Brain Implants for Prediction and Mitigation of Epileptic Seizures

Final CRADA Report

Nuclear Engineering
About Argonne National Laboratory
Argonne is a U.S. Department of Energy laboratory managed by UChicago Argonne, LLC under contract DE-AC02-06CH11357. The Laboratory’s main facility is outside Chicago, at 9700 South Cass Avenue, Argonne, Illinois 60439. For information about Argonne and its pioneering science and technology programs, see www.anl.gov.

DOCUMENT AVAILABILITY

Online Access: U.S. Department of Energy (DOE) reports produced after 1991 and a growing number of pre-1991 documents are available free via DOE’s SciTech Connect (http://www.osti.gov/scitech/)

Reports not in digital format may be purchased by the public from the National Technical Information Service (NTIS):
U.S. Department of Commerce
National Technical Information Service
5301 Shawnee Rd
Alexandria, VA 22312
www.ntis.gov
Phone: (800) 553-NTIS (6847) or (703) 605-6000
Fax: (703) 605-6900
Email: orders@ntis.gov

Reports not in digital format are available to DOE and DOE contractors from the Office of Scientific and Technical Information (osti):
U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831-0062
www.osti.gov
Phone: (865) 576-8401
Fax: (865) 576-5728
Email: reports@osti.gov

Disclaimer
This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor UChicago Argonne, LLC, nor any of their employees or officers, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of document authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof, Argonne National Laboratory, or UChicago Argonne, LLC.
Brain Implants for Prediction and Mitigation of Epileptic Seizures

Final CRADA Report

prepared by
Nachappa Gopalsami
Nuclear Engineering, Argonne National Laboratory

Participants
Flint Hills Scientific, LLC
5020 West 15th Street, Suite A
Lawrence, KS 66049

September 29, 2016
This page intentionally left blank
Non Proprietary
Final CRADA Report

Date: September 29, 2016

CRADA Number: C0100901

CRADA Title: Brain Implants for Prediction and Mitigation of Epileptic Seizures

CRADA Start/End Date: 12/18/2002 to 12/17/2005

Argonne Dollars: $808,500

Participant Dollars: $793,500

Argonne PI: Nachappa Gopalsami

Participant(s):

Flint Hills Scientific, LLC $793,000

5020 West 15th Street, Suite A, Lawrence, KS 66049

Complete Address

Summary of Major Accomplishments:

This CRADA, to develop brain implants for prediction and mitigation of epileptic seizures, is between Argonne National Laboratory and the Participating institution, Flint Hills Scientific, LLC of Lawrence, Kansa. The work was carried out by Biofil Ltd. in Sarov, Russia, which is a spin-off laboratory from Arzamas-16, under the supervision of Argonne. Epilepsy is the most common neurological disorder after stroke: it affects 1% of the U.S. population and as much as 10% of the population in some under-developed countries. A patient has described having seizures “as a life sentence without possibility of parole.” The purpose of this invention is to eliminate this state of hopelessness for many epilepsy sufferers.
Summary of Major Accomplishments:

Epilepsy is difficult to treat. In the U.S., a 1992 Roper poll of epileptics found that only 15% of respondents were free of seizures and medication side effects. Of the remainder, 42% had seizures and side effects and the remainder had seizures or side effects. In other words, 85% of sufferers in the U.S., and by extension the world, need a treatment that works or works more effectively. This leaves many epileptics disabled, unable to participate fully in society because of the unpredictability of their symptoms; many cannot drive or operate machinery, and employers are reluctant to hire epileptics.

The advent of a more effective treatment would rapidly rehabilitate tens or hundreds of thousands of epilepsy victims and save billions of dollars. Researchers have noted that the intense activity in the neurons involved in a seizure is associated with increased blood flow, which in turn produces a localized or diffuse temperature increase in the brain (Yang et al. 2002a; Trubel et al. 2004). Conversely, rapid cooling of epileptic focal points can interrupt and stop a developing seizure by abating or blocking the abnormal electrical oscillations associated with seizures (Yang et al. 2002b; Yang et al. 2003; Burton et al. 2005). Therefore, cooling-based therapy is becoming a viable option for patients who do not respond to other therapies but have identifiable “epileptogenic zones.”

This report represents the first automated system that can reliably predict seizures in advance of clinical onset (loss of function) and induce local hypothermia to the affected brain region fast enough to suppress the seizures. The seizure treatment system consists of miniature brain implants for automatic prediction and control of seizures in humans, with a small external unit for monitoring both patient and system. The detection device is a surface acoustic wave (SAW) probe implant, which measures local changes in the brain temperature as a predictor of epileptic neuron activity. The cooling device is an array of cooling probes that are implanted in the brain as a means of rapidly cooling the epileptic zone to suppress seizures. The cooling device and sensor electronics are mounted on the head; a small telemetry system worn around the waist interrogates the sensor readings and triggers the cooling device based on a decision threshold/algorithm.

