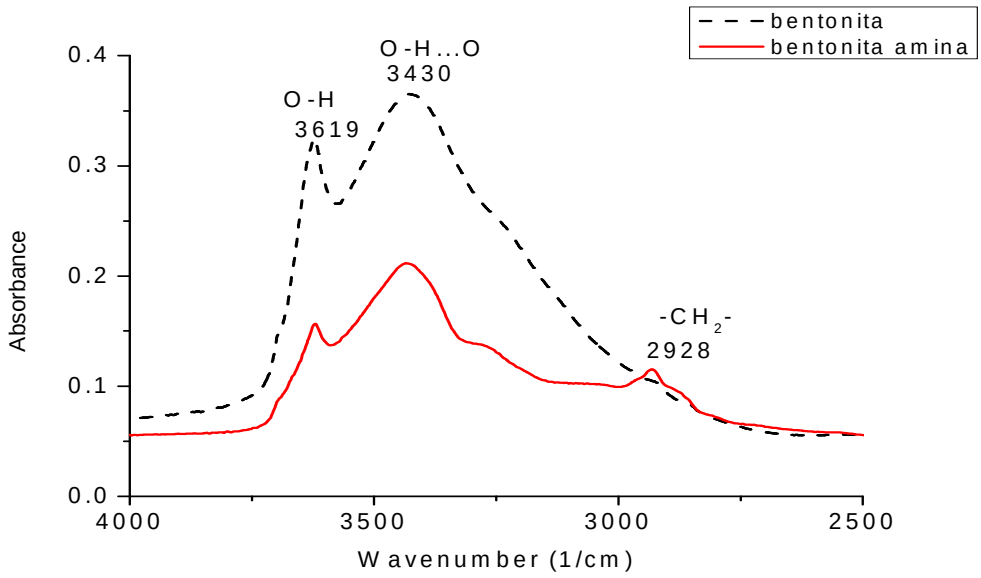

Fig. 17. FTIR spectra of unmodified bentonite (black) and chemically modified bentonite with –NH_2 (red), for 4000-2500 cm^{-1} spectra range

c)thermo analytical study

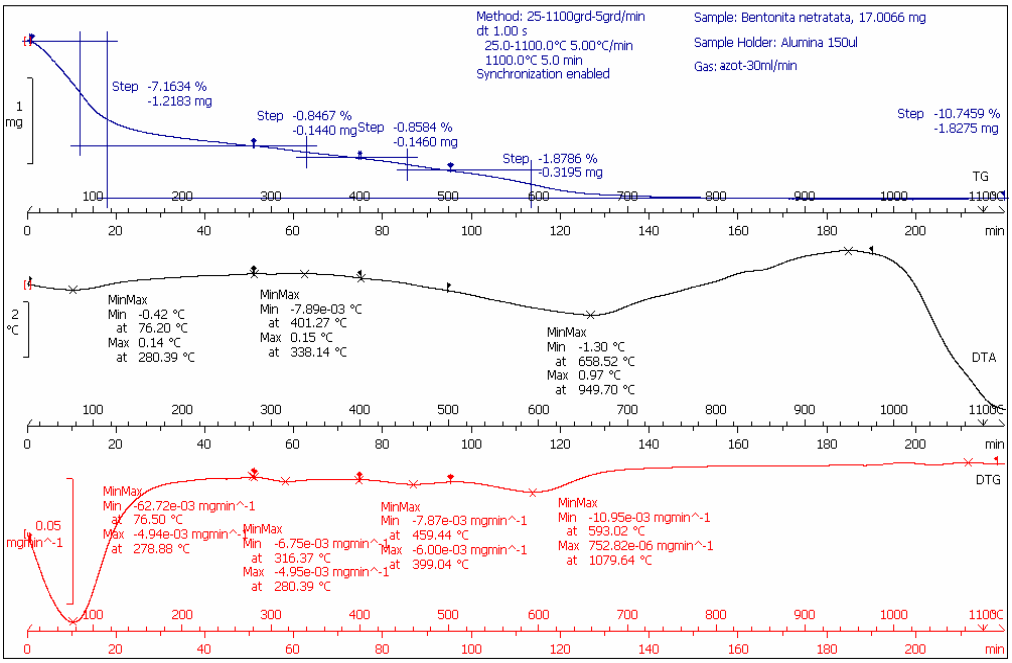

Fig.18. Thermo-gravimetric curves of the sodium bentonite sample

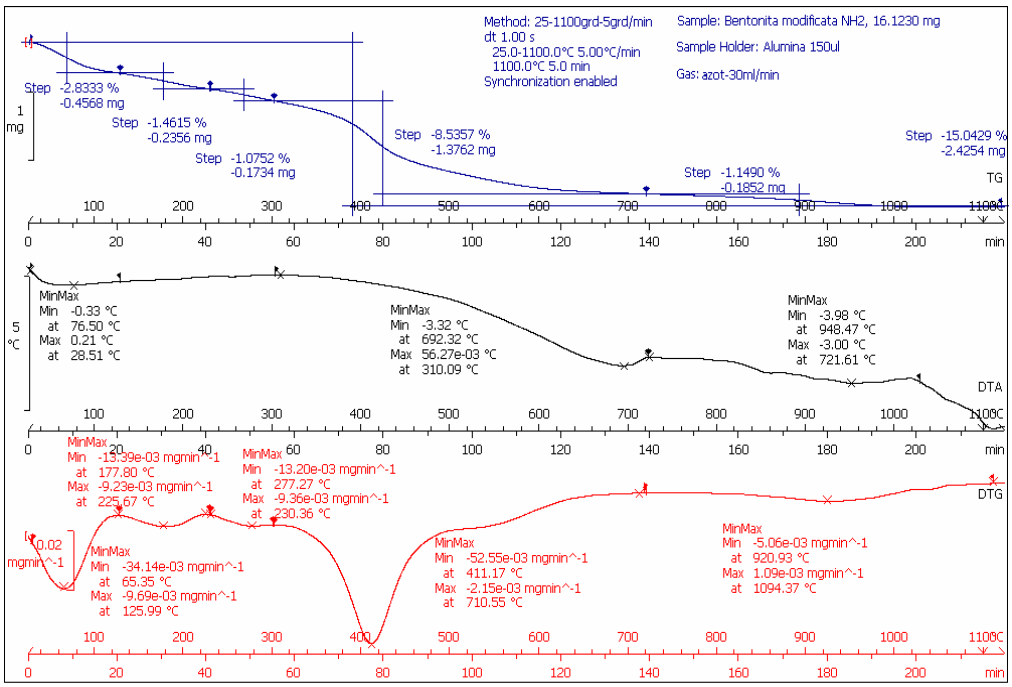

Fig.19. Thermo-gravimetric curves of the chemically modified bentonite sample

d)Chromatographic behavior

Table 13. R_Fx100 values of the compounds separated on chromatographic plates

Compound	Values RF x 100	
	Plates Nano-Sil-NH2	Plates with chemically modified (-NH2) bentonite
Uric acid	15	17
Xanthine	25	28.5
Hipoxanthine	38	43.2
Adenine	50	63.2

Conclusion

This new product can be used successfully as a polar stationary phase in liquid chromatography [295].

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