Formation of Nano-Void and Characteristics of Nano-Particles in Material Physics-Review

[1]Khelfa Fadelshedhan Muselmawe and [2]Abd Al-Abass Abd Al-Ameer Shakir Al-Hamadani
[1]Directorate General of Education in Babylon Governorate, Hillah, Iraq
[2]Directorate General of Education in Najaf Governorate, Najaf, Iraq

Abstract: This study explains the play of void or the inclusion of various mechanical properties and especially, the sturdiness of different polymers are explained. Impact of interphase around the voids turns out to be more essential and trademark changes in the distortion methodology of nano and micro particles. Minimizing the size of void and distance between the intervoid are the major concern. These techniques are uncovered by many different methods such as modified rubber polymer, nano fiber and nanocomposites. Few nanoscopic toughness methodologies are explained in detail. This study concluded with because of the advantages, nanovoids are selected over microvoids.

Key words: Nano-voids, deformation, nanocomposites, rubber polymer, combination of polymers, explained

INTRODUCTION

Under the circumstance of adding load, structure of the material gets affected by voids inclusions, structural defects which modify and often degrade the properties of materials. Meanwhile, from the beginning of human civilization the effect of the reinforcement are well known. Evidently, predominant importance is given to some materials due to the natural quality, sum and geometrical value of the interfaces. Also, it gives more outstanding performance in the discrete phases. Along these lines extensive favorable circumstances have been acquired from the nearness of nanoscopic charges. When overwhelmingly utilizing clay based nano charges for an instance, major importance has been given to micromechanics by considering nano reinforced composite technology, barrier and membrane properties (Paul and Robeson, 2008).

Initial numerical investigation of stress concentration caused by the availability of discontinuous present in general material and the effect of quality in the material gave an outstanding performance. Experimentation of elasto plastic has conducted by changing the time dependency and polymer material are illustrated in monograph and considered the impact of yielding, micro voiding and cracks (Williams, 1984). Additionally brings up the associated crack strength values Kinjit are vital amount which summaries the worldwide reaction of the material. Similarly it is even vital with respect to expanded crack mechanics guideline concerning sample geometry and loading conditions with a specific end goal to get K-values which portray the characteristic of a material and not just an investigation (Grellmann and Seidler, 2001).

Here, we are for the most part fascinated by the mechanical and structural phenomena in nanostructured polymers going before crack initiation such as material properties related towards enabling the interface layers. The development of voids activating the crazing, act of fibrils and impact of confinement derive from structural component. Since, the particles or voids in nano-composites is tremendous, even little adjustments of their nearby condition will impact the mechanical performance. These impacts the deformation mechanism and properties of nanostructure polymers are taken into considerable detailed explanation in this research.

Emergence of void: For the most part, opening of void debilitates the ability of bearing the load. This is the reason of broad investigation. One amongst the most exquisite examination to demonstrate the principle of governing impact in formation of void by comparing with the deformation of semi crystalline sample (Pawlak and Galeski, 2005; Pawlak and Galeski, 2010). It is done by biaxial and uniaxial pressure. When uniaxial voids are readily formed in light of the fact that unravelling as well as burst of particles are selected offering ascend to inter-lameller slip subsequently averting prominent hardering. At bi-axial pressure deformation happens through intra lameller slip and molecular orientation leads to prominent strain hardering. The unflattering quality and appearance of void on nano scale level (Clem *et al.*, 2001). Experimented and shown the results in electron micrographs for the essential part of entrapment in inter lamellar cavitation of semi crystalline polymers. In such case in distorting such polymers at lifted temperature cavitation is completely suppressed (Stern *et al.*, 2007; Clem *et al.*, 2001).

Corresponding Author: Khelfa Fadelshedhan Muselmawe, Directorate General of Education in Babylon Governorate, Hillah, Iraq

10169

Alnasraui (2018) experimented and seen that by light microscopy the development of cavity group gathering at the time of drawing of polypropylene films. By utilizing small example specimen, G'Sell developed one kind of video controlled test to exactly gauge the dilatation during pressure. The first strategy (Van der Geer *et al*., 2000) has been delivered to record the behavior of intrinsic plastic by observing the powerful strain and stress by investigating the sample profile continuously. Afterward, the created video traction technique was also connected to examine differently shaped samples and relative displacements. Specific investigation have been done (Seguela, 2007) on the strong positive effect of entanglements and intercrystalline tie molecules on the characteristic ratio and post yield strain hardening of PE based materials. Polymer nanocomposites demonstrate curious properties that are absent in miniaturized scale composites which are not similar.

