CARBON-BASED NANOMATERIALS FOR GOLD (III) RECOVERY: KINETICS AND LOADING INVESTIGATIONS

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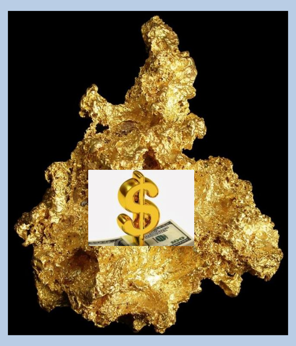
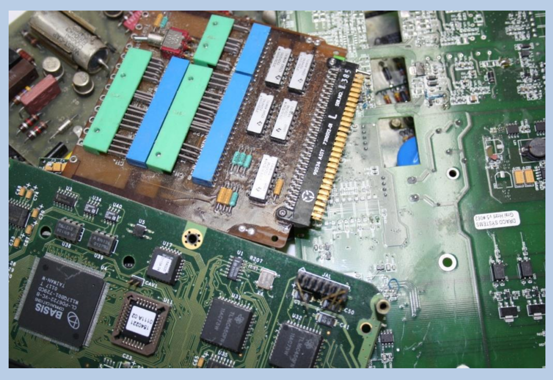
INTRODUCTION

Adsorption is a high efficiency, cost-effectiveness and easily handling method to recover pollutants or strategic metals from liquid effluents. Nowadays a research challenge is the development of new adsorbents. Carbon nanomaterials have adequate properties to be used as metal adsorbent.



Gold is a valuable metal, the price of this strategic metal in 20015 was 1.376 $ kg^{-1}. It is used in jewellery together with various industries due to its chemical and physical properties. Thus the recovery of it from various kind of wastes generated by these industries is also today of growing interest.



Electronic (Raw printed circuit board)

Jewellery

OBJECTIVE

The aim of this research was to establish the adequate conditions for achieving gold adsorption by carbon nanomaterials. The effect of different parameters, such as stirring speed, temperature, pH, carbon nanomaterials concentration was studied.

MATERIALS AND METHODS

REAGMENT

Stock metal solution was prepared from $HAuCl_4$. All chemicals used were A.R. grade

NANOMATERIALS

CNF- Carbon nanofibers (Manufactured by Antolin Group)
MWCNM- Multiwalled carbon nanomaterials (Commercial)
MWCNM_ox- Multiwalled carbon nanomaterials (Commercial)

