TWIST BIOSCIENCE

From DNA Synthesis on Chips to DNA Data Storage

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Twist's Breakthrough: DNA Synthesis on Silicon

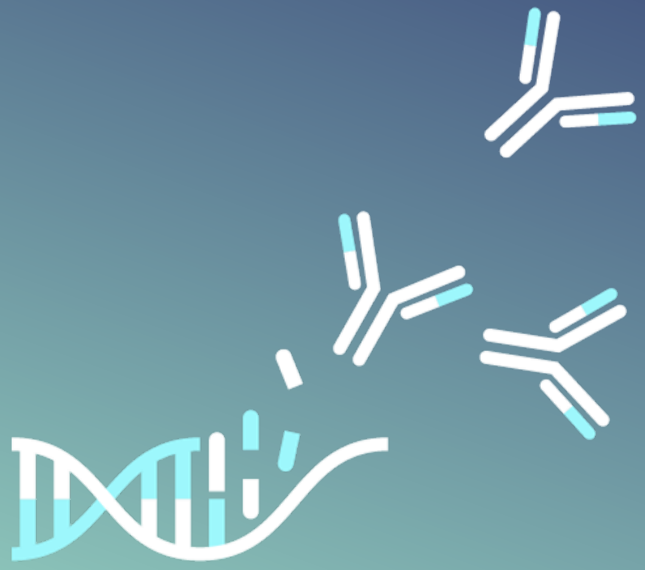
Established Market

Synthetic Biology
Precision at Scale

Genomics
Efficient NGS Target Enrichment

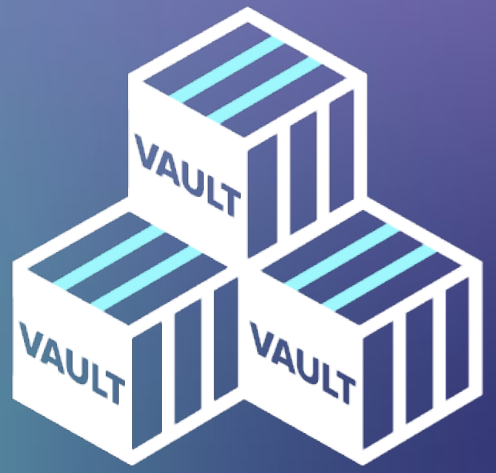
Current Initiative

Novel Therapeutics
Drug Discovery Library of Libraries