Another analysis has taken place from top to bottom of the molecular mechanisms engaged with cavitation and their effect on material durability. In excess of the most important group of altered polymer information is given as a function of molecular composition and fundamental geometrical filler particle parameters size, width and separation distance (Halary *et al*., 2011). In another similar analysis, the primary focus is in their equally comprehensive monograph nano- and micromechanics of polymers is coordinated towards an investigation of the morphological changes happens during loading in a excessive variety of neat and altered polymer materials and which are at the cause of their change of quality and sturdiness. Specifically nanovoid arrangement as result of disentanglement, particle cavitation, debonding and so forth are examined regarding hypothetical stress examination for organized polymers (Michler and Balta-Calleja, 2012).

In another model Fond *et al*. (1996), assessment is occurred by elastic energy Uelast stored in a particle and the energy Ucav for closing and opening of the inside surfaces which increases with the second intensity of the void range r. This condition is more effectively fulfilled for particle with larger Diameter D. Utilizing this model in addition to Uelast>Ucav another condition must be fulfilled, since, cavitation should be nucleated in a small molecular volume element by chain scission or void formation through unravelling the local strain vitality energy density must be adequately large to give the required potential energy Upot for the elementary events. This condition is evidently more promptly happy with smaller or core shell particles (Alnasraui *et al*., 2016).

With a specific end goal to more readily comprehend these perceptions we need to examine the distribution of void in a nanocomposite, the distance between the separation, the resulting pressure concentration and conceivable connection between overlapping stress fields (Kinloch, 1983).

MATERIALS AND METHODS

Characteristic analysis of material:
Allocation of particles: It is valuable to imagine how quickly the quantity of void incremented with decrement of size of the void, if the volume faction ϕ is to be kept steady. Unmistakably with expanding of void substance ϕ the average distances. A between the void surfaces decreases; for a cubic cross section plan of voids the distance A is given by:

$$A(\varphi) = \left(\sqrt{3}x/6\varphi\text{-}1 \right) * D \qquad (1)$$

Even for small void contents ϕ intervoid distances A of the order of the void size can be obtained. Equation 1 yields as a rough rule $A \approx 0.7D$ for a void content of 10% by volume and an $A \approx 0.5D$ for 15%. To be more specific the relative significance of a conceivable change of the void surface layer material. The amount of the modified material gets incremented. To this point, it offers rise to change from a polymer matric dominated material to quasi-polymer interfacial material.

Concentration of stress in void: In stacked materials, stress concentration at void, around void and between void can be measure with the theory of elastic stress concentration (Goodier, 1933). In the least demanding case, a spherical void in a vast elastic material is considered. In polar direction, three important stresses can be resolved $\sigma\delta\delta$, $\sigma\phi\phi$ and $\sigma\Gamma\Gamma$. The greatest stress is the component $\sigma\delta\delta$ in the central zone around the void (900 to the load direction) with a most extreme straight forwardly at the equator of 2.045 σ0. If the voids are not spherical but elliptical with a long axis 2a and a short axis 2b the tangential stress component $\sigma\delta\delta$ at the sharper curvature (smaller radius rK, largest stress concentration σK) is increased proportional by Neuber (1958):

$$\sigma K \approx \sigma 0 \left(1 + 2a/b \right) \text{for a} \gg rk \sigma K \approx 2\sigma 0 \sqrt{a}/rk \qquad (2)$$

Highlights of stress field: So far discussion has been done about the stress concentration for isolated single void. When analyzing the stress point at the surface of a void declines rapidly with expansion of distance from the surface. After some instance, over stress gradually vanishes when the distance get larger. Also for another instance when the stress between two distances is small, overlapping of the stress must be considered. On account of high void thickness stress field at the central area ends up remarkable; the stress concentration is higher than 10% of the applied pressure. The relation between the distances is smaller. The level of overlapping stresses at point P2 is much lower, however, it builds more quickly than those at the equator point P1. As an outcome, crazes

are most probably started in the equatorial region which prevails in the volume between voids. In the polar regions of the voids there are just small changes in the stress part (Broutman and Panizza, 1971). It must be said again that the level of the flexibility is calculated by the stress concentration in the void diameter. In any case, the size or areas get affected. Width also gets changed by stress concentrations which are given by Michler *et al.* (2003).