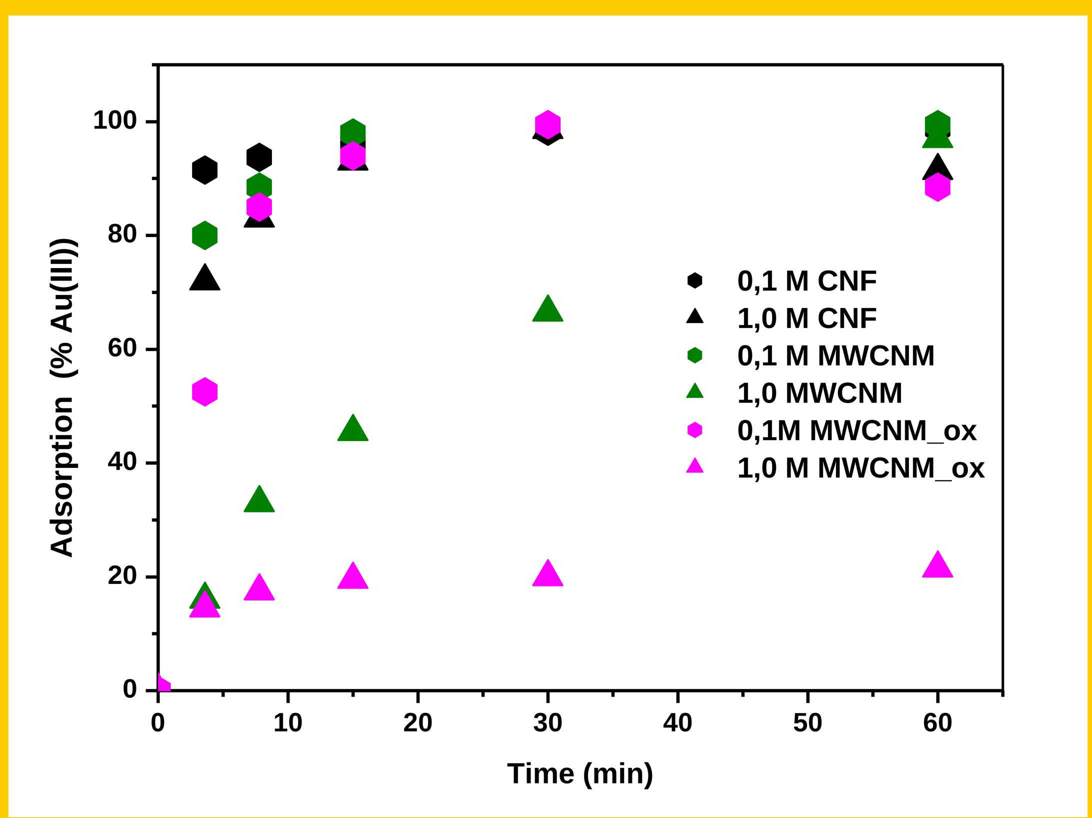
ADSORPTION PERCENTAGE

$$\% Au_{Ad} = [(C_0 - C_e)/C_e] \times 100$$

Where C_e(mg Au L^{-1}) is the equilibrium metal concentration in solution

RESULTS

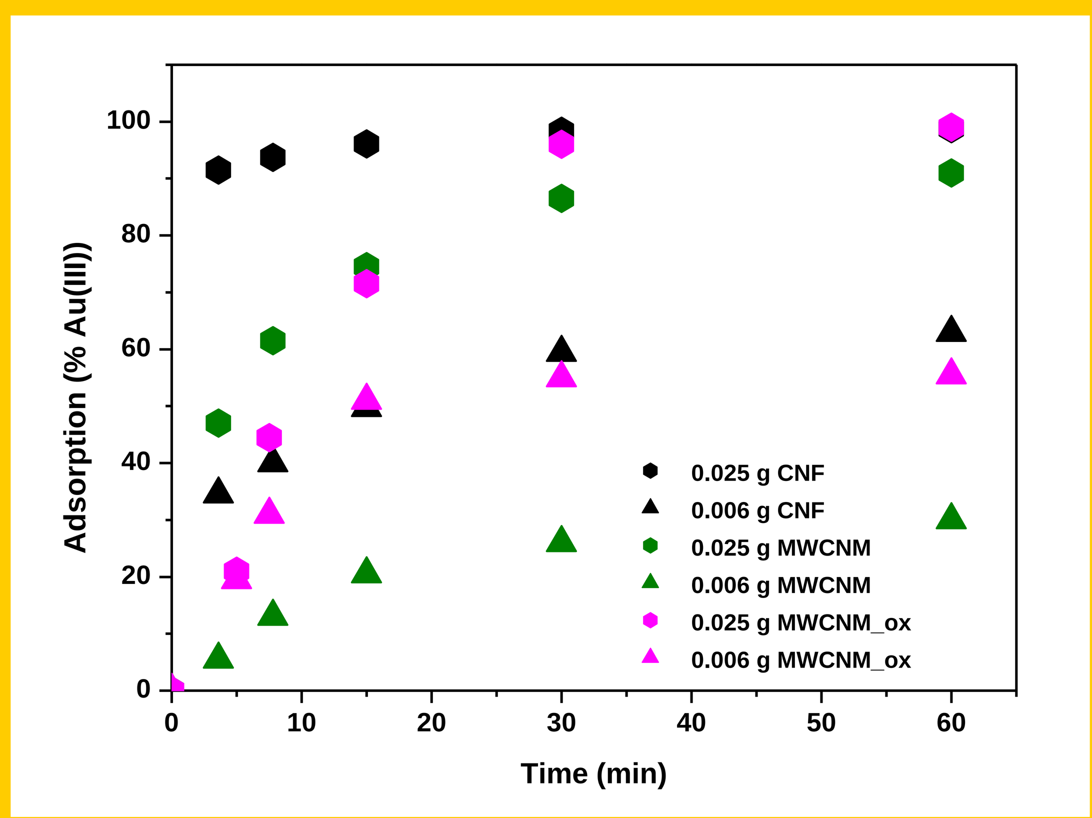
A) EFFECT OF ACIDITY



A) CNF [Au]=0.005g/L; [CNF]=0.025g; θ=2000 cm^{-1}; T=20ºC
MWCNM [Au]= 0.005 g/L; [MWCNM] =0.1g; θ=1000 cm^{-1}; T=20ºC
MWCNM_ox [Au]= 0.005 g/L; [MWCNM_ox] =0.1g; θ=1500 cm^{-1}; T=20ºC

