Abstract

In this project, the concept and realization of a sub-THz oscillator with an integrated patch antenna were analyzed. Using EM and circuit simulations, it was demonstrated that the concept of a patch antenna functions for coupling sub-THz radiation from a powerful oscillator. Integration of an array is also possible. In the technology section, two development processes were examined, with a recommendation for immersion development being made.

From the simulations, a variety of possible antenna geometries were obtained. Increasing the size of the patch lowers the resonance frequency of the oscillating system composed of the TB-RTD and the patch antenna. A similar behavior is observed when extending the feed line on the BCB. With larger technology deviations in geometry, the system will no longer oscillate at the selected frequency. These observations correspond with the theory of patch antennas.

Due to the low output power, numerous antennas must be connected in parallel for practical applications. To achieve good directional characteristics of the antenna arrangement without a silicon lens, the antennas are assembled in an array. The simulation demonstrated that, by using an array, the oscillators interfere like radiation at a grid. The optimal distance between the pixels to achieve the greatest possible gain depends on the arrangement of the oscillators themselves. A larger antenna spacing results in a smaller -3dB cutoff angle. In addition to improved directivity of the main lobe, the side lobe suppression decreases with greater spacing. For an antenna design, a function-specific optimum must be found between a narrow main lobe and a sufficiently small side lobe. Beam steering was also simulated through phase shifts of the oscillators, allowing for the possibility of influencing the radiation angles for specific applications. Gain, side lobe suppression, and 3dB cutoff angle behave with adjusted phase angles similar to an array without beam steering.

The expected deviations from the technology, such as the actual shape of the via and variations in layer thickness, were considered in the simulations. If they remain within the previously observed magnitudes, they have only a minor impact on the resonance frequency and still allow for radiation in the range of the chosen design frequency.

In the technology section, the known processes for BCB were adjusted based on documentation. For improved substrate adhesion, it is recommended to pre-heat the wafer for 15 minutes at 120°C before coating. Additionally, the option to encapsulate the adhesion promoter should be utilized. The best planarization was observed after extending the coating time to 50 seconds and a one-minute resting period before soft baking. The best resolution was achieved with an exposure time of 360 seconds. For a target thickness of 5 µm after processing, the spin speed also needs to be further adjusted. The best layer thickness of 7 µm was achieved at 4000 rpm, which is about 3 µm thicker than expected according to the documentation.

For the realization of a via, a sufficiently good resolution and a positive edge steepness are essential. The experiments confirmed that the steepness of the edge can be gradually adjusted via the development rate. Accurate and reproducible development is necessary for this. In puddle development, deviations of a few percent are unavoidable due to spin operations and the comparatively short endpoint time. With immersion development, adjusting by a few percent is easier due to the longer endpoint time. Very good edges could be processed with an immersion development of 110% of the endpoint time. The resolution of small structures improved with steep edges to the order of the BCB layer. Therefore, photo-BCB is functionally suitable for via fabrication regarding resolution and edge profile.

The investigated annealing process is a hard cure. The layer thickness decreases by 5% to a maximum of 10%, depending on the layer thickness before the cure. For processing at 5 µm, a target thickness of 5.5 µm after development should be aimed for. To ensure compatibility with additional layers, the cure temperature must be reduced.

With the results of this project, patch antennas can now be manufactured on BCB and their functionality examined. Comparing the behavior of a processed oscillator with the simulation results could be the subject of a subsequent project.