Concept of robustness. On the off chance that there is a strongly expanded elliptical void or a sharp break, the stress component σ_k can accomplish immense characteristics values (Griffith, 1920). Eventually it is profitable to recall that the initiation of quick crack development ought to be instantaneous once a break accomplishes a fundamental size and that all data on the cracking object:

$$\text{Fracture stress } \sigma B = \sqrt{2}E * \Gamma/\pi * a \qquad (3)$$

It was instantly observed and seen that the farthest limit of most materials for plastic deformation remarkably impacts in evaluated fracture stresses and energy specifically for polymers (Williams, 1984). Stress concentrations at impacts are overlap with thermal fluctuation yielding occasionally a high local energy. Here, binding stresses can be reached and because of crack of auxiliary or potentially essential bonds defects can be stretched out stepwise up to the shape and size of the essential crack. In this way, the life time of a concentrated stress material focused on stress, thermal activation energy and a basic structural factor:

$$\tau = \tau 0 * \exp\left(U0 - \gamma * \sigma\right)/kT \qquad (4)$$

Where:
U0 : Activation energy of fracture
γ : Structural parameter
$\tau 0$: $\approx$ 10-13 sec, period of natural thermal vibrations in solids
k : Boltzmann constant

In basic fundamental approach molecular break events such as chain backbone stretching and scission in exceedingly organized stacked system. This specific information has concluded that chain scission is somewhat the outcome of sample deformation and not the reason for the crack (Kausch, 1978). With both Griffith and fluctuation idea of stress concentration provoke a reduction of the sensible nature of a material to well underneath the theoretical binding stress. More often, for the majority of the mass material the theoretical quality is decreased by a factor of 100-1000-cf. This decrease is because of the extensive number of imperfections which are typical for the microstructure of a material and which

can be made as well as increased in the midst of creation, pre-treatment and administrative life, size of the most polymers are <10 mm.

Improvement of physical properties for interfacing: As discussed above, the properties of a material shaping an interface with another material are affected by the irregularity in attractive forces which results in contrasts in molecular mobility and organization. The physical and thermo dynamical properties of polymer at interfaces and the procedure of their examination are notable (Jones and Richards, 1999). The impact is especially, explained in nano-composites because of the tremendous size of interfacial zone present in such material. Their specialized application requires information about control of the physical and thermo dynamical properties of polymers at interfaces (Strunk and White, 1979; Muller and Schmidt, 2010) or the improvement of interfacial strength through molecular reputation is obtained (Creton *et al.*, 2001; Kausch, 1978).

RESULTS AND DISCUSSION

Theoretical analysis
Investigation of materials: Two different polymers are taken into investigation to exhibits the advantages of nanovoids over microvoids. They are rubber modified and nano-particle reinforces thermoplastics.

Modified rubber polymers: Here, two types of modification have been taken for a consideration. One was a commercial type of ABS from Bayer AG. Observation were also made on a copoly acrylate blend with a structure similar to ABS which was made by dissolve compounding PSAN with 20 vol% of preformed rubber particles. Each particle comprised of a single core of PMMA, an internal shell of PBA and a thin external shell of PMMA which is good with PSAN. The aggregate diameter of the particles was around 260 nm, the PMMA core had diameter of about 180 nm (Michler *et al.*, 2003). Similar particles were utilized for the preparation of a toughened transparent PMMA (Ong *et al.*, 2003). Another concept is that the sample was "reactor blend" in which the PP is modified with flexible rubber particles containing Ethylene/Propylene Rubber (EPR) shell covered with a rigid semicrystalline PE core. These particles were developed in situ in the midst of the polymerisation of the PP on introducing ethylene monomer into the reactor (from Borealis). They have average diameters about 0.3 mm (Kinloch, 1983).

