Polymeric and hybrid materials for electrooptical devices: polar order dynamics

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The rate of growth in data traffic in modern communication society has boosted the search for ever larger bandwidths in data transmission systems. Encoding information onto a lightwave carrier by modulating the light in phase or amplitude at high frequency (around and beyond 100 GHz) requires alternative materials with respect to the traditional ones (e.g. $LiNbO_3$).[1,2] On this respect, polymeric materials can bring great improvements related to their low dielectric constant and to the possibility of functionalization with strongly hyperpolarizable chromophores. Polymeric and glassy materials, however, are intrinsically centrosymmetric and additional post-deposition procedures are required for inducing the polar order ('poling') necessary for second order nonlinear optical (NLO) response. The ordering can be attained by either electric field or optical poling acting at molecular level. The latter technique is especially important for materials containing nondipolar molecules.[3] The electric-field-induced chromophore alignment has been widely used for all the cases in which the materials contain a dipolar chromophore. However the ordered state of NLO composite material will normally evolve back towards equilibrium isotropic state, once the poling electric field is removed. Orientation relaxation in poled systems arises from thermal effects whose rate is mainly governed by the mobility of the molecules in the matrix which is, in turn, determined by a number of parameters including glass transition temperature (T_g) and free volume content.[4] The use of matrices with high glass transition temperature (T_g) encounters possibly some limitation in the poling phase, when the sample has to be held at temperatures near the T_g and the active species, sensitive to thermal treatment, could undergo decomposition.

An alternative approach consists in the use of sol-gel materials.[5] Their rigidity can be attained with moderate thermal treatment and moreover sol-gel reaction is irreversible. The challenge here is to promote the network formation of the active molecules after orientation.[6]

The NLO response of a poled chromophore-functionalized materials yields a mean to get information on the orientation distribution of the NLO-active chromophore units. In-situ SHG measurements allow to follow the onset of a polar order within the functionalized materials during the poling procedure. The subsequent relaxation of the induced order can be followed monitoring the decay of the SHG signal. Particular procedures addressed to accelerate the aging of the poled materials opens the possibility to foresee their behavior at operating condition on very long times.

A review of some recent results on the polar order dynamics in polymeric and hybrid materials will be presented and the prospective for the application to the realization of electro-optic devices will be discussed.

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