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Effect of Gamma Irradiation on Polyvinyl Chloride, Polymethyl Methacrylate and Their Polymer Blends

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Abstract - *Specimens of polyvinyl chloride (PVC), Poly methyl methacrylate (PMMA) and their polymer blends with a different weight % ratio were radiated by Gamma radiation. The effect of radiation on the microhardness of the blended specimens was studied by a Vicker's microhardness tester attached to a Carl Zeiss NU-2 universal research microscope. The profiles of the curves for these two radiated specimens, 60 g and 100 g find the significant effect on the microhardness level of the blends. One of the remarkable feature was that the microhardness of irradiated pure PVC samples are more than that of the irradiated pure PMMA specimen, which otherwise is observed to be reversed for unirradiated specimen.*

Key Words: **γ-radiation, polyvinyl chloride, poly methyl methacrylate, microhardness**

1. INTRODUCTION

The properties of polymers are found to change on absorbing energy in the form of radiation, such as Gamma rays, accelerated electrons, α-particles proton and neutrons under different conditions[1-3]. The effect of such irradiation on the physical and mechanical properties of these materials is of considerable importance due to their applications in nuclear and space science.

PVC is one of the world's major bulk polymers, it owes its popularity to its versatility. Poly (Methyl methacrylate) PMMA is noted for its outstanding water-clear colour and the stability of the properties on aging under severe service conditions. The polymer blend(s) can produce some useful polymers for vast applications[4].

The interaction of gamma radiation with polymeric substances has been reported[4,5.] The large changes produced in polymers by radiation involve cross linking that provide hard and brittle materials whereas cleaving weapon or soften the polymers. Such studies under irradiation were elucidated by Alexander, Charlseby and coworkers.[5] Dubey et al.[6] and Bajpai et al.[7] have reported the radiation induced significant changes detected in polymers by means of microhardness testing. Present note reports Gamma irradiation effect on PVC: PMMA polyblends.

2. EXPERIMENTAL

For preparing the blends, the commercially available polymers PMMA and PVC were used, polymer granules were supplied by M/s Chemical Agencies, Mumbai, India. Both polymers were low weight substances. Its melting point and glass transition temperature were (180-185°C & 105°C) for PMMA and (212°C, 81°C) for PVC.

The solution casting method was utilized for preparing the blends of the different compositional ratio of the two polymers. PMMA was added in 5, 10, 15, 20 weight % ratio in PVC matrix for preparing blends and dimethyl formamide was used as a common solvent.

The polymer solution of known concentration and quantity is spread over a clean glass plate of known area which is placed horizontally over a mercury pool. The solvent is allowed to evaporate at a suitable constant temperature and the resulting pellet is gently detached from the substrate specimen of size 1 cm × 1 cm and thickness 0.04 cm were cut. Gamma irradiation was carried out at the University Science Instrumentation Centre (USIC), Nagpur University, India using Co-60 gamma chamber 900[8]. The average irradiation close rate was 0.35 Mrad/h.

The irradiated specimens were indented at room temperature by a mhp-160 Vickers microhardness tester attached with Carl Zeiss NU-2 universal research microscope. The value of H_v was then calculated for each specimen from the measured diagonal of the indentation.

$$H_v\,(Kg/mm^2) = \frac{1.854 \times L}{d^2}$$

Where L is the load (Kg) and d is the diagonal length (mm).

3. RESULTS AND DISCUSSION

Fig. 1 and 2 exhibit the effect of various doses of gamma irradiation on the microhardness ranging from 0 to 25 Mrad at the loads of 60 and 100 g, respectively, of pure PVC, PMMA and their polyblends. The H_v values for all the un-irradiated (0 Mrad) specimen are also plotted in the curves. It is evident from the figures that for all the specimens, almost similar trend is obtained. The surface microhardness initially increases with the dose of radiation in the range of 0 to 7 Mrad and thereafter it decreases up to the dose level of 25 Mrad. The maximum value of H_v is obtained at 7 Mrad.