Nanocomposites: Nanocomposites Polymethyl Methacrylate (PMMA) can be modified with 10 and 20 wt.% SiO_2 nano particles by solution blending (Kim *et al.*, 2006; Lach *et al.*, 2006). Another method to improve the

nanoparticle separation can be done by electrospinning. Electrospinning was carried out at ambient temperature in a vertical spinning configuration. High voltage power supply is applied for this process around 10-20 kV (Hindi *et al.*, 2017; Priestley *et al.*, 2005).

Analysis of micro/nanomechanical and morphology and properties. Morphology has been analyzed in different material by 120 and 200 kV Transmission Electron Microscopes (TEM). To enhance the contrast in the rubber modified polymers the samples are chemically mixed by which nanocomposites have been studied.

Deformation mechanisms of micro or nanomechanical properties are studied using three different techniques (Harrats *et al.*, 2005):

- Investigation of fracture surfaces using a Scanning Electron Microscope (SEM)
- Investigation of macroscopically deformed specimens using a TEM
- In situ deformation of thin material sections in a 400 kV TEM
- Details of the preparation methods and investigation techniques are summarized (Michler, 2008)

Theoretical analysis surveillance of deformation processes

Consequences of rubber particles: More often in modified rubber polymers rubber particles performs as stress concentrators and starts plastic yielding of the matrix at and between the rubber particles. The toughening impact can be upgraded because of cavitation inside the rubber particles. A fascinating cavitation methodology happens in core-shell particles with nano void development inside the shell and plastic extending of fibrils between the nano voids. The PMMA matric is observed to be deformed in the extremely stressed zones between te particles because of crazes or homogeneous yielding (Ong *et al.*, 2003). Similar micromechanical structures were observed in deformation ASA (Michler *et al.*, 2003; Starke *et al.*, 1997).

There are three advantages of core shell particles. The specific small modifier particle can be very much appropriated inside a polymer frame and with their sizes below 200 nm. Tough polymers can be prepared. This is one of the advantages of core shell particle. After that it is essential that the voids made after cavitation of the particle shells in dilatational strain fields are in the nm range that their sizes stay stable and that the void blend is counteracted with the outcome that prominent plastic deformation of the matric is nucleated. This behaviour is inverse to that of homogenous rubber particles. Which make bigger voids upon cavitation and by combine of voids forms in firmly associated rubber particles give rise to formation of crack and untimely fracture (Michler, 1999; Rittigstein *et al.*, 2007).

Above mentioned point of interest of core shell modifier particle allow to enhance outstandingly the low temperature sturdiness of PP (Michler *et al.*, 2003). The particles comprise of Ethylene/Propylene Rubber (EPR) shell encompassing an unbending semicrystalline PE core. Usually, below the glass change temperature of the modifier particles, the particles can never again acts as rubber stress concentrator. The initiation of plastic deformation in the matrix is lost and the material breaks in a brittle manner. In any case, it is all around perceived that the EP copolymer shell was cavitated, extended and fibrillated. The cavities in the shell acts as stress concentrators. And start rages in the neighbouring matrix. Hence, the toughest mechanism resembles to the toughening in HIPS and ABS (Van der Sanden *et al.*, 1993). The analytical examination was taken at a temperature well underneath the glass transition temperature of the rubbery stage, illustrating that a toughening procedure is not really restricted by the glass temperature of the modifier particles and provide frame nano voids even at low temperature.

Generally the hard polymer cores in the core-shell modifier particles are not deformed. So, far the particle core was thought to be detached individual in the generous strain deformation of the blend, staying in the inelastic zone up to the time when the structure breaks. This is affirmed in the above investigation where the hard cores in the core shell particles did not effectively joins in the energy absorption mechanism and kept their general round frame. This is generally acknowledged in light of the fact that it barely given off an impression of being possible to change a glassy or hard polymer core inside a rubbery shell.

