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STRAIN-INDUCED OPTICAL SECOND HARMONIC GENERATION

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스트레인에 의한 이차조화파 발생에 관한 연구

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I. INTRODUCTION

The methods of photoelasticity in linear optics are well developed for investigating strain in the solids. External strain applied to the solid leads to a change in the shape and symmetry of a specimen. Internal strain in composite materials, for example, in crystal films on substrates or multilayers, leads to the lowering of symmetry near the interfaces and to structural deformations induced by the misfit between crystal lattice constants. Second harmonic generation (SHG) is very efficient for investigation of thin films and interfaces.[1] The SHG signal is very sensitive to a change of symmetry induced by various physical actions, for example, by strain. Special kinds of internal strain (not hydrostatic) lead to the lowering of the symmetry of a crystal, i.e., to the missing of the inversion center. As a result, a bulk dipole-active optical SHG should be observed for transparent materials and for this case, SHG method is an effective tool for investigating stain-induced effects in solids and solid-state structures.

II. THEORY

In this article, we present the phenomenological description of strain-induced optical SHG and group-theoretical analysis of the second-order nonlinear optical susceptibility (NOS) tensor taking into account the nonlinear photoelastic interaction.

$$\chi_{ijk}^{(2)} = \chi_{ijk}^{(2,0)} + p_{ijklm}u_{lm}$$

From the considerations of symmetry properties of the nonlinear photoelastic tensor p_{ilm}, we studied the relationships between the strain tensor components and nonlinear p_{ijklm} and the results are summarized in tables.

Strain alters the physical properties of a crystal and leads to a lowering of symmetry. For example, the (001) surface of a cubic crystal has a 4mm tetragonal symmetry and changes into a mm2 orthohombic symmetry with application of the appropriate stress.[2] The symmetry class of a crystal imposes restrictions on the form of the second-order NOS tensor and the rotational anisotropy reflects the symmetry property of the medium, therefore, the strain tensor componenents which change the symmetry of the medium can be determined from the angular dependence of SHG intensities. We obtained formula to obtain strain components for 4mm and 3m crystals.

III. CONCLUSIONS

In conculsion, the strain-induced changes in the NOS tensor have been phenomenologically investigated by introducing the nonlinear photoelastic tensor. It is shown that the change of symmetry and related strain components can be determined from the measurements of angular dependencies of SHG.

We believe that the methods of strain-induced nonlinear optics described in this paper are very useful for the investigation of crystals and thin solid films on substrates, because such systems are characterized by a strain of different origin induced by: i) lattice mismatch and misfit dislocations located near the film-substrate interfaces and ii) dislocations in bulk crystals. Results of a theoretical investigation of strain-induced SHG in the system mentioned abovewill be published elsewhere. We would like to note the recent publication[3] where enhancement of SHG signal in $BaTiO_3/SrTiO_3$ superlattice was observed. This SHG enhancement was qualitatively (without giving theoretical analysis) explained with the large strain induced by lattice mismatch located near the interfaces in a superlattice. The results of our present article show how it is possible to describe a strain-induced optical SHG via nonlinear photoelastic interaction.

IV.ACKNOWLEDGEMENT

This work was supported by the Creative Research Initiatives of the Ministry of Science and Technology of Korea. One of the authors (I.L.L.) is very grateful to KISTEP for the finacional support of his visit to Korea and to CNSM at KAIST for hospitality extended during his stay in Taejon.

V. REFERENCES

[1] B. S. Mendoza, A. Gaggiotti and R. Del Sole. Phys. Rev. Lett. **81**, 3781 (1998).

[2] F. Barocci, Opt. Comm. **3**, 189 (1971).

[3] J. P. Hirth and J. Lothe, Theory of Dislocations (McGraw-Hill, Inc., New York, 1968).