Flux Pinning in Thin Films of High Temperature Superconductors for Use in Wind Turbines

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FROM GLOBAL ENERGY DEMAND TO FLUX PINNING

While the global demand for energy continues to grow, the world's depots of fossil fuels decrease. Logically, scientists have researched in different ways of creating sustainable energy. Dams, solar power and wind energy are all different ways of extracting power from nature. Having neither mountains nor many hours of annual sunshine, Denmark is, however, a flat country with many kilometers of coast line and calm weather, and therefore is perfectly suited for wind energy. Because of these facts, Denmark has always been a pioneer within the wind industry, building the world's first off-shore wind energy park in 1991. In recent years, wind turbines have grown dramatically in size and capacity. Scientists predict that in order to make wind energy a more suitable alternative to fossil fuels, the wind turbines have to become even larger. The major problem with these super wind turbines, however, is the weight of the nacelle, of which a heavy part is the gear box.

In order to avoid having a gear box in the wind turbine, a direct driven generator has been proposed, where superconductors play an important role. Energy losses due to Joule heating will be eliminated and high temperature superconductors are capable of working in high magnetic fields (several Teslas). The alternative to superconductors are permanent magnets, but the required amount would become expensive and inaccessible, while superconductors can be made from easily accessible elements. However, using superconductors also pose considerable challenges; low temperature cooling systems are required and the superconductors need to be of high quality.

High temperature superconductors is a relatively new field of study, with the first discoveries made in the 1980s [**1**, **2**]. Having found materials with superconducting properties at relatively high temperatures, the issue of optimizing other properties arose. A pinning center is an irregularity in the crystal, which destroys the superconducting properties. Here the magnetic field lines can penetrate without causing further damage to the superconductor. In 2005 Misko *et al.* found that a gradient in density of pinning centers could increase the critical current density (J_c) in a magnetic field [**3**]. Pinning centers had been known to optimize superconductors, but with this new information, scientists have been equipped with a new tool to make superconductors more suitable for wind turbines.

Since Misko *et al.* first predicted that different pinning densities throughout the superconductor could improve superconductors; many attempts have been made in order to show this property experimentally. Different methods to create the desired pinning patterns experimentally include *Molecular Beam Epitaxy* and *E-beam Lithography*. These methods are, however, both very expensive, making them less attractive for industrial production. This project investigates different options of creating simple gradients in the pinning center density.

REFERENCES

[**1**] Bednorz, J. G., and K. A. Müller. "Possible High *Tc* Superconductivity In the Ba-La-Cu-O System". Zeitschrift Für Physik B - Condensed Matter 64.2 (1986): 189-193.
[**2**] Wu, Ashburn, Torng, Hor, Meng, Gao, Huang, Wang, and Chu. "Superconductivity At 93 K In a New Mixed-Phase Y-Ba-Cu-O Compound System At Ambient Pressure". Physical Review Letters 58.9 (1987): 908-910.
[**3**] Misko, Vyacheslav, Franco Nori, and Sergey Savel'Ev. "Critical Currents In Quasiperiodic Pinning Arrays: Chains and Penrose Lattices". Physical Review Letters 95.17 (2005): -.