Dr. Neil Canter / Contributing Editor

Potential for windmills at the microscale

Micro-windmills can operate without even standing up.

THE CHALLENGE IN FINDING LONG-TERM LUBRICATION solutions for wind turbines is well known and documented. One approach that has been discussed involves finding ways to reduce the stress on individual wind turbines in a farm in order to improve their longevity.

In a previous TLT article, researchers used a technique known as Simulator for Offshore /Onshore Wind Farm Applications to examine an existing wind farm and studied five scenarios in which the turbines are spaced in a different manner from each other.[1] The results from these scenarios indicate that staggering wind turbines leads to a significant improvement in the efficiency of each individual unit. A second factor is that reduction of the number of wind turbines also results in greater efficiency.

A good deal of attention has also been paid to determining how lubrication occurs at the nanoscale and what types of materials should be used to improve the performance of devices such as microelectromechanical systems (MEMS). One concern with small electrical devices is how to effectively dissipate the heat they generate.

Developing a device that can assist with this process is one of the reasons why work was initiated to design a turbine that functions on the microscale. J.C. Chiao, Greene and Garrett Professor of Electrical Engineering at The University of Texas-Arlington in Arlington, Texas, says, "We have been working to develop MEMS turbine devices for the past six to seven years. My group is involved in the design of new MEMS platforms and we felt that placing a turbine on a silicon chip will have two benefits. The turbine can harness energy that passed by the chip in the form of air circulation or cool the silicon chips operating in an electrical device."

Initial attempts at developing a micro-windmill did not work. Chiao says, "Our initial micro-windmills were fabricated in silicon, which is a very robust material. But under the conditions of strong wind force, the silicon-based micro-windmill became brittle and shattered immediately once wind speed picked up."

The benefits of a micro-windmill can only be achieved if a more durable material can be used. Such a material has now been found.

KEY CONCEPTS

- Micro-windmills with blades that are approximately 0.9 millimeters in length have been developed from a nickel alloy.
- In contrast to macro-windmills, micro-windmills do not need to stand up and can be placed flat on a surface.
- One important application for micro-windmills is to dissipate heat buildup in MEMS.

NICKEL ALLOY

Chiao and his research associate, Dr. Smitha Rao, produced durable micro-windmills through the use of a nickel alloy. Chiao says, "After consultations by one of our research partners, we found that they fabricated micro-machined devices using a nickel alloy instead of silicon. The advantage of the nickel alloy is that it has a lower Young's modulus and is more flexible than silicon. This property enables the alloy not to shatter when it bends."

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Fabrication of the micro-windmill was not easy because there was no existing tool to run simulations to evaluate potential designs. Chiao says, "We tried more than 20 different ideas, but finally settled on a design that was inspired by Dr. Rao's daughter who likes to run around with a pinwheel on her head."

The design combines origami concepts with conventional wafer-scale semiconductor device planar layouts. Chiao says, "We fabricated the nickel alloys in a multilayer fashion. Five layers of the nickel alloy with sacrificial layers provide us with required thickness in 3-D structures."

The manufacturing cost is independent of the number of micro-windmills prepared in a wafer. A micro-windmill blade is approximately 0.9 millimeters in length, which means that it will turn with a diameter of 1.8 millimeters. Figure 1 provides a perspective on the size of a micro-windmill relative to a penny.

The dimensions for the initial micro-windmills are purely intuitive at this point. Chiao says, "We need to optimize the length of the blades. Longer blades will lead to more torque, which will increase the speed and effectiveness of the device. But it will reduce the number of windmills in a defined area. So we need to optimize its size to get the maximum combined power."

In contrast to macro-windmills that are built vertically above the ground to use wind blowing horizontally, air patterns on the micro level are different. Chiao says, "Air moves orthogonally to the micro-windmill, which means that the device does not need to stand up and can be placed flat on a surface. Holes are placed in the micro-windmill to enable air to flow through."

Chiao is unsure about how the air velocity fluctuates at the micro-level.

