New Platinum Nanocrystal-Based Silicon Nanotubes for Targeting Breast Cancer

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I. Introduction

Cancer is a major cause of death worldwide, and every year millions of people are diagnosed with it. Platinum compounds play an important role as anticancer agents. Their ability to bind to DNA in the nucleus (by a process known as intercalation within DNA base pairs) result in DNA damage and cell death.

Our research group has developed a straightforward method to produce a well-defined nanoscale drug carrier known as silicon nanotubes (SINTs), along with a way to incorporate platinum on their surface using (3-Aminopropyl) triethoxysilane (APTES) as a functional arm. These silicon nanotubes have attracted great attention in applications relevant to diagnosis and therapy, owing in part to its biocompatibility and biodegradability in cells.

Cancer activates signaling pathways that translates on overexpression of specific proteins/receptors. Particularly, folate receptors (FR) are present in 90-98% of ovarian, prostate, uterus, breast, as well as some adenocarcinomas. FR expression is very limited in normal cells and generally not accessible to blood flow which makes it a suitable and promising system to target Cancer. These receptors are glycopolypeptides that present high affinity for folic acid (FA). We propose to incorporate folate to our silicon-based Pt nanoparticles to enhance selectivity.

II. Methods

A. Synthesis of Silicon Nanotubes (SiNTs)

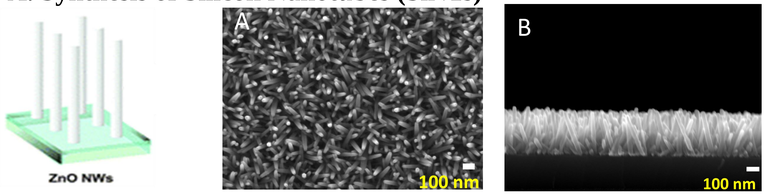

Fig 1. (A) SEM image of ZnO NWs on fluorine-doped tin oxide (FTO) substrate; (B) SEM image cross-section of ZnO NWs on FTO substrate. Growth of ZnO NWs at 95◦C.

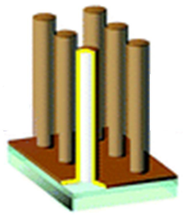

Fig 2. Si/ZnO NWs

Deposition of Si on ZnO Nws via chemical vapor deposition of SiH_4 at 543 ◦C.

$$SiH_{4(g)} \longrightarrow Si_{(s)} + 2H_{2(g)}$$

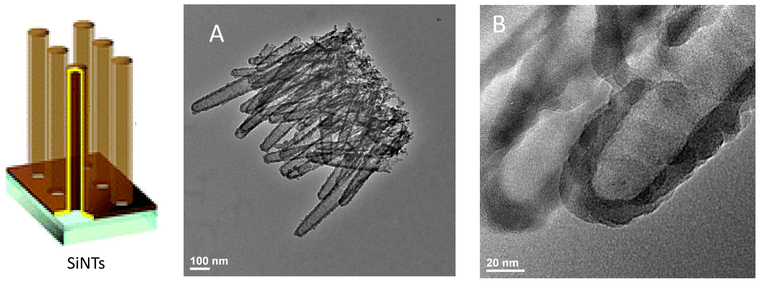

Fig 3 (A) TEM image Silicon Nanotubes (SiNTs) low magnification; (B) Higher magnification

Removal of ZnO NWs to produce hollow SiNTs

$$ZnO_{(s)} + 2HCl_{(g)} \rightarrow ZnCl_{2(s)} + H_2O_{(g)} \quad (1)$$

$$ZnCl_{2(s)} + NH_{3(g)} \rightarrow Zn(NH_2)Cl_{(g)} + HCl_{(g)} \quad (2)$$

B. Formation of Pt Nanocrystals on SiNTs

1. Functionalization of SiNTs with primary amino groups using APTES

Zeta Potential analysis was performed to evaluate the surface charge of SiNTs before and after APTES functionalization.

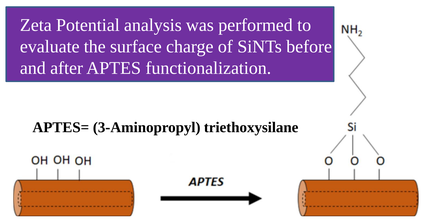

Fig 4. Scheme of functionalization of SiNTs with 2% of APTES in Toluene for 4 h at room temperature

Table 1. Zeta Potential of SiNTs before and after functionalization in DI water at pH 6.5

Samples	Zeta Potential (mV)
Unmodified SiNTs	-17.04 ± 0.70
APTES-functionalized SiNTs	+35.87 ± 1.96

2. Incubation of APTES-SiNTs in K_2PtCl_4 solution at room temperature.

Incubation of APTES-SiNTs was for 24 h 1.5 mM K_2PtCl_4 solution at room Temperature

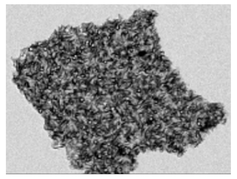

Table 2. Elemental analysis of Bundle PtNCs-SiNTs (TEM-EDX)