A) Gold adsorption diminished with the increase HCl concentration

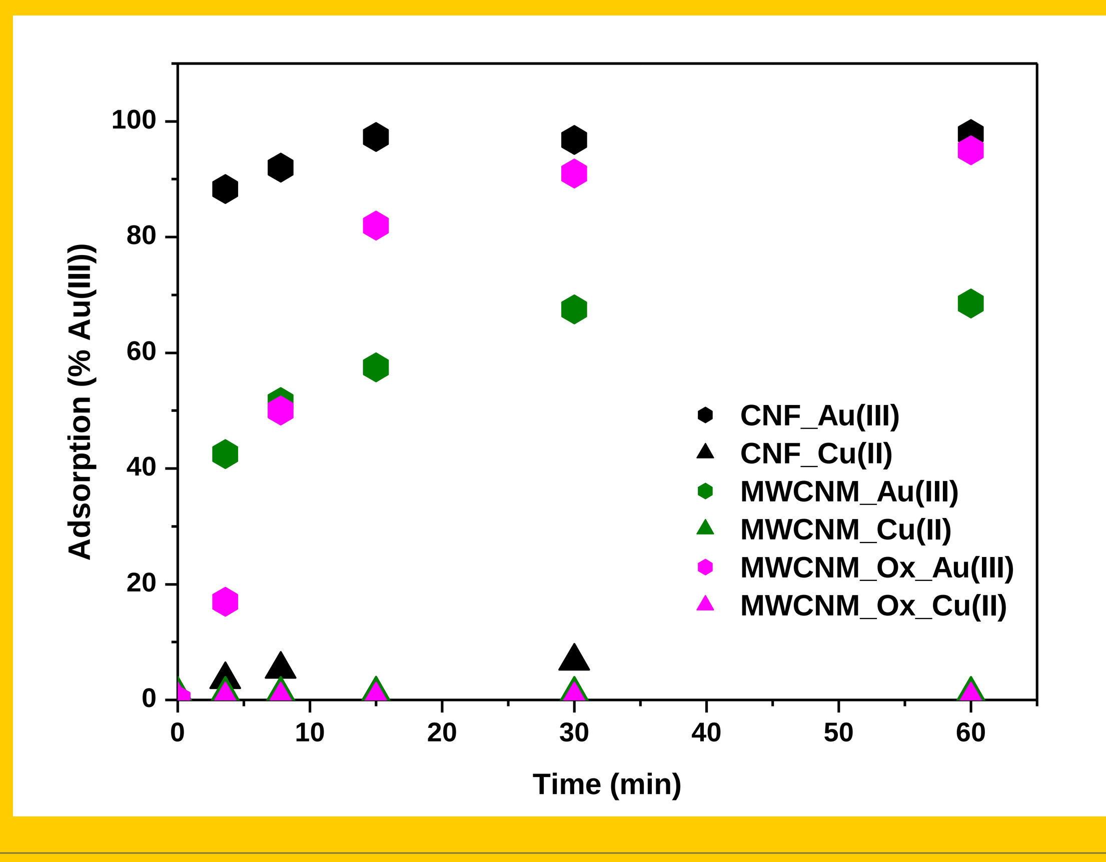
B) ADSORBENT DOSAGE



B) CNF [Au]=0.005g/L; [HCl]=0.1M; θ=2000 cm^{-1}; T=20ºC
MWCNM [Au]= 0.005 g/L; [HCl] =0.1M; θ=1000 cm^{-1}; T=20ºC
MWCNM_ox- [Au]= 0.005 g/L; [HCl] =0.1M; θ=1500 cm^{-1}; T=20ºC

B) An increase in carbon nanomaterials amount raised the percentage of Au(III) adsorbed

C) Au(III) and Cu(II)



C) CNF [Au]=0.005g/L; [Cu]=0.013g/L; [HCl]= 6M; [CNF]=0.1g; θ=2000 cm^{-1}; T=20ºC
MWCNM [Au]= 0.01g/L; [Cu]=0.03g/L; [HCl]= 0.1M ; [MWCNM] =0.2g; θ=1000 cm^{-1}; T=20ºC
MWCNM_ox- [Au]= 0.01g/L; [Cu]=0.03g/L; [HCl]= 0.1M; [MWCNM_ox]=0.1g; θ=1500 cm^{-1}; T=20º

C) Au(III) is preferably adsorbed on the carbon nanomaterials over the Cu(II)

