Hyperpolarization of thin films with dynamic nuclear polarization using photoexcited triplet electrons†

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With dynamic nuclear polarization using the photoexcited triplet electron spin (triplet-DNP) of pentacene,[1)] nuclear spins can be hyperpolarized more than 10% even in a low magnetic field at room temperature. DNP is a means of transferring spin polarization from electrons to nuclei. In the field of experimental nuclear physics, a nuclear spin polarized target in a low magnetic field (<0.5 T) opens new research possibilities. The polarized target used presently in RI beam experiments is 1-mm thick.[2)] The relatively large target thickness prevents us from applying the target to low-energy experiments. In the experiments, beam and scattered particles have energies as low as several MeV/nucleon and cannot penetrate the 1-mm thick material. In order to perform low-energy scattering experiments, a polarized film with a thickness of less than 100 μm is desirable. However, it is difficult to cut the fragile organic crystals to such a thickness from a large crystal prepared by the conventional method.[1,2)] In this work, we succeeded in polarizing ^{1}H spins in a thin film of *p*-terphenyl and *trans*-stilbene doped with pentacene fabricated with a new method.

In order to achieve the ideal sample thickness and pentacene concentration, we applied the cell method to the sample preparation.[3,4)] The method is as follows: A powder mixture of *p*-terphenyl doped with pentacene was melted and absorbed into a gap between two quartz plates adjusted with copper foils. When this arrangement was cooling at room temperature, a single crystal, shown in Fig. 1(a), was grown in one minute. After removing one of the plates, we measured the thickness of the sample using a surface profiler. The result is shown in Fig. 1(b). From experiments, we determined that the film plane is the cleavage plane. Optimizing the sample thickness and the pentacene concentration, we obtained ^{1}H spin polarization of 12.9% in a 7-μm thick film of *p*-terphenyl doped with 0.05 mol% pentacene in 0.4 T and at room temperature. The slightly lower value of the achieved polarization compared to that for the bulk crystal grown by the conventional method may be due to the degradation of the crystal quality.

The advantage of the cell method is not only in the adjustability of the thickness over a wide range but also in a short crystal growth time. *trans*-Stilbene cannot be grown up to a single crystal doped with pentacene by the conventional method because melted *trans*-stilbene decomposes pentacene immediately. By adopting the cell method, we succeeded in avoiding considerable decomposition, preparing a single crystal of *trans*-stilbene doped with pentacene, and polarizing it with triplet-DNP for the first time. The achieved polarization was improved to 3.9% at 150 K in a 60-μm thick film of *trans*-stilbene doped with 0.05 mol% pentacene.

The polarized thin films also enable new applications of triplet-DNP in general NMR spectroscopy with the realization of Tycko ’ s proposal,[5)] which claims that the use of multi layered structures of hyperpolarizing layers and any material of interest allows polarization transfer through the interfaces. This will open new opportunities in various fields such as chemistry, life science, and medical science.

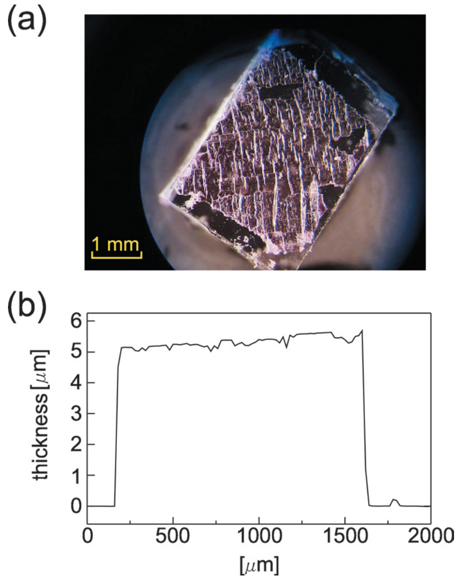

Fig. 1. (a) Photograph of *p*-terphenyl doped with 0.05 mol% pentacene grown by the cell method. (b) Typical sample thickness measured using surface profiler.

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† Condensed from the article in J. Phys. Soc. Jpn. **82**, 084005 (2013)

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