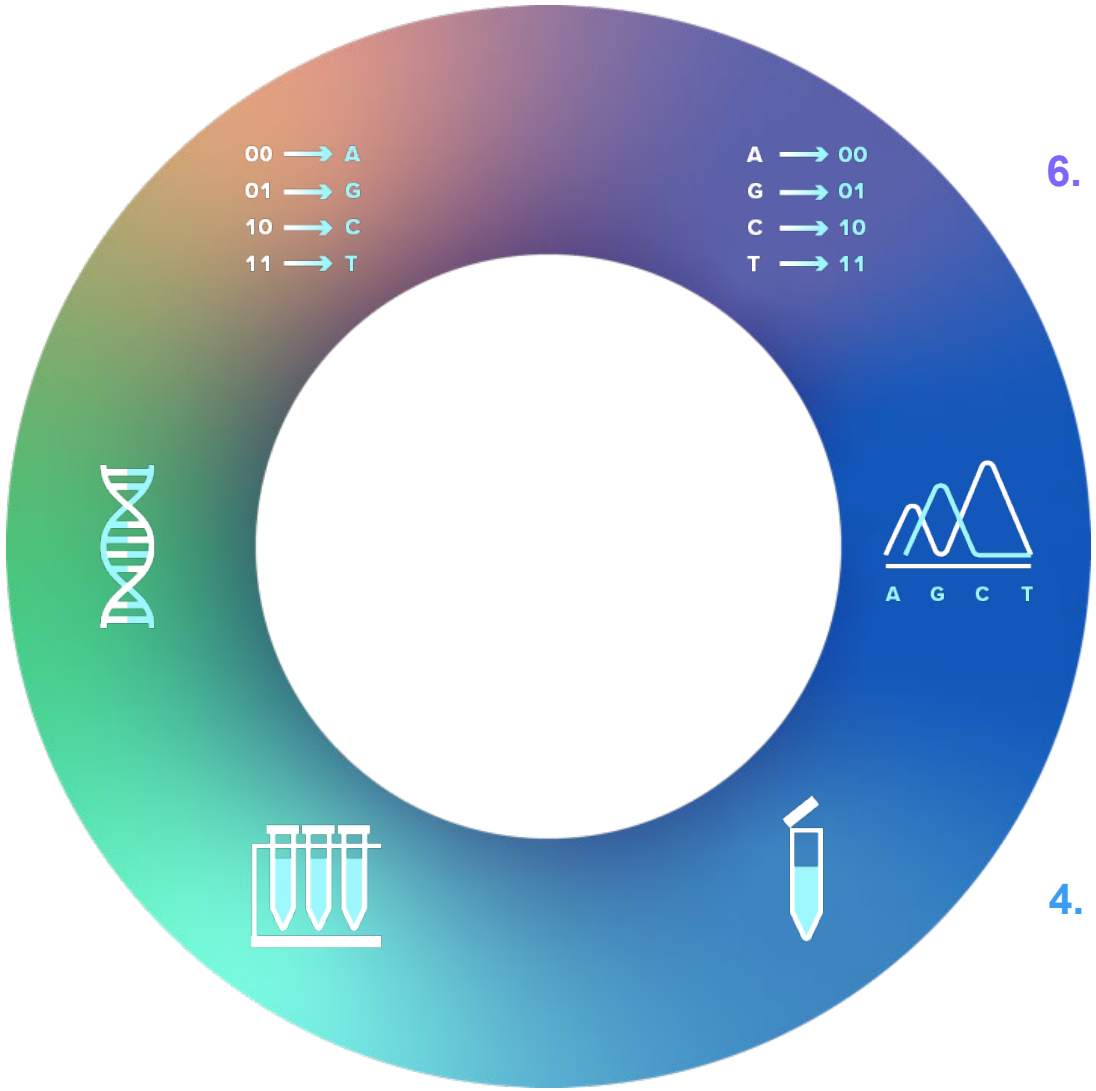


In Development

DNA Data Storage
Universal Read/Write Media
Inspired by Nature



DNA Data Storage Workflow



Key Features

- Compact: Holds the promise to meet the projected data storage scaling needs
- Longevity: 1000+ year shelf life without needing migration
- Low power: Zero power consumption during storage
- Data resilience: Error correction coded data assures very low bit error rate

