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Biomimetic inertial sensor based on nanowires and magnetoresistance

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Abstract – Nature demonstrates fantastic solutions in many aspects. Bionics imitates by artificial means. We try to combine different nano-objects to mimic a most sensitive mechanosensor from nature. Self-assembled nanowires, magnetic components and magnetoresistive layers are integrated to realize an inertial sensor.

Crickets, and other orthopteroidea, possess one of the most sensitive hair-based sensory systems found in nature [1]. Tiny hairs on the backward Cerci (figure 1) feel slightest air movements of only 0.1 m/hour velocity. We try to mimic this concept in an artificial sensor combining nanowires and magnetic detection. The intention of the collaborative project is to integrate self-assembled nanowires containing magnetic components in thin film sensors exhibiting giant magnetoresistive (GMR) effects (figure 1, right). Any movement of the nanowires is translated to the adherent magnetic components and can be detected via their stray fields by the adjacent GMR stack. The proposed sensor is supposed to be very simple, and hence low-cost and competitive.

Vertical Ge and Si nanowires are grown by Vapor-Liquid-Solid (VLS)-CVD method. The diameters are typically around 100 nm and can be controlled by adjusting the Au seed sizes. Resonance frequencies of kHz to MHz depend on the nanowires lengths. We developed a low temperature process for Ge nanowires at moderate 310°C which enables the direct growth on a GMR film while the magnetoresistive signal amplitude show only a slight degradation (decrease to an acceptable value of 9%). The GMR stack comprises MgO 4nm/ CoFe 2nm/ (Cu 2,4nm/ NiFe 3nm) x10/ Ta 2nm and shows a high sensitivity of 1,5mΩ/Oe at a total magnetoresistance amplitude of 12%. A critical issue is the implementation of suitable magnetic components to the nanowires. Chemical fixation of functionalized magnetic nanoparticles on the topmost Au seeds by mercaptan binding appears not to be selective and reliable enough. However, it worked out that a lithographic process would be applicable if all self-organized approaches would not. Resist covered Si nanowires are etched in oxygen plasma until only their tips are visible (figure 2). The latter are cladded after deposition of ferromagnetic material and a successive lift-off process.

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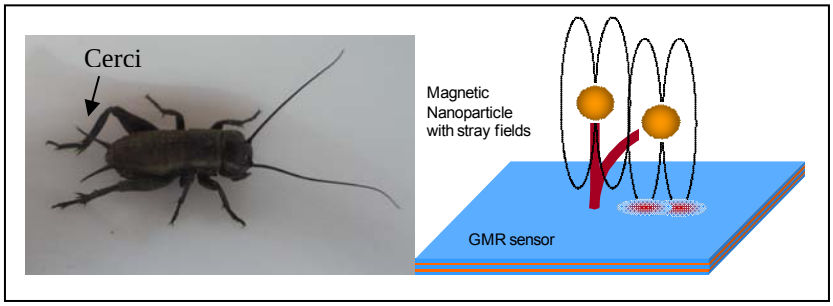

Figure 1: Left: Field crickets have two Cerci. Right: Nanowire, magnetic nanoparticle and GMR sensor mimic the cricket's sensor.

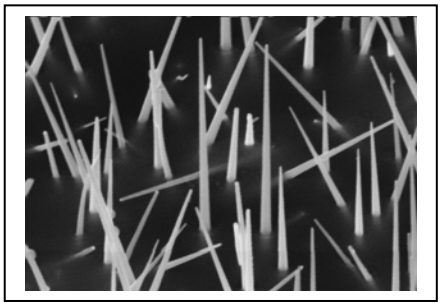

Figure 2: Tip ends of Si nanowires embedded in resist polymer.

References

[1] W. Gnatzy, in "Information processing in animals", Vol. 10, (ed. M- Lindauer), pp. 1-92 (1996)