Nanopore Sequencing

Patent Landscape Analysis, February 2019

With the coming launch of new products for various technologies, which companies will lead the nanopore sequencing IP landscape?

REPORT OUTLINE

- Nanopore sequencing
- Patent landscape analysis
- February 2019
- Ref.: KM19002
- PDF >170 slides
- Excel file >7,200 patents
- €6,490 for a multi-user license

REPORT'S KEY FEATURES:

- **IP trends**, including time-evolution of published patents, and countries of patent filings
- Patents' **current legal status**
- Ranking of **main patent assignees**
- **Key players' IP position** and **relative strength** of their patent portfolios
- **IP analysis of nanopore technologies** (solid-state nanopores, protein nanopores, and hybrid nanopores) and **IP analysis of applications** (oncology, plant genetics, infectiology, etc.)
- **Main patent litigations**
- **Description of key players** and **key patents**
- **Excel database** with all patents analyzed in this report, including technology segmentation

LINKED REPORTS

- *CRISPR Technology & Market Overview: from Lab to Industry 2018*
- *Liquid Biopsy: From Isolation to Downstream Applications 2018*
- *Thermo Fisher - Ion 520 DNA Sequencing Chip*

Nanopore sequencing is a promising technology in the field of next-generation sequencing

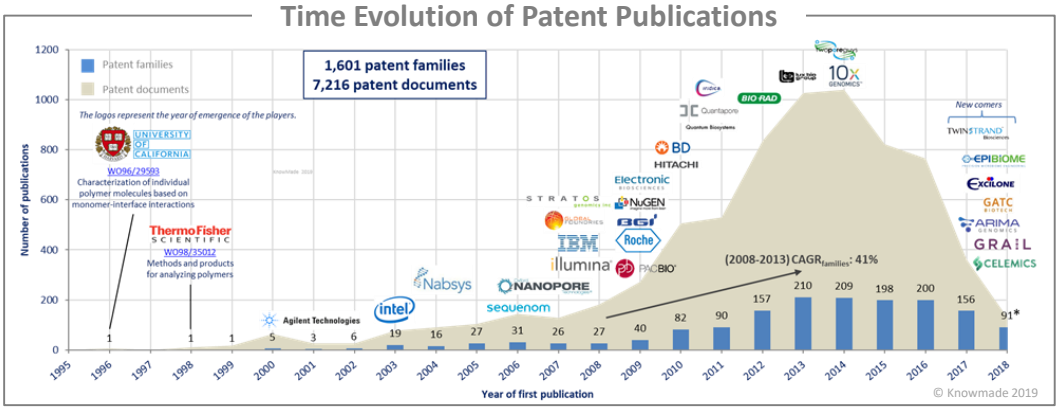
Nanopore sequencing is one of the next-generation sequencing (NGS) technologies believed to be capable of revolutionizing DNA analysis. Different modalities of nanopore sequencing have been developed over time, including protein nanopores, solid-state nanopores, and hybrid nanopores. The technology enables production of ultra-long reads at very high speeds, reducing sample preparation time as well as the data-processing time required to reassemble the reads into their original sequence.

This novel technology could tap into a brand-new sector of customers who may require genetic fingerprinting for fast identification of cancer types and pathogens. According to DataBridge, the global NGS market will grow fast, from $US 4.83B in 2017 to $US 16.35B in 2024, at an estimated compound annual growth rate (CAGR) of 19.2% (from 2018 - 2024).

Today, Oxford Nanopore Technologies is the only company to have brought nanopore-based sequencers to market. However, several other companies are developing their own technology, and Oxford Nanopore may not be the only supplier of nanopore-based sequencers much longer. For example, Two Pore Guys has announced the release of its product suite in spring 2019.

With new products launching in the near future, it is crucial to understand the intellectual property (IP) position and strategy of established nanopore sequencing players, while identifying the IP newcomers and the threat they represent. To this end, Knowmade has identified the key IP players involved in nanopore-based sequencing technologies (protein, solid-state, and hybrid) and their applications (oncology, plant genetics, etc.). Such knowledge can help detect business risks and opportunities, anticipate emerging applications, and enable strategic decisions to strengthen one's market position.

