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Quasicrystals: A Review of the Discovery, History and Thermoelectric Properties of these Amazing Materials

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abstract

Dan Shecktman first discovered Quasicrystals in 1982, while on sabbatical at Johns Hopkins University and working at the US National Bureau of Standards (now NIST). Shecktman's work and the significant discovery of Quasicrystals in the early 1980's led to him being awarded the *2011 Nobel Prize in Chemistry*. Since then, there has been a renewed interest in various aspects of these materials. Quasicrystalline materials exhibit a quasi-periodic structure that appears to exhibit a *forbidden 5-fold rotational symmetry*. A quasiperiodic structure, as in a Penrose tiling, can fill all space but lacks longrange order. However, there does exist some short-range order. Quasicrystals were really both a crystallographer's dream as well as a nightmare. The discovery of these materials caused much controversy within the crystallographic community and many debates ensued. Eventually, many others starting confirming Shecktman's work and the community eventually recognized his significant discovery and as stated, he was awarded the *2011 Nobel Prize in Chemistry* for his work on Quasicrystals. In the news report, Shecktman mentioned two applications of Quasicrystals: one as a hardened non-stick coating for frying pans and the other as potential thermoelectric (TE) materials. From about 1997 until around 2005 my group at Clemson University performed an extensive amount of research on the TE properties of quasicrystalline materials. Recently, I have received many requests for talks on the subject, one being a keynote address at the 2012 International Conference of Thermoelectrics in Denmark. As part of this current talk I will try to walk you through Shecktman's journey: from discovery, to ridicule and then to the Nobel Prize. The aspect that first drew my attention to quasicrystals was their inherently low thermal conductivity ($\kappa \approx 1$ Wm-1K-1) and electrical conductivity, ($\sigma \approx 1000$ S/cm), similar to other thermoelectric materials but with an unusual temperature dependence. One of the main challenges was to enhance the thermopower (α) in these materials. In addition, it had been predicted theoretically, that Quasicrystals could possibly exhibit a dimensionless figure of merit, ZT =$\alpha 2\sigma$ T/κ, between 1 and 2. This talk will review some background in crystals and crystallography, the history of these materials and some aspects of thermoelectrics. It will also highlight a fraction of some of the experimental results obtained by my group and others. In the end, I will give an evaluation of my perspective of the potential for Quasicrystals as TE materials and give tribute to an amazing scientist whose discovery forced us to redefine our definition of what a crystal really is.