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Plasmonic Behavior in Individual Conical Silicon Nanowires of Varying Lengths

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Introduction

The study of plasmonic behavior in nanomaterials has garnered significant interest due to the unique optical properties exhibited at the nanoscale, which are critical for applications in sensing, imaging, and energy harvesting. Among the various nanostructures explored for plasmonic applications, Silicon Nanowires (SiNWs) stand out due to their unique electronic properties, ease of fabrication, and the potential for integration with existing silicon-based technologies. Silicon, being one of the most widely used materials in semiconductor industries, offers a promising platform for developing plasmonic devices. Conical silicon nanowires, in particular, have received growing attention due to their ability to support Localized Surface Plasmon Resonances (LSPRs), a phenomenon that occurs when free electrons on the surface of a conductor resonate with incident light. The plasmonic response of silicon nanowires is highly dependent on their shape, size, and structural properties, making them an ideal candidate for exploring how geometric features influence plasmonic behavior. This research focuses on the plasmonic behavior in individual conical silicon nanowires, specifically investigating how varying lengths of the nanowires impact their optical properties and resonance characteristics.

Description

The interaction between light and the surface of a nanowire leads to the excitation of surface plasmons, which are collective oscillations of free electrons that can enhance the local electromagnetic field. In conical silicon nanowires, the geometry plays a crucial role in shaping the plasmonic response. The tapered shape of the nanowire allows for a concentration of the electric field at the tip, which can lead to stronger plasmonic resonance at specific wavelengths. The length of the nanowire further influences the resonant modes that are supported by the system. Shorter nanowires may support different plasmonic modes compared to longer nanowires due to variations in the boundary conditions at the ends of the wire, as well as the collective interactions between surface electrons. These changes in the resonance behavior can be exploited to tune the optical properties of the nanowires for specific applications. By varying the length of the nanowires, researchers can gain insights into how the plasmonic resonances shift, intensify, or attenuate, which can be crucial for the design of plasmonic sensors, modulators, and other optical devices.

The plasmonic behavior of conical silicon nanowires is primarily characterized by their localized surface plasmon resonance peak, which is the wavelength at which the resonance occurs. This peak is strongly influenced by the geometry of the nanowire, particularly the aspect ratio, which is determined by both the length and diameter of the wire. Conical nanowires, by virtue of their tapered structure, exhibit a spatially varying plasmonic response, with the resonance being most prominent at the tip where the curvature is highest. The electric field at the tip of the conical nanowire can be significantly enhanced due to this geometric effect, leading to stronger plasmonic coupling and higher intensity in the localized plasmonic modes. As the length of the nanowire increases, the overall size of the nanowire becomes more significant in determining the plasmonic behavior. Longer nanowires are more likely to support multiple plasmonic modes, including longitudinal and transverse modes, depending on the specific dimensions of the wire. These different modes contribute to the complex optical response of the nanowire, and their interaction can lead to broadening or shifting of the LSPR peak.

Experimental studies on conical silicon nanowires of varying lengths have demonstrated that the plasmonic response shifts with the length of the nanowire. As the length increases, the resonance wavelength typically red-shifts, which can be attributed to the increased electron interaction along the length of the nanowire. This red-shifting behavior is similar to that observed in other nanostructures, where larger structures tend to support lower energy plasmonic modes. Conversely, shorter nanowires often exhibit blue-shifting or higher frequency resonances due to the reduced interaction length of the free electrons and a more confined plasmonic mode at the tip. The shift in resonance wavelength can be attributed to the complex interplay between the size-dependent capacitive coupling and the overall geometric factors that influence the confinement and propagation of surface plasmons along the length of the wire. Furthermore, the intensity of the LSPR can also vary with the length of the nanowire, with longer nanowires often exhibiting a more intense plasmonic resonance due to the larger surface area and the increased number of free electrons that participate in the resonance.

Another important factor influencing the plasmonic behavior of conical silicon nanowires is the surrounding environment. The refractive index of the medium surrounding the nanowire, such as air, water, or other dielectric materials, has a significant effect on the resonance frequency. For instance, if the nanowire is placed in a medium with a higher refractive index, the plasmonic resonance will typically shift to lower frequencies. This sensitivity to the surrounding medium makes silicon nanowires an excellent choice for sensing applications, as even small changes in the environment can be detected through shifts in the resonance wavelength. This property is particularly useful for chemical and biological sensing, where the binding of molecules to the surface of the nanowire can cause detectable changes in the plasmonic resonance.

The ability to tune the plasmonic response of conical silicon nanowires by varying their length offers a new degree of flexibility in the design of plasmonic devices. By precisely controlling the length of the nanowires, it is possible to engineer the plasmonic resonance to occur at specific wavelengths, which can be tailored for particular applications such as biosensors, energy harvesting devices, or even for use in photonic integrated circuits. Additionally, the strong local field enhancement at the tips of conical

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nanowires makes them attractive for enhancing light-matter interactions, which is essential in applications such as surface-enhanced Raman spectroscopy or light-emitting diodes. The increased sensitivity and tunability of the plasmonic modes with varying lengths of the nanowires further enhance the versatility of this nanostructure for a wide range of applications in nanophotonics [1-5].

Conclusion

In conclusion, the plasmonic behavior of individual conical silicon nanowires is strongly influenced by their geometric properties, particularly the length of the nanowire. The tapered structure of the nanowire leads to enhanced plasmonic resonances at the tip, and the length plays a crucial role in determining the specific plasmonic modes supported by the system. By varying the length of the nanowires, researchers can effectively tune the resonance wavelength, which opens up opportunities for designing plasmonic devices with tailored optical properties. The ability to control and manipulate the plasmonic response of these nanowires is crucial for advancing applications in sensing, energy harvesting, and other areas of nanophotonics. With further research into the behavior of plasmonic modes in nanowires of different geometries and environmental conditions, conical silicon nanowires hold great potential for the development of advanced optical and photonic technologies.

Acknowledgment

None.

Conflict of Interest

None.

References

1. Stelzner, Th, M. Pietsch, G. Andrä and F. Falk, et al. "Silicon nanowire-based solar cells." *Nanotechnology* 19 (2008): 295203.
2. Wu, Yueying, Guoliang Li and Jon P. Camden. "Probing nanoparticle plasmons with electron energy loss spectroscopy." *Chem Rev* 118 (2017): 2994-3031.
3. Rafique, Rizwan, Antonino La Magna, Antonio Mio and Salvatore Patanè, et al. "Transversal plasmon resonance observed in tapered silicon nanowires." *In 2024 International Conference on Optical MEMS and Nanophotonics (OMN)*, IEEE (2024): 1-2.
4. Puglisi, Rosaria A., Corrado Bongiorno, Sebastiano Caccamo and Enza Fazio, et al. "Chemical vapor deposition growth of silicon nanowires with diameter smaller than 5 nm." *ACS Omega* 4 (2019): 17967-17971.
5. Morral, A. Fontcuberta I., Jordi Arbiol, Joan Daniel Prades and Albert Cirera, et al. "Synthesis of silicon nanowires with wurtzite crystalline structure by using standard chemical vapor deposition." *Adv Mater* 19 (2007): 1347-1351.

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