Anyway withstanding of electron microscopic investigation of some rubber modified polymers have uncovered another particular small scale framework (Starke *et al.*, 1997; Michler *et al.*, 2003). After straining a pattern of light dilatation bands appears formed as a result of cavitation within the modifier particles and subsequent crazing in the PSAN matrix. The large plastic deformation of the glassy thermoplastic cores is an additional mechanism of energy absorption and thus of polymer toughening. "Core flattening" must be considered as a third advantage offered by the use of core-shell modifier particles (Michler and Bucknall, 2001; Michler *et al.*, 2003).

Reaction of deformation through inorganic particles: The SiO_2 nano particles are consistently scattered in the PMMA matrix with no proof of agglomerates. With the guide of automated image examination the size of the nanoparticles is quantitatively analyzed from TEM micrographs. As an outcome, this nanocomposites uncovers fantastic optical properties. Light transmission is not influenced by the inclusion of SiO_2 nanoparticles. This nanoparticle modulated crazing constitutes a source for energy absorption and consequently for development in facture durability (Lach *et al.*, 2006). The electro spun fibers has relative uniform measurement of under 500 nm

and displayed nano porous morphology on the fibre surface. The pores have an extremely slender size distribution and the normal pore size is of the demand of 100 nm in width and 200 nm long and the pores are organized along the fibre axis. The premature structure seen on the fibre surface emerges from a fast phase detachment in the midst of the electro spinning process (Kim *et al*., 2005).

To inquire about the deformation mechanism single strands are extended in situ under TEM. In deformation process the electro spun fibre will be marginally stretched along the fibre axis because of stress concentration caused by the nano pores which prompts to a decline in the size of the fibre. With a further increment in strain, the necking advances along the fibre until the point when the moment that the fibre falls flat. While the mass nanocomposite deforms in a fragile way, the electrospun nano porous fibre deforms in a bendable way with a extensively expanded strain at break. It is known from numerous polymers that an microscopic deformation mechanism of shear yielding is typically associated with a higher sturdiness of the material in associated with a crazing mechanism.

Hence, it tends to be accepted that nanofibres have a higher strength than the mass material inspite of the fact than an direct confirmation by stress strain measurement of nanofibres is stunning or if nothing else extremely hard to perform. This homogeneous extending resembles the impact of thin layer yielding in layered block copolymers; the polymer strands between nano voids are more slender than the critical value for thin layer yielding. It shows that the electro spinning process gives an elective method to change the intrinsically weak mass nano composite into a ductile form without fundamentally relinquishing other appealing properties. This exceptional synergistic energy absorbing mechanism exhibits an exceedingly encouraging route to strengthening polymer composites with an incredible capability of new mechanical applications (Kim *et al*., 2006, 2005).

Outcomes of sturdiness: In the previous section it was appeared that in the midst of deformation of filled multi phase polymers voids or pores were with begun due to cavitation inside rubber particle or be debonding at the matric particle interface. As opposed to going about as small imperfections and various voids tend to support plastic deformation phenomena. The void distance ought to have a size equivalent to the typical ordinary deformation event. This typical size is generally between few tens of nm and 1 mm. In this even that the voids are excessively large or on the off chance that they blend because of little separation between them, they can start breaks and untimely fracture. This implies voids in mm measure act similarly as a genuine toughening operator. In case they are homogeneously scatted and do not form cluster or agglomerates.

As we have showed up in core shell rubber particles or at nano particles nano pores appears. If they are homogeneously conveyed, they were being ductile deformation mechanism with a low risk of premature sample failure. Additionally, if the voids or inter particle separation are sufficiently little, generally in the extent of some place in the range of 10 nm they begin new, additional deformation strategies. For instance, the core flattening mechanism, thin layer yielding and Nano void modulated crazing.

For PS layer thicknesses of in excess of 30 nm crazes are formulate in some PS layers which cause concentration of stress in contiguous layers prompting development of break and sample crack. By minimizing thickness of the PS layers the action of break increases slightly because of the increment in the force of unusual deformation zone. When thickness get smaller than basic fundamental thickness level for craze formation, the change in thin layer yielding characteristic change will takes place, nearby crazing will be smothered and deforms, the stretching of sample crack increment drastically. Initially, the lameller structure has a normal extensive long stretch of 33 nm with PS lamellae thickness of around 21 nm. After disfigurement, the lamellar thickness and spacin have been minimized by over half as an indication of extensive plastic deformation (Michler *et al*., 2002). As differentiated along HIPS and ABS, the lamellar systems demonstrate a lower yield stress, however a considerably greater extension at break and strength are extra favorable.

