an existing problem is that the deposition rate less than a level of 1 nm/sec should be controlled precisely by varying the parameters of an ion source in a rough vacuum [28]. In particular, the possibility of slow and spontaneous transformation of the morphology for ultrathin gold films makes the bimetallic substrates improper for a sensitive SPR imaging detection. Qi et al. demonstrated that a thin gold film with a thickness smaller than 10 nm tends to change from the initially continuous layer to nanoporous or nanoparticle structures at room temperature without surface treatments. Moreover, these nanostructures can induce a localized surface plasmon (LSP) band [29]. Since the presence of LSP modes and their interaction with propagating surface plasmons may strongly influence the broad reflectivity spectrum and decrease the sensing contrast, the SPR imaging sensitivity would be deteriorated even more drastically by the morphology transformation of thin gold coatings.

Further, the graphene-on-silver substrate could potentially facilitate the applications of its electric conduction property to the identification of single biomolecules. For example, when the metallic substrate with a graphene coating was combined with the tip of atomic force microscopy (AFM) or scanning tunneling microscopy (STM), the signal-to-noise ratio of the measured electrical signals was found to be high enough to distinguish individual nucleobases of ss-DNA [30]. This was even better than the signal-to-noise ratio of the conventional metallic surface without the graphene film. Hence, with the help of conductive AFM or STM tips, the graphene-based SPR imaging substrate can serve as a multi-functional bio-platform, enabling high-accuracy sequencing of DNA strands as well as sensitive biosensing. These are the main advantages of the excellent electric conduction compared to the results obtained from nonconductive substrates, which could lead to ambiguous topological images [31].

5. Conclusion

In this numerical study, we explored a novel SPR imaging biosensor based on a graphene-on-silver substrate in terms of the imaging sensitivity characteristics. When no graphene sheet is employed, the peak imaging sensitivity was obtained to be as high as 3.82 with the silver thickness of 60 nm, presenting 5.6 times larger sensitivity than for the gold film. However, we found that the addition of a few graphene sheets decreases the sensitivity of the silver film due to an absorptive damping process caused by graphene with a nonzero imaginary part. Nonetheless, the high impermeability of graphene could potentially to be used as a protective layer that prevents undesired oxidation of silver. More importantly, the graphene-on-silver substrates with extremely thin graphene sheets exhibited an extremely high sensitivity. The SPR imaging sensitivity was increased up to 3 times higher in detecting DNA hybridization interactions, compared to the conventional gold substrate. Considering rapid advances in fabrication techniques, we envision that true realization of a single graphene sheet attached to silver surfaces. Its applications to a sensitive SPR imaging for a number of biomolecular reactions will be readily achieved.

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