For pure PMMA in the given dose range the microhardness, H_v increases from the value of 10.06 Kg/mm^2 at 0 Mrad (un-irradiated) to 11.66 Kg/mm^2 at the dose of 7 Mrad at the load of 60 g (fig 1). Beyond the dose of 7 Mrad the value of H_v gradually decreases with dose up to 25 Mrad. At 25 Mrad, the value of H_v is 9.88 kg/mm^2, which is less than even for un-irradiated specimens. Thus, in pure PMMA, gamma irradiation imparts hardening due to radiational crosslinking. The crosslinking density is maximum at 7 Mrad. However the degree of crosslinking decreased beyond 7 Mrad. Moreover, up to 20 Mrad, the H_v values of irradiated specimens were more than un-irradiated ones. At 25 Mrad, irradiation caused scissioning of the chains of PMMA. This cleavage of the main chain of PMMA ultimately caused softening of the polymer.

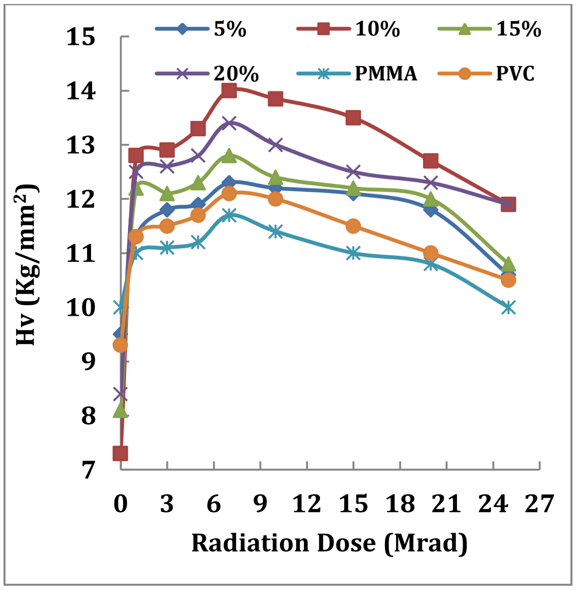

Fig 1: Variation of H_v with various doses of gamma irradiation at 60 g specimen of PVC, PMMA and PVC:PMMA with different wt% of PMMA.

Similar results were obtained for pure PMMA when indented at the load of 100 g (fig 2). However, the level of microhardness is higher as compared to the indented specimen at 60 g. Thus, PMMA which is a typical degradable polymer can be crosslinked up to the optimum dose of 7 Mrad. Thereafter the degrading phenomenon predominates and ultimately leads to the radiational scissoning at 25 Mrad.

For pure PVC specimens, the gamma irradiation imparts over all hardening effect. This was due to the radiational crosslinking. The H_v value increased from 9.55 kg/mm^2 at 0 Mrad to a maximum value of 12.07 kg/mm^2 Mrad. However, H_v value decreased beyond 7 Mrad and upto 25 Mrad these values were still higher than H_v values for un-irradiated (0 Mrad) specimen. One of the remarkable feature is that the H_v values of irradiated PVC specimen were more than that of irradiated pure PMMA specimen, which, otherwise is observed to be reversed for un-irradiated specimens. Thus, there is a predominance of the radiational crosslinking in pure PVC in the entire dose range from 1-25 Mrad and a predominance of radiational scissioning in pure PMMA beyond 20 Mrad. Similar results were obtained for irradiated PVC specimen when indented at the load of 100 g (fig 2) with increased level of microhardness.

