Abstract Submitted
for the MAR07 Meeting of
The American Physical Society

Nanometer voids prevent crack growth in polymer thin films[1]
HIDEAKI YOKOYAMA, CEDRIC DUTRIEZ, AIST, KOTARO SATOH, MASAMI KAMIGAITO, Nagoya Univ. — Macroscopic voids initiate cracks and cause catastrophic failure in brittle materials. The effect of micrometer voids in the mechanical properties of polymeric materials was studied in 1980's and 90's with the expectation that such small voids may initiate crazing, the toughening mechanism in polymer solids, similar to dispersed rubber particles widely used in industry. However, the micrometer voids showed only limited resistance against crack growth, and it was concluded that much smaller voids are necessary for the drastic change in mechanical properties. We have recently succeeded the nondestructive introduction of nanometer voids (30–70 nm) in polymeric materials using block copolymer template and carbon dioxide (CO_2) by partitioning CO_2 in CO_2-philic nanodomains of block copolymers. The reduction of Young's modulus with such nanometer voids was minimal (2 to 1 GPa) due to the (short-range) ordered spherical voids. While the unprocessed copolymer films failed in brittle manner at around 2 % of tensile strain, the processed copolymer films with nanometer voids did not break up to at least 60 %. A microscopic observation under strain of the crack tip revealed that the nanometer voids were deformed under strain and directly converted into the networked fibrils near the crack tip similar to crazing and thus prevented the crack growth.

[1]This work has been supported by NEDO.

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Date submitted: 27 Dec 2006 Electronic form version 1.4