Element	Wt%
Oxygen (O)	10.64
Silicon (Si)	36.80
Platinum (Pt)	51.64
Chlorine (Cl)	0.93

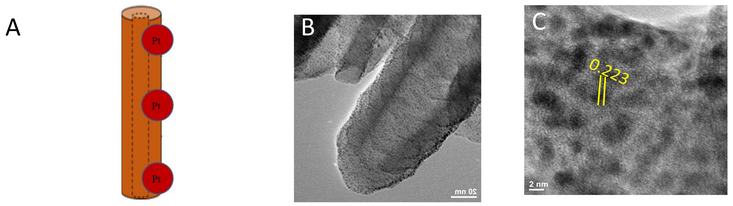

Fig 5. (A) Scheme of platination of APTES-SiNTs with K_2PtCl_4; (B) TEM image of PtNCs-SiNTs low magnification; (C) TEM image of PtNCs-SiNTs highlining the lattice spacing lines.

C. Conjugation of PtNCs-SiNTs with Folate

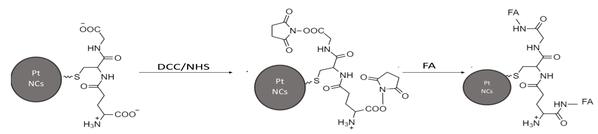

Fig 6. Scheme of Folic Acid attachment with PtNCs

III. Results

A. FT-IR spectra Folate-PtNCs-SiNTs

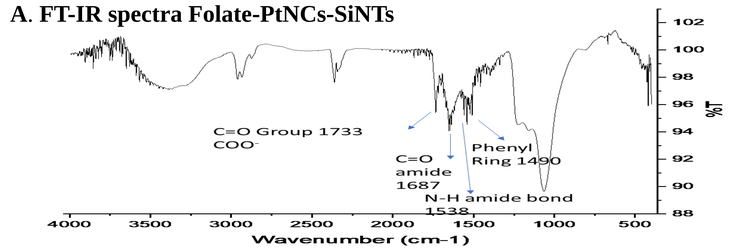

Fig 7. FT-IR spectra of FA-PtNCs-SiNTs

B. Folic Acid surface-bound for Cancer targeting

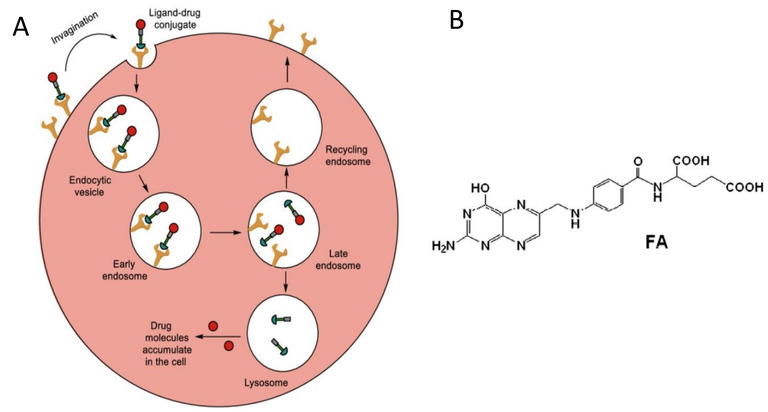

Fig 8. (A) Receptor-mediated endocytosis of a Folate drug-conjugate (3), (**B**) Folic Acid

C. Evaluation of Cell Viability of HeLa Cells after Treatment with Pt NCs-pSiNTs

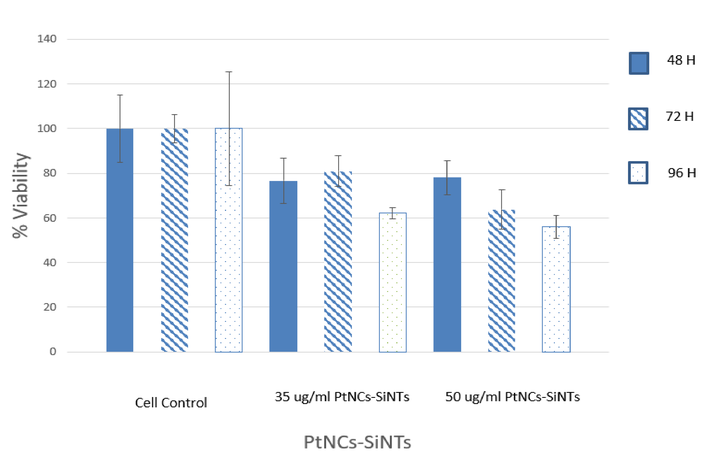

Fig 9. Cell viability after treatment with PtNCs-SiNTs at different incubation times

IV. Conclusions and Future Work

- The properties of this material have a high toxicity against HeLa cells inducing apoptosis(2).
- The FT-IR spectra and Zeta potential results confirms the attachment with folate.
- Next step is evaluating the cell viability against HeLa cells with Folate-PtNCs-SiNTs

V. References

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2. Nguyen T. Le; , Giridhar R. Akkaraju and Jeffery L. Coffer. *ACS Appl. Bio Mater.* 2020, 3, 1, 208–216
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