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Vertically Aligned SiNW Arrays with TCS as Precursor

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Aim : providing cost-effective route for VASiNWs processing and help enabling their commercial applications

SILICON NANOWIRES [SiNWs]

Potential applications:
- Energy harvesting [1]
- Protein detection, biosensors [2]
- Bioengineering platform [3]
- Gas sensing [4]
- Energy storage [5,6]
- Thermoelectricity [7]

Current challenges:
- **Materials research level:** controlled distribution in properties (aspect ratio, doping levels, crystallographic orientation, surface roughness)
- **Production level:** reduce production costs by developing lower cost scalable processing solutions
- **Nanodevice fabrication:** Large scale microscopic arrangements (Vertically or Horizontally Aligned Si Nanowires [VASiNWs, HASiNWs]

Modes of fabrication:
Chemical vapor deposition - Vapor Liquid Solid (VLS) growth, metal assisted chemical etching, oxide-assisted catalyst free method, solution techniques, laser ablation.

TRICHLOROSILANE [TCS] as a Mass-Production PRECURSOR for SiNWs

TCS is already the principal precursor for Si in the semiconductor industry, it is the main source for polysilicon production plants (***Siemens process, which uses TCS, counts for 75% of market share***)

	Previous works		Our work
Precursor gas	Silane	Silicon tetrachloride	Trichlorosilane
Formula	SiH_4	$SiCl_4$	$HSiCl_3$
Process temperature for SiNWs	Starting at 450˚C	Starting at 800˚C	Starting at 800˚C
Type of SiNWs on Si(111)	Randomly aligned	Vertically aligned	Vertically aligned
Requirement for directional alignment	Requires additional HCl	Ready to use	Ready to use
Cost	$$$	$$$	$

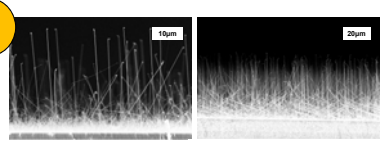
VLS Growth of VASiNWs as a case study for our NanotoMacro™ process solutions

NanotoMacro™ process solutions for scaling-up nanomaterials synthesis process development and pilot production while:
> Achieving high quality materials *via* simplified CVD routes
> Developing universal solutions
> Targeting sustainable production routes

Growth conditions investigated here for proof of principle:
(e-beam deposited gold catalyst layer is chosen as a robust technique)
> Temperature : 700˚C to 900˚C
> Growth time: 60s to 30min.
> Gold catalyst layer thickness: 1nm, 3nm, 5nm
> Target : 4" Si(111) wafer batch processing [up to 50]

RESULTS

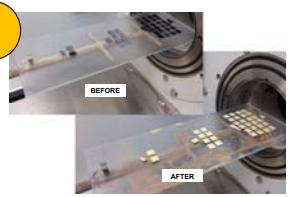
1



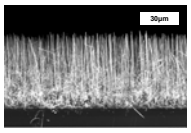
700 C - 5 min - 1nm Au *800 C - 5min - 1nm Au*

Optimum temperature for growth of densely packed array is found to be around 850C

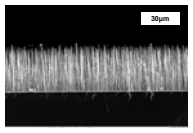
2



Experimental set-up with 5"process tube (10mm x10mm diced samples)



850 C - 30min - 5nm Au front of reactor (Si rich)

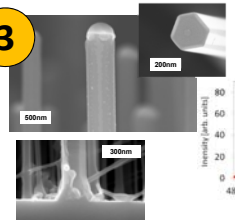


850 C - 30min - 1nm Au rear of reactor (HCl rich)

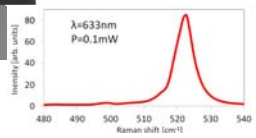
Quartzware equipment used

Reactor/injector design with inner liner provides effective in situ production of HCl and repeatable results with minimal maintenance

3



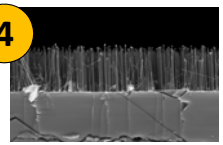
850 C - 30min - 5nm Au



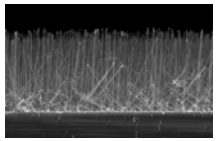
Typical Raman spectra of transferred SiNWs on glass

Highly crystalline Si nanowires can be obtained

4



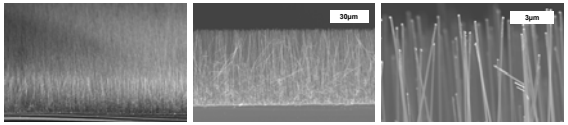
850 C - 1min - 5nm Au [6µm tall]



850 C - 1min - 1nm Au [10µm tall]

Au Catalyst thickness impacts overall growth rate

5



850 C - 30 min - 1nm Au

Uniform growth on 4" wafer scale achieved at a rate of 5µm/min with TCS

next

Technical : investigate other catalyst materials, collaboration with partners for Li-ion battery anode development and biosensors in particular.

Comparison of quality and throughput with randomly aligned SiNWs on stainless steel foil substrates using silane as a precursor to further quantify the benefits of the TCS process for industrial applications.

REFERENCES

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