The plastic disfiguration of glassy lamellae obtained in unbalances lamellar block copolymers is in accordance with different investigation of disfigured block copolymers utilizing TEM and SAXS. Under deformation at higher strains inverse to lamellae implies chevron morphology was shaped by plastic disfiguration and bending of the PS layers (Kawai *et al*., 1980; Cohen *et al*., 2000). Overall, chevron folding shows up in a few layered materials as a reaction to a disfiguration drive acting inverse to the layering and have been obtained in a variety of block copolymers and semicrystalline polymers (Krumova *et al*., 2006).

Nanovoid modulated crazing is on a basic level of a various differences, typical repetition of the thin layer yielding part in a line inverse to the stacking course (Lach *et al*., 2006; Kausch and Michler, 2007). In such case, routinely organized nano voids and fibrils looks fundamentally the same as a craze. Nano particles are debonded from the small particle agglomerates are separating, producing small voids, the polymer strands between the voids are then extended into fibrils. The most outrageous elongation of these fibrils is restricted by that of the entrapment network similarly as in the standard craze fibrils in fragile polymers. Here, the breaking point or debonding stress decided the crazing stress which is lower than that in unmodified polymers. Subsequently,

crazing is simpler and more crazes can be made realizing about a beneficial outcome on strength. This generally simple commencement of crazes nuclei and development of crazes opens up an approach to upgrade the strength of nanocomposites together with modification of various properties such as strength (Kramer, 1984).

CONCLUSION

Here it is very well expresses that nanovoids which are started because of cavitation inside particles in rubber modified polymers or by debonding at the matrix particle interface in polymer composites act in a complex positive manner. In rubber toughened polymers modifier particle with the capacity of internal nanovoid development engage a more compelling strengthen because of a simpler commencement of energy absorbing crazes or shear yielding and minimized threat of untimely crack. Nanovoids can start a similar energy absorbing mechanism as mm voids, yet with a much lower threat of untimely crack. If the separated distance between the voids happens to be in a perfect range of few 10 nm, the polymer strands between the voids distort in a homogeneous flexible manner. The connection between void diameter and void distance and void content gives void distances of 20 nm and void sizes of 20 nm appear at void content of about 10%. If the voids are bigger, a higher void substance is important to understand a similar 20 nm distance. A higher void substance in any case, brings a higher threat for void combination and commencement of an untimely crack. It ought to be specified that these beneficial outcomes could on a fundamental level likewise to be acknowledged by nanovoids which are brought into the polymer in the midst of handling the preparation of a sort of nanofoams. In any case, there is up to now no methods to create such nanofoams with practically identical size. So, far voids produced in the midst of preparing demonstrate a broad distribution of void sizes up into the mm range and the mechanical properties of the voided material are for the generally charged by the bigger void accordingly wiping out the constructive outcomes of the nm scale voids.

REFERENCES

Alnasraui, A.H.F., 2018. Development of SOI based microdosimeter for tackling tissue equivalence by BNCT and fast neutron and proton therapy. J. Pharm. Sci. Res., 10: 442-449.

Alnasraui, A.H.F., M.Y.H. Almansoori and A.T.K. Aljana, 2016. Synthesis and characterisation of nanostructured ferric oxide. Intl. J. Res. Eng. Appl. Sci., 6: 45-54.

Broutman, L.J. and G. Panizza, 1971. Micromechanics studies of rubber-reinforced glassy polymers. Intl. J. Polym. Mater., 1: 95-109.

Clem, P.G., M.A. Rodriguez, J.A. Voigt and C.S. Ashley, 2001. Process for forming epitaxial perovskite thin film layers using halide precursors. US Patent No. 6,231,666. USA Patent and Trademark Office, Washington, DC., USA. https://patents.google.com/patent/US6231666B1/en

Cohen, Y., R.J. Albalak, B.J. Dair, M.S. Capel and E.L. Thomas, 2000. Deformation of oriented lamellar block copolymer films. Macromolecules, 33: 6502-6516.

