1. Introduction

1.1 Significance of Environmental Stress Cracking for the Long-Term Service of Plastic Products

Failure has been a serious problem in the use of materials since the beginning of recorded history. These sometimes catastrophic failures were a driving force for the development of material science and engineering. Failure can be described as any change of properties which make the material or component functionally, structurally or aesthetically unacceptable. In the last few decades, engineering polymers have succeeded in replacing metals in many demanding applications and such failures will become even more important. It is often necessary to understand why polymer failure has occurred, so that measures can be taken to prevent its reoccurrence. Polymeric materials are sensitive to processing and affected by the environment, time and temperature during storage, transportation and service. Especially the long-term properties are frequently “unpredictable”.[1] Failure in polymer components can occur at relatively low stress levels (far below the tensile strength in many cases) due to long-term stress (creep rupture), cyclic stresses (fatigue failure) or liquid agents (environmental stress cracking). When a polymer is stressed in air to just below its yield point, stress cracking can occur after period of time. However, when simultaneously exposed to both stress and a chemical medium this will result in a dramatic reduction of the time to failure. This type of failure has been named environmental stress cracking (ESC). ESC has been a subject of extensive investigations for almost 50 years. It has deserved much attention because approximately 15-20 % of all failures of plastic components in service are due to ESC.[2] In addition the phenomenon of ESC is very interesting to both chemists and physicists as it involves, stress enhanced absorption, permeation, the thermodynamics of mixtures, local yielding, cavitation, fibrillation and fracture.[3]

In the early days of its commercial development, polyethylene was widely considered to be inert to all liquids. The supposed stability of this new material lead immediately to new applications, e.g. one of the first polyethylene bottle applications was the packaging of concentrated hydrofluoric acid.[4] At this point, the industry was confronted with numerous reports of polyethylene failure. Polyethylene was reported to be unsatisfying for cable usage, and it was found to crack violently on contact with methanol at room temperature.[5] The term ESC was officially defined by J. B. Howard who had pioneered research in this phenomenon. Polyethylene offers a good property profile and through corresponding treatment and/or additives the range of possibilities of application becomes more diverse. Therefore, the
problem of ESC is very important for many applications including packaging industry (bottles, containers, foils, films, etc.), electric industry and electronics (wire and cable insulation), medicine (labware, caps, implant components, etc.), automobile industry (tanks, pipes, coatings, etc.) and many more.

1.2 Research Tasks

Within the framework of the Ph.D. thesis, investigations on environmental stress cracking resistance (ESCR) were carried out on polyethylene compounds comprising low density polyethylene (LDPE) and different amounts of ethylene-vinyl acetate random copolymer (EVA). Furthermore, the system contains carbon black as filler. These blends are used mainly as cable insulation. It is well known that neat LDPE is susceptible to ESC. It has been known that the addition of an elastomeric material to polyethylene can improve its resistance to ESC. EVA is a rubber-like material that may retard the process of ESC in polyethylene. The primary aim of this work is to investigate the ESCR of LDPE/EVA blends. Bell-telephone test is carried out in order to investigate the influence of the EVA content and the test temperature on the failure time. As a result of the long thermal treatment of the samples during the Bell telephone test, different reorganization processes can occur. Therefore, any changes in the thermal properties are detected by differential scanning calorimetry. Wide- and small angle X-ray scattering investigations are carried out for determination of any changes in the crystal structure and lamellae arrangement as a result of the long thermal treatment in the Igepal surfactant during the Bell telephone test. Relevant microscopic techniques (atomic force microscopy, transmission electron microscopy, scanning electron microscopy, high voltage electron microscopy) are applied for morphology characterization, monitoring the process of brittle failure and micromechanical deformation mechanism. The morphological data should be then correlated with the results of the ESCR test and the mechanical tests in order to create a correlation model for morphology and ESCR behavior of polyethylene compounds.