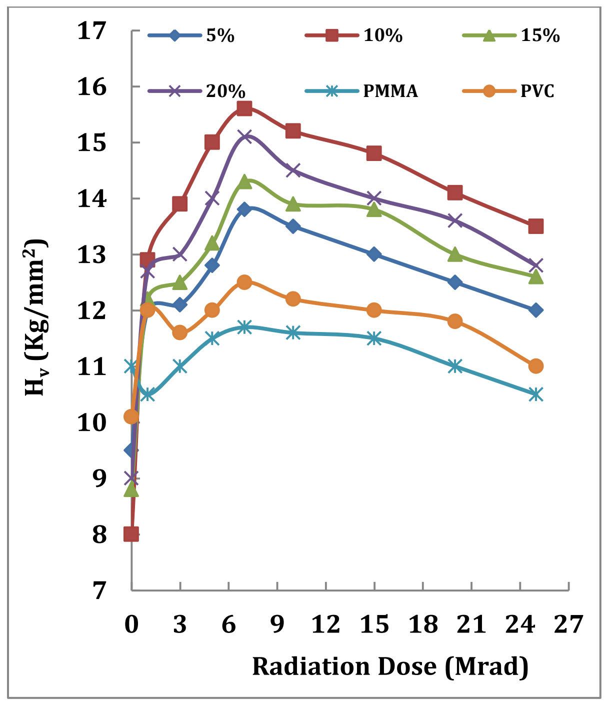

Fig 2: Variation of H_v with various doses of gamma irradiation at 100 g specimen of PVC, PMMA and PVC:PMMA with different wt% of PMMA.

In case of PVC: PMMA polyblends, the effect of gamma irradiation on the microhardness was observed to be quite interesting. First of all, the H_v values at all doses were higher for all the irradiated polyblend specimens as compared to the corresponding un-irradiated specimens, both at the load of 60 and 100 g (Fig 1 and 2). This clearly indicates the predominance of radiational crosslinking in the polyblend specimen. Secondly, the plasticization effect detected with blending of PMMA in PVC matrix in various proportions of 5, 10, 15 and 20 weight% seems to get hardened due to radiational crosslinking. Thirdly, the order of the microhardness level for plasticized polyblends gets reversed with gamma irradiation, it was observed that increasing the content of PMMA in PVC from 5 to 20 wt% decreased the H_v values yielding plasticized polyblends, whereas irradiation increased the H_v values to a remarkable extent. The level of microhardness increased with increases in the weight percentage of PMMA from 5 to 20 wt %. However, the maximum value of H_v was obtained for irradiated polyblend specimens with 10 wt% of PMMA. This clearly reveals that gamma irradiation transforms the plasticization effect into crosslinking and thus yielding hardened specimen.

PMMA which is a typical degradative polymer, can be crosslinked with PVC as an effect of irradiation. There are many evidences of crosslinking occurring in the blends of PMMA and some other polymers[9,10,11,12,13]. Maximum radiational crosslinking is observed at the dose of 7 Mrad. Beyond this dose level, the degree of crosslinking density decreases with increases in dose upto 25 Mrad for the polyblend specimen. PVC:PMMA blend with 10 wt % PMMA is optimum to yield radiational crosslinked hardened specimen. The H_v values of 13.85 kg/mm^2 for 60 g and 15.73 kg/mm^2 for 100 g at the dose of 7 Mrad are the highest amongst the polyblend specimen. Further one of the other significant feature observed is that all the irradiated polyblend specimens have higher H_v values as compared to pure PVC or PMMA specimen. This confirms that PMMA can be crosslinked to PVC in the various weight proportions under gamma irradiation. Thus plasticized PVC can be crosslinked.

The effect of gamma irradiation on the microhardness of pure PVC, PMMA and its various polyblend specimen is multifarious. Pure PVC exhibit hardening due to radiational crosslinking, while pure PMMA illustrates radiation hardening only upto 20 Mrad and scissioning effect predominates beyond the dose. The polyblends of PVC : PMMA can be crosslinked with gamma irradiation. The polyblend with 10 weight% of PMMA and dose level of 7 Mrad are optimum for radiational crosslinking. The developed plasticized blend can be hardened by irradiation.

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