Time Evolution of Patent Publications



The analysis of the time-evolution of patent publications shows an important increase in nanopore sequencing-related patenting activity from 2008 - 2013. This increase follows the work of academic research teams (Harvard University and University of California) that proved the concept of nanopore sequencing.

Even though the industrial players developing nanopore-based sequencing are steadily gaining importance, Harvard's patent portfolio remains the strongest, followed by Illumina, Agilent, University of California, and Roche, whose influence in the IP landscape is growing. In fact, Roche is now the **most prolific applicant in nanopore sequencing**. Contrarily, **Oxford Nanopore Technologies**' patent portfolio is not the strongest, but the company benefits from the numerous partnerships it has with universities (**Harvard**, **University of California,** and **Boston University**). Moreover, several companies with strong experience in microelectronics and semiconductors (Hitachi, IBM, Samsung Electronics, Intel, and GlobalFoundries) have recently filed patents claiming solid-state nanopores.

Most main patent assignees have developed an international IP strategy. American players have a strong presence in the US and Europe. Some European companies are also well ranked, and a few Asian firms play a significant role in the patent protection of nanopore sequencing.

Analyzing patents for each main nanopore technology and application

Patents are categorized by nanopore technology (protein, solid-state, and hybrid) and by main application. Also, IP trends and the relative strength of each main patent assignee was analyzed. These findings reveal that solid-state nanopore-related patents are more numerous than those related to protein nanopore or hybrid nanopore. From an IP perspective, Roche leads for technologies related to protein nanopore, and Oxford Nanopore Technologies leads the solid-state nanopore and hybrid nanopore segments. **Regarding applications, the main patented application for nanopore sequencing is oncology**. Plant genetics, epigenetics, and transcriptomics are also important application domains for nanopore sequencing. Among the main applications for nanopore sequencing, microbiome analysis is the most recent, but already a few companies are positioned in this segment.

Main Assignees, by Application

TOP ASSIGNEES FOR APPLICATION SEGMENTS	Number of Families	Main nanopore sequencing applications								
		Oncology	Plant genetics	Transcriptomics	Epigenetics	Infectiology	Whole genome sequencing	Prenatal diagnosis	Drug resistance	Microbiome
COMPANY XXX (US)	72	47	41	12	10	26	31	24	14	0
SEQUENOM (US)	44	42	39	18	38	35	13	41	0	0
UNIVERSITY OF CALIFORNIA (US)	43	18	12	6	8	5	3	2	4	1
HARVARD UNIVERSITY (US)	51	16	4	6	4	12	11	4	3	0
COMPANY XXX (US)	44	15	11	7	11	4	4	2	2	2
CHINESE UNIVERSITY OF HONG KONG (HK)	17	15	0	3	11	4	10	16	0	0
COMPANY XXX (US)	14	14	13	13	2	9	2	2	0	0
THERMO FISHER SCIENTIFIC (US)	37	13	6	13	1	3	8	0	2	0
COMPANY XXX (US)	14	12	14	13	2	1	5	3	1	3
COMPANY XXX (CH)	85	12	7	2	4	4	2	2	7	0
COMPANY XXX (US)	23	12	4	5	1	13	4	0	8	0
COMPANY XXX (US)	11	11	8	6	1	5	5	2	4	7
AGILENT TECHNOLOGIES (US)	51	9	12	4	2	3	1	2	2	0
COMPANY XXX (US)	10	9	7	3	4	3	1	2	0	0
COMPANY XXX (US)	9	9	0	4	0	1	1	1	1	0
COMPANY XXX (UK)	57	8	34	1	12	2	0	0	1	0
COMPANY XXX (US)	8	8	2	5	8	5	4	3	3	0
COMPANY XXX (US)	8	8	1	4	6	4	4	0	8	0
LELAND STANFORD JUNIOR UNIVERSITY (US)	11	7	3	5	1	4	2	2	2	0
COMPANY XXX (US)	8	7	3	4	0	0	5	4	0	3
UNIVERSITY OF UTAH (US)	10	7	2	2	5	1	1	1	2	1
COMPANY XXX (US)	6	6	3	6	6	2	6	5	1	0
FOUNDATION MEDICINE (US)	7	6	0	5	2	0	0	0	5	0
COMPANY XXX (US)	8	6	0	5	0	0	0	0	0	0
BROAD INSTITUTE (US)	5	5	4	4	3	3	2	0	1	0
COMPANY XXX (UK)	5	5	4	0	0	3	2	0	1	0

IP profile of main players, and analysis of their key patents

KnowMade's study includes IP profiles for key players and a description of their key patents. The key-patent analysis includes the legal state of the family for each of the main territories, the number of received citations, the review of main claims, the description of interesting features disclosed about the innovation, and relevant figures illustrating how the innovation works. This section also covers patents involved in litigations.

