| Brief Biography of Professor Supriyo Bandyopadhyay |

Supriyo Bandyopadhyay is Commonwealth Professor of Electrical and Computer Engineering at Virginia Commonwealth University, Richmond, USA, where he directs the Quantum Device Laboratory. Research in the laboratory has been featured in national and international media (newspapers, internet blogs, magazines such as Business Week and EE Times, CBS, NPR, journals such as Nature and Nanotechnology, and internet news portals).

Prof. Bandyopadhyay was named *Virginia's Outstanding Scientist* by Virginia's Governor Terence R. McAuliffe in 2016. His alma mater, the Indian Institute of Technology, Kharagpur, India named him a distinguished alumnus in 2016. His current employer Virginia Commonwealth University bestowed upon him the Distinguished Scholarship Award and the University Award of Excellence (the highest honor the University can bestow on a faculty member, given to one faculty member in any year) in 2017. His department gave him the Lifetime Achievement Award (one of two given in the department's history). In 2018, he received the *State Council of Higher Education for Virginia Outstanding Faculty Award*. This is the highest award for educators in private and public universities in the State of Virginia and recognizes outstanding scholarship, teaching and service.

Prof. Bandyopadhyay has authored and co-authored nearly 400 research publications and presented some 150 invited talks and colloquia across four continents. He has also authored/co-authored three classic textbooks on spintronics and quantum device theory. He is a Fellow of the Institute of Electrical and Electronics Engineers, Institute of Physics (UK), American Physical Society, the Electrochemical Society and the American

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सत्येन्द्र नाथ बसु राष्ट्रीय मौलिक विज्ञान केन्द्र

Satyendra Nath Bose National Centre for Basic Sciences

Straintronics: Extremely energy-efficient computing with strained nanomagnets

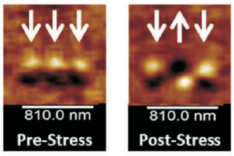
Supriyo Bandyopadhyay

ABSTRACT

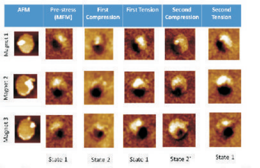
Many of today's computing challenges (protein folding, decoding the human genome, weather forecasting, predicting stock market behavior) require massive computational resources and cognitive computing capability that call for major advances in computing machinery. Two looming roadblocks in the way of such advances are: (1) the excessive energy dissipation that occurs in performing a computation, and (2) the inability of the same device to perform a computation and then store the result in-situ, thereby doubling as both logic and memory.

We have developed the field of "straintronic computing" which is an extremely energy-efficient hardware platform where Boolean and nob-Boolean operations are performed with multiferroic nanomagnets that have two stable magnetization states for encoding the binary bits 0 and 1. Switching between these states is accomplished by mechanically straining the multiferroic nanomagnets with a small voltage (few mV) which results in a miniscule energy dissipation of few aJ. We have experimentally demonstrated Boolean logic operation, Bennett clocking, and non-volatile rewritable non-toggle memory with Co and FeGa nanomagnets fabricated on a piezoelectric PMN-PT substrate. The energy dissipation per bit operation extrapolated from the experimental results is 3-4 aJ for scaled devices.

Straintronic switches are non-volatile, i.e. the switch persists in its final state indefinitely after powering off. This feature can be exploited to build powerful non-Boolean computing architectures such as Bayesian inference engines which can compute in the presence of uncertainty (stock market, disease progression), artificial neurons, ternary content addressable memory, and even all-hardware image processors for specific tasks. They are predicted to exhibit excellent performance figures. This talk will provide a broad overview of straintronic computing and discuss recent progress.



Bennet clocking of a nanomagnet chain with electrically generated stress - MFM images (Nano Letters, 16, 1069 (2016)).



Toggling of a multiferroic nanomagnet cell between two magnetizations states upon application of tensile and compressive stress (Scientific Reports, 5, 18264 (2015).

In collaboration with Prof. Jayasimha Atulasimha of Virginia Commonwealth University, Prof. Jianping Wang of Univ. of Minnesota, Prof. Csaba Andras Moritz of Univ. of Massachusetts at Amherst and Prof. Amit Ranjan Trivedi of University of Illinois at Chicago. This work has been supported by the US National Science Foundation under four different grants, as well as by the Semiconductor Research Corporation and the State of Virginia through the Center for Innovative Technology.

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by

Prof. Supriyo Bandyopadhyay
Virginia Commonwealth University, USA
&
DST-VAJRA Faculty, S.N.Bose National Centre for Basic Sciences

on

Friday, 27th July, at 4:00 pm

to celebrate

125th Birth Anniversary of Professor Satyendra Nath Bose

Prof. Samit Kumar Ray
Director

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