Creton, C., E.J. Kramer, H.R. Brown and C.Y. Hui, 2001. Adhesion and Fracture of Interfaces Between Immiscible Polymers: From the Molecular to the Continuum Scal. In: Molecular Simulation Fracture Gel Theory, Brown, H.R., C. Creton, C.Y. Hui, W.H. Jo, E.J. Kramer, K. Suematsu and J.S. Yang (Eds.). Springer, Berlin, Germany, ISBN: 978-3-540-42126-9, pp: 53-136.

Fond, C., A. Lobbrecht and R. Schirrer, 1996. Polymers toughened with rubber microspheres: An analytical solution for stresses and strains in the rubber particles at equilibrium and rupture. Intl. J. Fract., 77: 141-159.

Goodier, J.N., 1933. Concentration of stress around spherical and cylindrical inclusions and flaws. TASME, Vol. 55,

Grellmann, W. and S. Seidler, 2001. Deformation and Fracture Behaviour of Polymers. Springere, Berlin, Germany, ISBN: 9783540412472.

Griffith, A.A., 1920. The phenomena of rupture and flow of solids. Philosophical Trans. Loy. Soc. London, 221: 163-198.

Halary, J.L., F. Laupretre and L. Monnerie, 2011. Polymer Materials: Macroscopic Properties and Molecular Interpretations. John Wiley and Sons, Hoboken, New Jersey, USA., ISBN: 9780470922880, Pages: 432.

Harrats, C., S. Thomas and G. Groeninckx, 2005. Micro-and Nanostructured Multiphase Polymer Blend Systems: Phase Morphology and Interfaces. CRC Press, Boca Raton, Florida, USA., ISBN: 9781420026542.

Hindi, N.K.K., I.F. Abdul-Husin, Z.K.A. Al-Mahdi, R.M. Ewadh, A.O. Hossain, M.J. Kadhim and A.A. Al-Yaseri, 2017. Effectiveness of Aqueous extract of Green, Black and Red Tea Leaves against some types of Gram positive and negative bacteria. Res. J. Pharm. Technol., 10: 1957-1962.

Jones, R.A.L. and R.W. Richards, 1999. Polymers at Surfaces and Interfaces. Cambridge University Press, Cambridge, UK., ISBN-13: 978-0521479653, Pages: 388.

Kausch, H.H. and G.H. Michler, 2007. Effect of nanoparticle size and size distribution on mechanical behavior of filled amorphous thermoplastic polymers. J. Appl. Polym. Sci., 105: 2577-2587.

Kausch, H.H., 1978. Polymer Fracture. Springer, Berlin, Germany, ISBN: 9780387087863.

Kawai, H., T. Hashimoto, K. Miyoshi, H. Uno and M. Fujimura, 1980. Microdomain structure and some related properties of block copolymers. II. Plastic deformation mechanisms of the glassy component in rubber-toughened plastics. J. Macromol. Sci., Part B. Phys., 17: 427-472.

Kim, G.M., G.H. Michler and P. Potschke, 2005. Deformation processes of ultrahigh porous multiwalled carbon nanotubes/polycarbonate composite fibers prepared by electrospinning. Polymer, 46: 7346-7351.

Kim, G.M., R. Lach, G.H. Michler, P. Potschke and K. Albrecht, 2006. Relationships between phase morphology and deformation mechanisms in polymer nanocomposite nanofibres prepared by an electrospinning process. Nanotechnology, 17: 963-972.

Kinloch, A.J., 1983. Fracture Behaviour of Polymers. Springer, Berlin, Germany, ISBN: 9780412540707, Pages: 496.

Kramer, E.J., 1984. Craze fibril formation and breakdown. Polym. Eng. Sci., 24: 761-769.

Krumova, M., S. Henning and G.H. Michler, 2006. Chevron morphology in deformed semicrystalline polymers. Philos. Mag., 86: 1689-1712.

Lach, R., G.M. Kim, G.H. Michler, W. Grellmann and K. Albrecht, 2006. Indentation fracture mechanics for toughness assessment of PMMA/SiO$_2$ nanocomposites. Macromol. Mater. Eng., 291: 263-271.