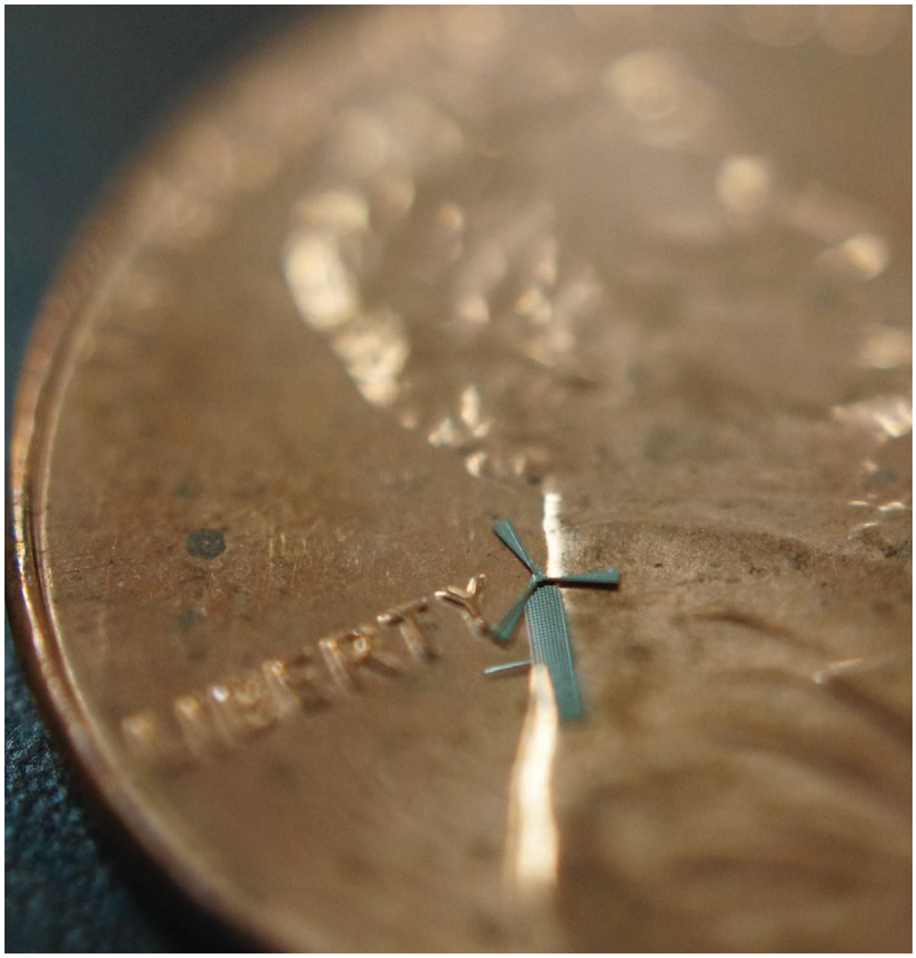

Figure 1 | **The small size of a micro-windmill is shown relative to a penny and means that this device can potentially be used to dissipate the heat buildup in MEMS.** *(Courtesy of The University of Texas-Arlington)*

'We do not know at this point but believe to maximize the benefit of the micro-windmill in a specific application, the mechanical configuration for that application must be designed around the turbine.'

He says, "We do not know at this point but believe to maximize the benefit of the micro-windmill in a specific application, the mechanical configuration for that application must be designed around the turbine. The wind gradient at the micro-level is much different from what is seen in a conventional wind tunnel that is several meters wide. This is due to the narrower dimensions at the micro-scale."

Evaluation of the micro-windmill is in progress at this point. Chiao says, "We did some elementary tests to make sure the device works such as using a tiny vacuum tube to blow air on it and also using a hair dryer. Currently, we are in the process of building an apparatus to more systematically evaluate the micro-windmill."

When asked about the use of lubricants, Chiao indicates that currently none are in use for such MEMS devices. He says, "We believe lubricants will be needed to run the micro-windmills in the future. One area where lubricants will be needed is to protect the micro-windmill from water. Moisture can be a big problem that leads to an increase in friction at the micron or submicron scale."

Chiao believes that micro-windmills can be used in a number of applications including remote sensors to evaluate the health of infrastructure. He says, "Maintaining infrastructure is a big issue, and the micro-windmills could be used in a wireless sensor to monitor the health of infrastructure such as bridges in a cost-effective manner."

The researchers have applied for a provisional patent on this technology. Further information can be obtained by contacting Chiao at **jcchiao@uta.edu.**

REFERENCES

1. Canter, N. (2014), "Staggered wind turbines," TLT, **70** (2), pp. 12-13.

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