Key Patent Analysis

Title	Characterization of individual polymer molecules based on monomer-interface interactions
Publication Number	WO 96/29593
Assignee(s)	Harvard University, also for some members University of California

Territory	USA	Europe	China	Canada	Japan	Australia	South Korea
Patent status	Expired	Expired	No Patent Filed	No Patent Filed	No Patent Filed	No Patent Filed	No Patent Filed

Family involved in a US Patent Infringement case ?	NO
Received citation count	218
Number of citing assignees	132

Nanopore described: Protein Nanopore, Solid-state Nanopore

What was claimed:
A nanopore sequencer comprising:
- Two pools of electrically conductive medium;
- One of the two pools contains a polymer molecule to be sequenced;
- The two pools are separated from one another by an impermeable barrier containing the ion-permeable passage; and
- The measurement of the conductance of the ion-permeable passage in the presence of a voltage differential between the pools as the polymer molecule passes through the ion-permeable passage allows the characterization of the polymer.

Interesting features:
This patent family comprises the **very first patent application about nanopore sequencing** ever published (in September 1996). The corresponding scientific paper (Kasianowicz et al. *PNAS* 93 (24) 13770-13773) was published two month later, in November 1996.

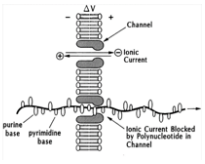
In this patent family, the term "nanopore" was used for the first time in the claims of the European divisional application (EP 1 956 367).

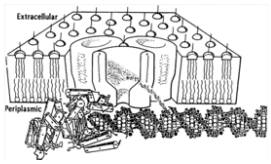
Even if the specifications of the invention only describe embodiments including protein nanopores the very definition of the term "ion-permeable passages" used in the PCT application refers to both **protein pores** and "**synthetic pores**", the last category can be formed chemically or mechanically in a membranous material.

This founding patent family mentioned multiple sorts of protein that can be used as nanopores: Gramicidin A, B, C, D, or S (from *Bacillus brevis*); Valinomycin (from *Streptomyces fulvissimus*), LamB (maltoporin), OmpF, OmpC, or PhoE from *Escherichia coli*, *Shigella sp*, and other Enterobacteriaceae, alpha-hemolysin (from *Staphylococcus aureus*), Tsx, the F-pilus, and mitochondrial porin (VDAC).

In this patent family, the preferred **protein channels** are the **α-hemolysin** and **maltoporins**.

Key figures:





This report also includes an **Excel database** containing the **>7,200 patents** analyzed in this study. This useful database allows for **multi-criteria searches** and includes patent publication numbers, hyperlinks to original documents, priority date, title, abstract, patent assignees, and each patent's current legal status, as well as **nanopore technologies** and **applications**.

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OXFORD NANOPORE TECHNOLOGIES, ROCHE, ILLUMINA, PACIFIC BIOSCIENCES OF CALIFORNIA, QUANTAPORE, ELECTRONIC BIOSCIENCE, STRATOS GENOMICS, TWO PORE GUYS, HITACHI, AGILENT TECHNOLOGIES, THERMO FISHER SCIENTIFIC, SEQUENOM, INTEL, IBM, GLOBALFOUNDRIES, ABBOTT, BECTON DICKINSON, BGI, NUGEN TECHNOLOGIES, QUANTUM BIOSYSTEMS, SAMSUNG, BIO RAD, LUX BIO, TWIST BIOSCIENCE, 10X GENOMICS, CARIS LIFE SCIENCES, QUANTUMDX, DOVETAIL GENOMICS, CELEMICS, GRAIL, GATC BIOTECH, ARIMA GENOMICS, EXCILONE, TWINSTRAND BIOSCIENCES, and more

TABLE OF CONTENTS

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