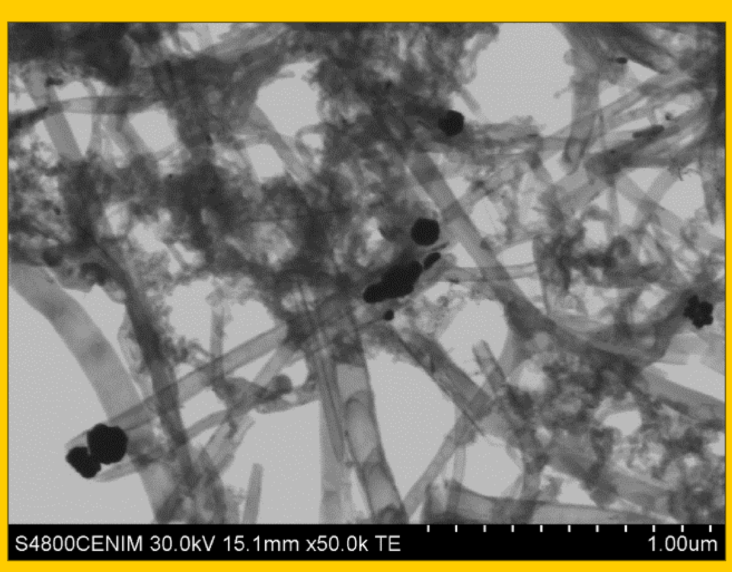
OPTIMAL CONDITION	CNF	MWCNT	MWCNT_ox
[Au] 0.005g/L; [HCl] 0.1M; 20ºC; 2000rpm, 0.006g solid	0.34		
[Au] 0.005 g/L; [HCl] 0.1M; 20ºC; 1000rpm; 0.005g solid		0.15	
[Au] 0.005 g/L; [HCl] 0.1M; 20ºC; 1500rpm; 0.006g solid			0.23

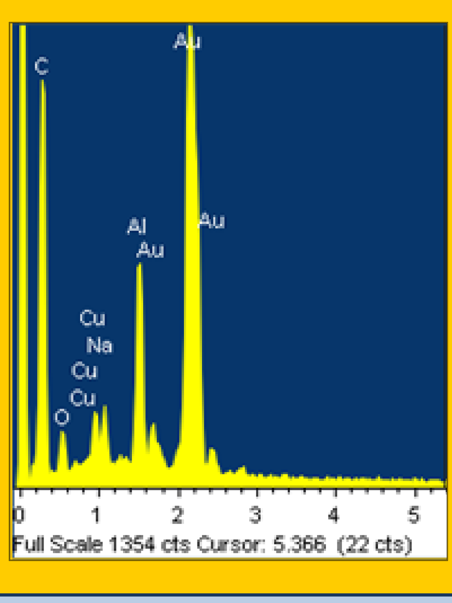
Adsorption of gold on the optimal conditions by carbon nanomaterials (mmol Au/g nanomaterials)

KINETICT	PFORE			PSORE		
	$K_1(min^{-1})$	qe(mg/L)	R^2	K_2(g/mg min)	qe(mg/L)	R^2
CNF	0.088	38.9	0.972	0.040	54.1	0.999
MWCNM	0,088	12.5	0.994	0,010	19.76	0.999
MWCNM_ox	0.124	31.2	0.991	0.002	26.81	0.928

ISOTHERMAL	FREUNDLICH			LANGMUIR		
	n	K_f(mg/L)	R^2	q_{max}(g/L)	b(L/mg)	R^2
CNF	3.7	40.8	0.982	51.8	9.1	0.908
MWCNM	4.7	21.6	0.987	29.7	4.8	0.976
MWCNM_ox	3.9	28.4	0.589	37.7	5.0	0.987

PFORE- Pseudo first-order rate equation
PSORE- Pseudo second-order rate equation





TEM micrographs CNF loaded with Au and the elemental composition analysis of the dark particles. (Au^0)

Probably the reduction occurs on the nanocarbon surface

a) Direct reduction Au(III) metallic gold

$AuCl_4^- + 3e^- \rightarrow Au^0 + 4Cl^-$ E^0= 1.00V

b) Reduction via the formation of $AuCl_2^-$.

$AuCl_4^- + 2e^- \rightarrow AuCl_2^- + 2Cl^-$ E^0= 0.92V

$AuCl_2^- + e^- \rightarrow Au^0 + 2Cl^-$ E^0= 1.00V

In any case the electron donor is the carbon nanofibers:

$C + 2H_2O \rightarrow 4H^+ + CO_2 + 4e^-$ E^0= 0.21 V

CONCLUSIONS

It is possible to use carbon nanomaterials to recover a strategic metal, such as Au(III) in effluent liquid at HCl medium. One possibility of gold adsorption is by reduction on the nanocarbon surface. The adsorption is selective from other metals, such as Cu(II), Fe (III) and Ni(III).

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