**Modeling and experimental validation of effective medium model for multilayer dielectric with periodic inclusion**

**Abstract**

Multi-layered dielectric structures are widely seen in modern semiconductor industry. Their applications cover multi-scaled areas such as in chips, packaging and printed circuit boards. Effective medium modeling for these structures enables fast yet accurate analysis so that the computational cost are reduced dramatically. In this dissertation, the numerical modeling techniques and experimental validations are explored for a general multilayer dielectric with periodic inclusions structure.

The effective medium model based on the same reflection and transmission coefficients are introduced. The extraction procedure for effective constitutive parameters is described in detail. The branch cut issue in extraction procedure is examined and the solutions are provided so that the results are physically reasonable. Expressions of effective permittivity and permeability are given for both normal and oblique incidence, parallel and perpendicular polarizations. Analytical forms for low frequency limits of effective parameters are derived and numerical simulations are provided to verify the results.

Based on the summary of Maxwell-Garnett mixing rule (MG formula), the asymptotic forms for the frequency dependent term in MG formula is derived. Then the transition of periodic dielectric to periodic metal objects is studied. Numerical results are presented to verify the transition. A multi-effective layer model is also evaluated. And the numerical results show that under certain conditions this model achieves better accuracy than simple MG formula.

To validate our numerical modeling approach, experimental tests are performed. Using standard 4 layer printed circuit boards (PCB) technology, we are able to build periodic metal patches embedded in multi-layered dielectric. Different testing structures such as parallel plate capacitors and micro-strip with de-embedding structures are fabricated and measured. We've proposed an analysis procedure based on micro-strip with de-embedding structure and full wave modeling of micro-strip line. The approach has the advantage of easy material preparation, broadband results for both complex permittivity and permeability. The experiment results are compared with our modeling results and good agreement has been achieved.