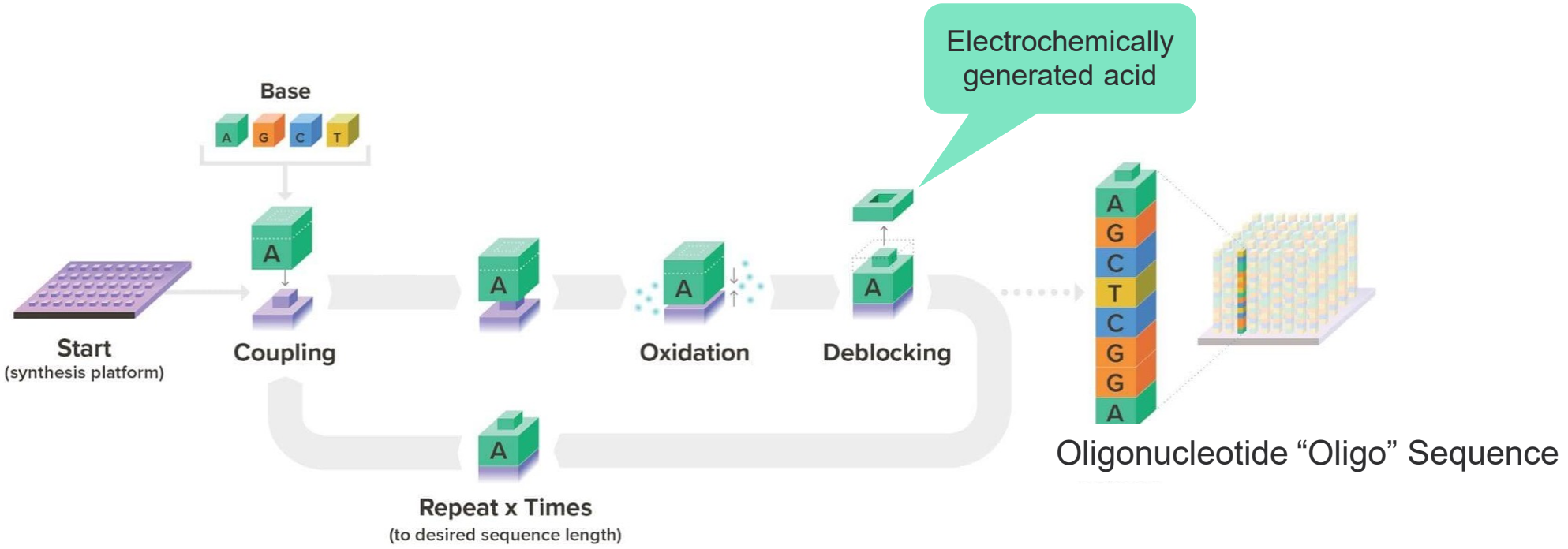
Lowest TCO for Archival Solution

Technology	Speed	Capacity	Copies	Format	Archive	TCO*
DNA	24 hrs.	Configurable	Free	Universal	**1,000+ yrs.**	**$**
Tape	1 hr.	Fixed	$/copy	Media specific	**Data migration**	**$$**
Hard Disk Drive	5 ms	Fixed	$/copy	Media specific	**Data migration**	**$$$**
Solid State Drive	50 us	Fixed	$/copy	Media specific	**Data migration**	**$$$$**

* TCO: Total cost of ownership

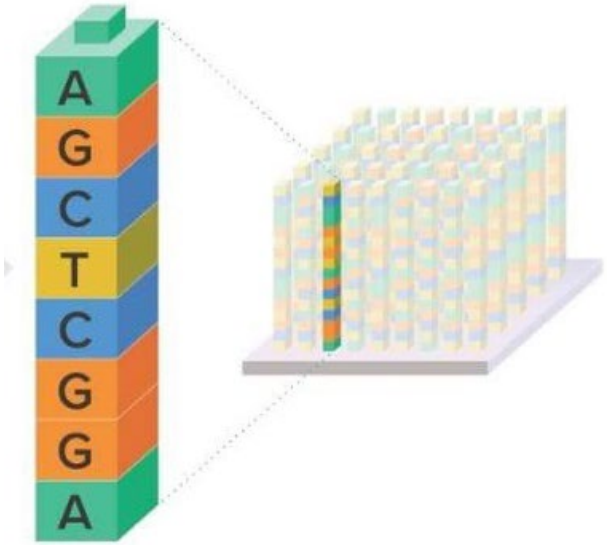
Well-established CMOS-based DNA Synthesis Process

- High-density 2D device array enables massively-parallel synthesis



1TB DNA Pool Contains Large Number of Indexed Oligos

- Writing 1TB of data in DNA
  - Synthesize **5 x 10^{10}** *unique* oligos
  - 1,000 copies per *unique* oligo
- Storing 1TB of data in DNA
  - Oligos are washed off chip into small container
  - After freeze drying, oligo volume is $(150\ um)^3$



Oligonucleotide “Oligo” Sequence

Typical 200 base oligo stores 20 bytes

ATCGATCGATCGGTAATCGATCGATCGATCGGTAATCGATCGATCGATCGGTAATCGATCGATCGATCGGTAATCGGTCGGCAATCGATCGATCGGTAATCGATCGATCGATCGGTAATCGATCGATCGATCGGTAATCGGTCGGCA

