

# Organic Materials for Spintronics

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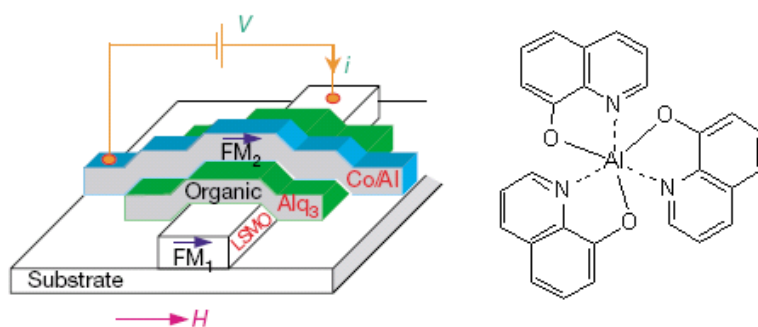
Literature Seminar

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Spintronics is a new sub discipline of electronics<sup>1,2</sup> based on the active manipulation on the spin of electrons, compared with conventional electronics where the charges are manipulated by electric fields but the spin degree of freedom is ignored. A spintronic device allows for the efficient control on the motion of electrons by acting on their spin through magnetic means, and has the advantages of high storage capacity, high integration density and increased processing speed over conventional electronic devices<sup>1</sup>. The field of spintronics emerged with the discovery of giant magnetoresistance (GMR), which was observed as a significant change in the resistance of a nonmagnetic layer depending on whether the magnetizations of adjacent ferromagnetic (FM) layers are parallel or antiparallel<sup>3</sup>. More generally, magnetoresistance (MR) refers to the ratio of the resistance of a material in the absence of a magnetic field to its resistance in a magnetic field. Devices of larger MR effect are desirable for successful applications.<sup>4</sup>

So far materials studied for spintronics have been dominated by conventional metallic compounds and semiconductors<sup>5</sup>. Yet it is a natural idea to build molecular components into spintronic systems with the trend toward device miniaturization. The potential benefits of organic spintronics<sup>6</sup> include the ease of fabrication, the tunability on their electronic and magnetic properties, and most importantly, a much longer spin relaxation time due to the very small spin-orbital coupling<sup>7</sup> in carbon-based compounds.

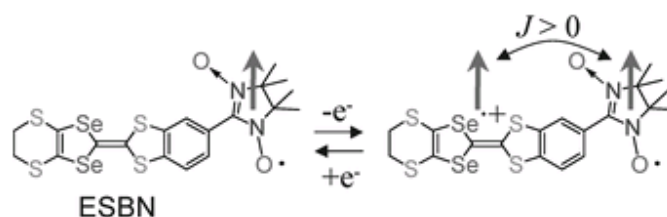
Recent research has demonstrated that spin-polarized current induced by ferromagnetic electrodes can efficiently transport through diamagnetic organic spacers. The first organic spintronic device was an organic spin valve (OSV) fabricated by Vardeny et. al.<sup>8</sup>, following an earlier report of spin injection from a ferromagnetic electrode to an organic semiconductor.<sup>9</sup> The device consisted of LSMO and Co ferromagnetic electrodes sandwiching a thick (100-200 nm) layer of tris(8-hydroxyquinoline) aluminum(III) (Alq<sub>3</sub>) grown by UHV evaporation.(Figure 1) Under sweeping external magnetic field the device exhibited an up to 40% negative GMR effect. After this first experiment, a variety of organic semiconductors have been studied for their spin-transport property and the spin-relaxation time (10<sup>-6</sup> s to 10<sup>0</sup> s) was consistently larger than metallic compounds.<sup>7, 10</sup>



**Figure 1:** Schematic of LSMO/Alq<sub>3</sub>/Co spin valve device and molecular structure of Alq<sub>3</sub>

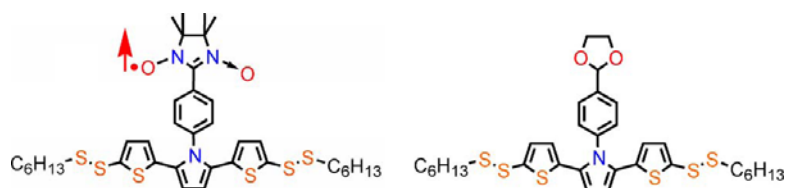
Another approach to achieve spin-dependent current is coupling paramagnetic molecules

with diamagnetic electrodes. Sugawara et. al. reported an organic material that possesses a coexisting system of conductivity and magnetism, which showed MR effect without the spin-polarized current injection<sup>11</sup>. A spin carrying donor molecule, ESNB, was prepared and its mixed-valence salt, (ESNB)<sub>2</sub>ClO<sub>4</sub>, was obtained by electro-crystallization.(Figure 2) Due to intramolecular  $p\pi - p\pi$  interaction, the conducting electron scattering was suppressed when localized spins were aligned under magnetic field. A magnetoresistance of -70% was observed for this material under 9T at 2K. More recently, the neutral crystal of a similar spin donor molecule was also found to manifest interactive conductivity and magnetism.<sup>12</sup> However, increasing the operating temperature as well as preparing thin films still remains challenging for such materials to be practical.



**Figure 2:** Generation of ground-state triplet cation-diradical species of ESNB

The ability of current manipulation by spin-polarized molecular wires (SPM) has also attracted considerable attention. In a recent report<sup>13</sup>, a network structure of gold nanoparticles connected with oligothiophene-type SPM and spinless molecular wires (SLM) respectively. (Figure 3) Under 30K, the conduction through the network is dominated by co-tunneling with SPM and SLM as tunnel junctions. Because external magnetic field is able to orientate the localized spin on SPM and thus suppress spin-flipping scattering of the tunneling electrons, the SPM network exhibited up to -2.5% magnetoresistance at B=6 T. This is the first experimental demonstration of the interaction between a single organic localized spin with an electron tunneling through the molecule. Recent computations<sup>14,15</sup> have also indicated that organic radicals can function as spin filters, favoring transport of electrons with either spin up or spin down.



**Figure 3:** Molecular structure of SPM (left) and SLM (right)

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