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Programming of material's properties over extended time intervals via self-irradiation phenomena

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We consider theoretically the possibility of programming the ageing processes in materials via the introduction of small quantities of unstable nuclei in a material's structure. Ageing of materials is usually considered as a harmful and undesirable process, which limits the lifetime of many consumer products. In certain instances, however, changing of physico-chemical properties with time constitutes a part of material's functionality. Structure transformations owing to self-irradiation of materials by fission products of unstable isotopes constitute a special case of ageing processes. They are quasi-independent on environmental factors, such as heat, light, humidity, aggressive chemicals. A well-known example is metamictisation of zircon due to the decay of uranium and thorium atoms present in the mineral's crystal lattice.

In our work we suggest to exploit self-irradiation phenomena to programming of material's properties over extended time intervals. Using literature data on the action of ionizing radiation on different materials, we argue that incorporation of minuscule amounts of radio-active species, such as tritium, in the structure of certain polymers can lead to profound change of their physico-chemical characteristics over the times ranging from few months to several years. For instance, introducing tritium in the structure of polytetrafluoroethylene (PTFE) via substitution of a small fraction of the fluorine atoms can be used for programming radiolysis of the polymer and it´s self-destruction to a certain date. The date can be preset by concentration of tritium in the material, which is typically a few mg of tritium per kilogram of the polymer. Radio-active isotopes can be incorporated in the structure of conductive polymers, such as a blend of polyaniline (PANI) with poly (vinyl chloride) (PVC). Self-irradiation can lead to significant change of electronic properties of the material due to self-doping of PANI by hydrochloric acid released by the partner polymer upon irradiation. It is known that refractive index of materials (polymers, glasses) also can vary upon the action of ionizing radiations. Therefore it might be possible to program the value of the refractive index by radio-isotope engineering. Finally, self-irradiation can be applied to scheduled relaxation of internal mechanical stresses in materials.

Materials with time-programmed characteristics can find numerous applications in different fields of technology. For instance, polymer or inorganic semiconductors with programmed electronic properties can be used for the design of electronic devices which can be disabled or activated at a well-defined date. Due to miniaturisation of electronic circuits, tiny quantities of radio-active substances might be sufficient for this purposes.

[1] V. Luchnikov, "Time programming of material's properties via self-irradiation phenomena", J Mater Sci (2009) 44:6294–6301

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