20 base primer | 20 base index | 140 base payload | 20 base primer

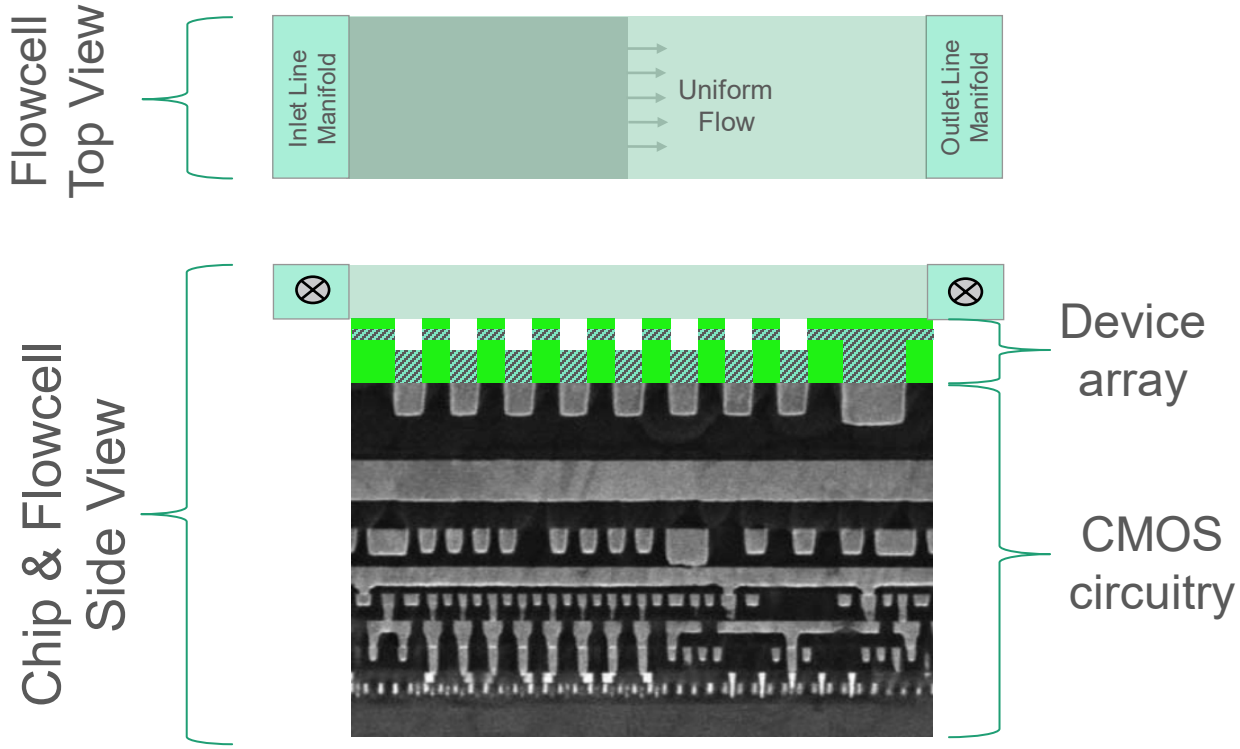
High Density Chip-Based DNA Synthesis System

- Modular Chip Design

	GEN 1 Alpha	GEN 2 Beta	GEN 3 Enterprise
Chip width (cm)	4	4	4
Chip length (cm)	3	3	3
Oligos	3.E+09	1.E+10	**5.E+10**
Data (GB)	62.5	250	**1,000**

- Modular Fluid Delivery System

Modules	4	8	16
Chips per module	2	4	8
Chips per system	8	32	128
Capacity (TB) / run	1	8	**128**

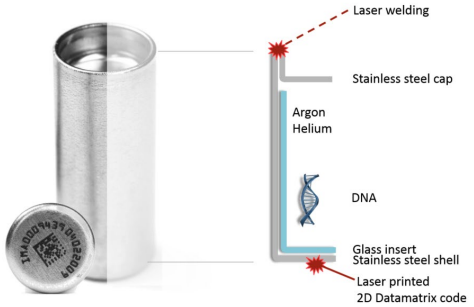


Lowering the Cost of DNA Synthesis

- Fixed costs
  - System
    - Runs per day → 4X
  - Chips
    - Reuse → 100X
- Variable costs
  - Reagents
    - Supply chain / reuse → 10X
  - Volume per reaction
    - High density → 40X

Other Elements required for DNA Data Storage

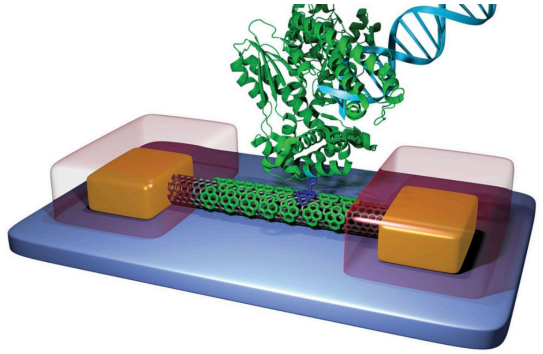
- Storage
  - Off-the-shelf, hermetic solution exists
  - Reconfigurable to match use case



Approx. 8mm x 24mm

Imagene SA

- Sequencing
  - Molecular electronics
  - Multiple companies working on low-cost solution



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Path to Commercialization

- Technology development
- System development
- Quality Management System development
- Ship products

Basic Product Options

- End-to-end system
- Synthesis / sequencing as a service

Summary

- DNA is a high-performance storage solution
  - Robust when properly stored
  - Multiple copies produced during write process, and DNA pools are easily copied
- DNA Data Storage is coming sooner than you think
  - POC system is imminent
  - Production systems to follow
- This is just the beginning
  - Multiple groups working on basic compute functions
  - Neuromorphic computing on large data sets is on the horizon

Twist Bioscience

DNA Data Storage