17th International Conference on Advanced Computational Engineering and Experimenting
BARCELONA, 1-5 July 2024
www.acex-conference.com

ABSTRACT:

Heterogeneous Strain-Induced Crystallization in Natural Rubber under Homogeneous Strain States

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Strain-induced crystallization (SIC) is one of the most fascinating phenomena occurring during the deformation of natural rubber. Although Katz first highlighted this phenomenon in 1925 [1], it is still not fully understood. It continues to be studied intensively using the X-ray diffraction technique, which provides various information on SIC (the crystalline phase structure [2], chain orientation [3], crystallization kinetics [4]), but requires compliance to specific layouts of the test laboratory and regulatory constraints within the laboratory. In the 70s, Göritz and co-workers carried out the first calorimetric studies of natural rubber deformation and showed that the SIC thermal energy, and hence the crystallinity, can be accurately quantified using a "stretch calorimeter" [5]. Inspired by Göritz's approach and pushing forward the processing of the heat source, the IR thermography can be used as a surface calorimeter to evaluate the crystallinity [6,7] and provide instantaneous access to the crystallinity field instead of scanning the sample with the X-ray spot [8]. In studies of SIC where the mechanical tests are performed under a homogeneous strain field, SIC is assumed to occur instantaneously and the crystallinity is measured at one point (the X-ray spot). However, in our laboratory we have regularly observed heterogeneous temperature fields on cruciform samples in areas where the mechanical field should be quasi-homogeneous (uniaxial tension). We undertook a study to investigate this heterogeneity under homogeneous uniaxial tension conditions and the results show highly heterogeneous thermal fields and crystallinities along the width at half-height of a symmetrically stretched sample [8]. This is the first evidence of SIC heterogeneity

under a homogeneous loading, which could be explained by strain/stress concentrations at the macromolecular scale.

[1]J. Katz, Nature 4 (169) (1925).
[2] C.W. Bunn. Proc. R. Soc. London, Ser. 1, 180:40 (1942).
[3] G. Rajkumar, J.M. Squire, and S. Arnott. Macromolecules, 39:7004 (2006).
[4] S. Toki, I. Sics, S.F. Ran, L.Z. Liu, B.S. Hsiao, S. Murakami, M. Tosaka, S. Kohjiya, S. Poompradub, Y. Ikeda, and A.H. Tsou. 42:956–964 (2004).
[5] D. Göritz and F. H. Müller. Kolloid-Zeitschrift und Zeitschrift für Polymere, 241:1075–1079 (1970).
[6] J.-B. Le Cam. Strain, 54(1):e12256 (2018).
[7] J B. Le Cam, P.-A. Albouy, and S. Charlès. Review of Scientific Instruments, 91:044902 (2020).
[8] J.-B. Le Cam, A. Tayeb and S. Charlès. Polymer, 255:125120 (2022).