Both SAW probe and a miniature cooling probe were designed, built, and tested in brain phantoms. The SAW probe, which predicts the onset of epileptic seizures from local changes in brain temperature, is a micro device that can be operated wireless, needs no external power supply, and can detect temperature changes of 5 milliKelvin (mK). The cooling probe is designed to cool a volume of 1 cubic inch of brain tissue from 37°C to 16°C in 30 seconds. In vivo cooling tests of animal brains have indicated that this cooling scope and rate effectively prevents seizures without causing irreversible brain damage. The SAW and cooling probes may be integrated together as a single unit and implanted, for example, in the hippocampus, a part of the temporal lobe where intractable seizures commonly occur. Only needle-type probes are implanted in the brain, while the sensing electronics and the refrigerant storage and pumping devices are placed outside it. The telemetry device, which reads sensor data continuously, triggers the cooling device based on a prediction algorithm, and logs data, was also built and tested under this CRADA.
Summary of Technology Transfer Benefits to Industry:
Development of a new non-surgical treatment method for epilepsy consisting of a SAW probe for detecting the onset of seizures and a cooling probe for arresting the progress of seizures.

Other Information/Results: (Papers, Inventions, Software, etc.)
Summary

This CRADA to develop brain implants for prediction and mitigation of epileptic seizures is between Argonne National Laboratory and the Participating institution, Flint Hills Scientific, LLC of Lawrence, Kansas. The work was carried out by Biofil Ltd. in Sarov, Russia, which is a spin-off laboratory from Arzamas-16, under the supervision of Argonne. Epilepsy is the most common neurological disorder after stroke: it affects 1% of the U.S. population and as much as 10% of the population in some under-developed countries. A patient has described having seizures “as a life sentence without possibility of parole.” The purpose of this invention is to eliminate this state of hopelessness for many epilepsy sufferers.

Epilepsy is difficult to treat. In the U.S., a 1992 Roper poll of epileptics found that only 15% of respondents were free of seizures and medication side effects. Of the remainder, 42% had seizures and side effects and the remainder had seizures or side effects. In other words, 85% of sufferers in the U.S., and by extension the world, need a treatment that works or works more effectively. This leaves many epileptics disabled, unable to participate fully in society because of the unpredictability of their symptoms; many cannot drive or operate machinery, and employers are reluctant to hire epileptics.

The advent of a more effective treatment would rapidly rehabilitate tens or hundreds of thousands of epilepsy victims and save billions of dollars. Researchers have noted that the intense activity in the neurons involved in a seizure is associated with increased blood flow, which in turn produces a localized or diffuse temperature increase in the brain (Yang et al. 2002a; Trubel et al. 2004). Conversely, rapid cooling of epileptic focal points can interrupt and stop a developing seizure by abating or blocking the abnormal electrical oscillations associated with seizures (Yang et al. 2002b; Yang et al. 2003; Burton et al. 2005). Therefore, cooling-based therapy is becoming a viable option for patients who do not respond to other therapies but have identifiable “epileptogenic zones.”

This report represents the first automated system that can reliably predict seizures in advance of clinical onset (loss of function) and induce local hypothermia to the affected brain region fast enough to suppress the seizures. The seizure treatment system consists of miniature brain implants for automatic prediction and control of seizures in humans, with a small external unit for monitoring both patient and system. The detection device is a surface acoustic wave (SAW) probe implant, which measures local changes in the brain temperature as a predictor of epileptic neuron activity. The cooling device is an array of cooling probes that are implanted in the brain as a means of rapidly cooling the epileptic zone to suppress seizures. The cooling device and sensor electronics are mounted on the head; a small telemetry system worn around the waist interrogates the sensor readings and triggers the cooling device based on a decision threshold/algorithm.

Both SAW probe and a miniature cooling probe were designed, built, and tested in brain phantoms. The SAW probe, which predicts the onset of epileptic seizures from local
changes in brain temperature, is a micro device that can be operated wireless, needs no external power supply, and can detect temperature changes of 5 milliKelvin (mK). The cooling probe is designed to cool a volume of 1 cubic inch of brain tissue from 37°C to 16°C in 30 seconds. In vivo cooling tests of animal brains have indicated that this cooling scope and rate effectively prevents seizures without causing irreversible brain damage. The SAW and cooling probes may be integrated together as a single unit and implanted, for example, in the hippocampus, a part of the temporal lobe where intractable seizures commonly occur. Only needle-type probes are implanted in the brain, while the sensing electronics and the refrigerant storage and pumping devices are placed outside it. The telemetry device, which reads sensor data continuously, triggers the cooling device based on a prediction algorithm, and logs data, was also built and tested under this CRADA.