Mettam, G.R. and L. Adams, 1999. How to Prepare an Electronic Version of your Article. In: Introduction to the Electronic Age, Jones, B.S. and R.Z. Smith (Eds.). E-Publishing Inc., New York, USA., pp: 281-304.

Michler, G.H. and C.B. Bucknall, 2001. New toughening mechanisms in rubber modified polymers. Plast. Rubber Compos., 30: 110-115.

Michler, G.H. and F.J. Balta-Calleja, 2012. Nano-and Micromechanics of Polymers: Structure Modification and Improvement of Properties. Carl Hanser Verlag, Munich, Germany, ISBN: 9781569904602, Pages: 566.

Michler, G.H., 1999. Micromechanics of polymers. J. Macromol. Sci. Phys., 38: 787-802.

Michler, G.H., 2008. Electron Microscopy of Polymers. Springere, Berlin, Germany, ISBN: 9783540363521.

Michler, G.H., F.J. Balta-Calleja, R. Adhikari and K. Knoll, 2003. Microindentation hardness of SB-block copolymers relating to nano-mechanical mechanisms. J. Mater. Sci., 38: 4713-4723.

Michler, G.H., R. Adhikari, W. Lebek, S. Goerlitz, R. Weidisch and K. Knoll, 2002. Morphology and micromechanical deformation behavior of styrene/butadiene block copolymers. I. Toughening mechanisms in asymmetric star block copolymers. J. Appl. Polym. Sci., 85: 683-700.

Muller, A.H.E. and H.W. Schmidt, 2010. Complex Macromolecular Systems II. Springer, Berlin, Germany, ISBN: 978-3-642-12911-7, Pages: 220.

Neuber, H., 1958. Kerbspannungslehre. Springer, Berlin, Germany,.

Ong, R.J., J.T. Dawley and P.G. Clem, 2003. Chemical solution deposition of biaxially oriented (Ba,Sr)TiO$_3$ thin films on <100> Ni. J. Mater. Res., 18: 2310-2317.

Paul, D.R. and L.M. Robeson, 2008. Polymer nanotechnology: Nanocomposites. Polym., 49: 3187-3204.

Pawlak, A. and A. Galeski, 2005. Plastic deformation of crystalline polymers: The role of cavitation and crystal plasticity. Macromolecules, 38: 9688-9697.

Pawlak, A. and A. Galeski, 2010. Cavitation and morphological changes in polypropylene deformed at elevated temperatures. J. Polym. Sci. Part B. Polym. Phys., 48: 1271-1280.

Priestley, R.D., C.J. Ellison, L.J. Broadbelt and J.M. Torkelson, 2005. Structural relaxation of polymer glasses at surfaces, interfaces and in between. Science, 309: 456-459.

Rittigstein, P., R.D. Priestley, L.J. Broadbelt and J.M. Torkelson, 2007. Model polymer nanocomposites provide an understanding of confinement effects in real nanocomposites. Nature Mater., 6: 278-282.

Seguela, R., 2007. On the natural draw ratio of semi crystalline polymers: Review of the mechanical, physical and molecular aspects. Macromol. Mater. Eng., 292: 235-244.

Starke, J.U., R. Godehardt, G.H. Michler and C.B. Bucknall, 1997. Mechanisms of cavitation over a range of temperatures in rubber-toughened PSAN modified with three-stage core-shell particles. J. Mater. Sci., 32: 1855-1860.

Stern, C., A. Frick and G. Weickert, 2007. Relationship between the structure and mechanical properties of polypropylene: Effects of the molecular weight and shear induced structure. J. Appl. Polym. Sci., 103: 519-533.

Strunk, Jr. W. and E.B. White, 1979. The Elements of Style. 3rd Edn., Macmillan, New York.

Van der Geer, J., J.A.J. Hanraads and R.A. Lupton, 2000. The art of writing a scientific article. J. Sci. Commun., 163: 51-59.

Van der Sanden, M.C.M., H.E.H. Meijer and P.J. Lemstra, 1993. Deformation and toughness of polymeric systems: 1. The concept of a critical thickness. Polymer, 34: 2148-2154.

Williams, J.G., 1984. Fracture Mechanics of Polymers. Prentice Hall, Upper Saddle River, New Jersey, USA., ISBN:9780133252590, Pages: 302.