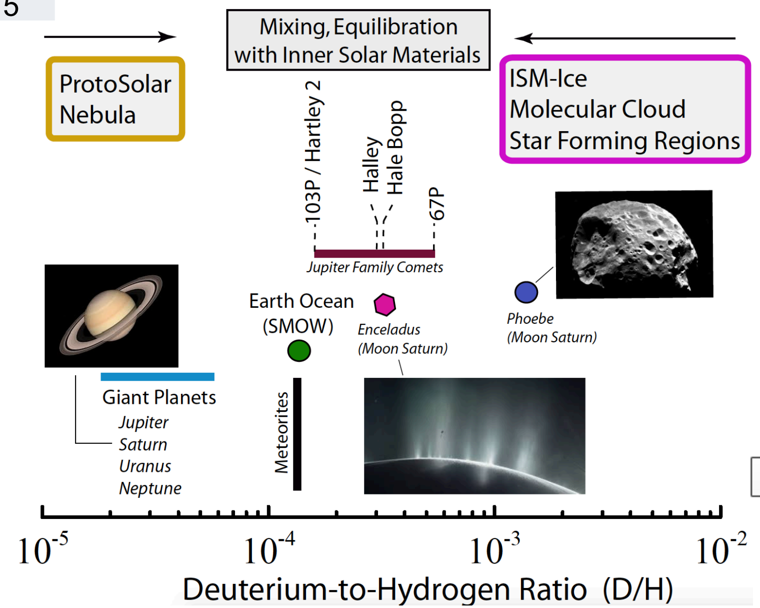
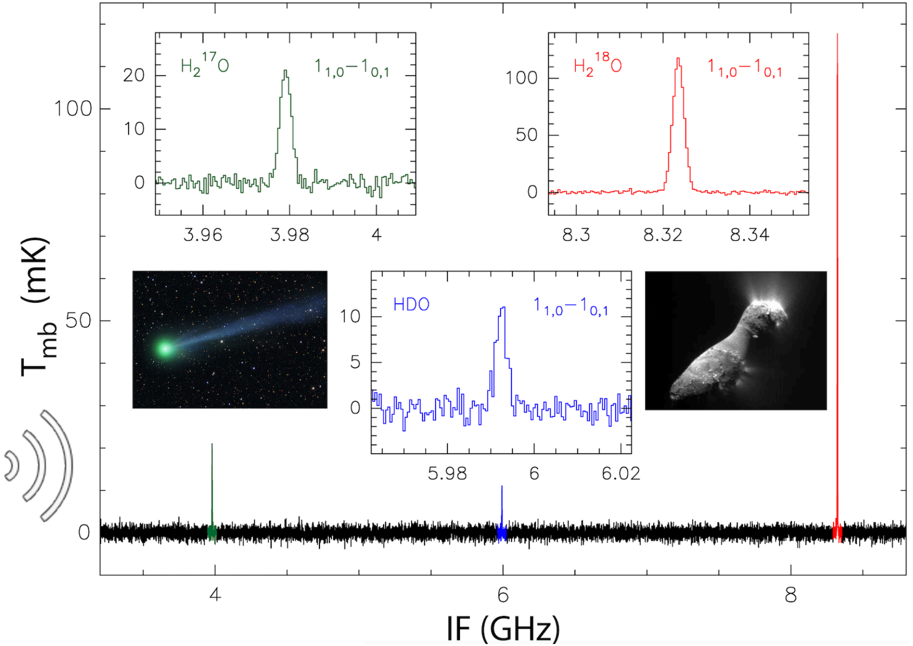
RPC-215





Virtual Research Presentation Conference

NbTiN SIS Wafer Characterization for Cometary Isotopic Ratio Determination

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Assigned Presentation # RCP-215

Program: (Spontaneous Concept)

Jet Propulsion Laboratory
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Tutorial Introduction

Abstract

Isotopic ratios provide a unique fingerprint of the origin and thermal history of water and are critical for understanding how water was delivered to the Earth and to other habitable planets. Asteroids and comets have been proposed as possible sources of Earth's water. Understanding cometary water content and isotopic composition is thus of key interest [1].

Comets are small solar system bodies that formed, and remained for most of their lifetimes, at large heliocentric distances. Therefore, they likely contain some of the least-processed, pristine ices from the Solar Nebula disk. The Herschel Space Observatory (ESA) provided for the first-time access to multiple rotational transitions of both ortho- and para-water, and its isotopoloques [2].

The primordial [D]/[H] ratio is 2.7×10^{-5} but a variety of processes affect the ratio in specific molecules. The D/H ratio of Earth's ocean water is 1.5576×10^{-4} ("Vienna Standard Mean Ocean Water"). Measurements in a dozen of comets show variations between 1 and 3 times VSMOW. However, the existing sample is small and observations of a statistically significant sample of comets, both Oort Cloud and Jupiter Family, are key for understanding the origin of Earth's oceans and its habitability. Heterodyne spectroscopy is the best technique for such studies, and the possibility of future JPL-led space missions will be enhanced by demonstration of sensitive mixers above 1 THz.

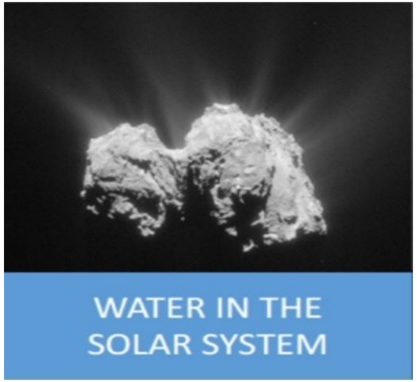

Figure 1: Comet 67P/Churyumov–Gerasimenko

Problem Description

a) Context: Heterodyne spectroscopy is the best technique for the study of primordial [D]/[H]

b) SOA: The use of silicon-on-insulator (SOI) technology combined with Superconducting-Insulator-Superconducting (SIS) NbTiN mixers offers for the first time quantum noise limited sensitivity up to 1.2 THz. The ability to demonstrate this kind of 'photon counting' sensitivity will be very enabling for the scientific community and will advance future NASA space missions.

c) Relevance to NASA and JPL: The possibility of future JPL-led space missions will be enhanced by demonstration of sensitive mixers above 1 THz.

Methodology

a) The characterization and testing of the existing NbTiN wafers consists of: 1) dicing and releasing chips from different areas of the (three) processed wafers, 2) mounting selected chips in chip carriers, 3) dipping into a LHe (4.2 K) bath, recording the I/V curves with and without magnetic field (to suppress Josephson oscillations), and 4) analyzing of the thus obtained I/V curves. Combining SEM pictures of the active device area with analyses of the I/V curves provides, normal state resistance, sub-gap leakage, gap sharpness, junction area undercut, and general statistics. With this information, knowledge of the junction specific capacitance, and electro-magnetic (em) analyses an accurate estimate of the potential performance and yield can be obtained.

b) This RTD advanced our understanding, processing, and handling of NbTiN film on SOI substrates as shown in Fig. 1 below.

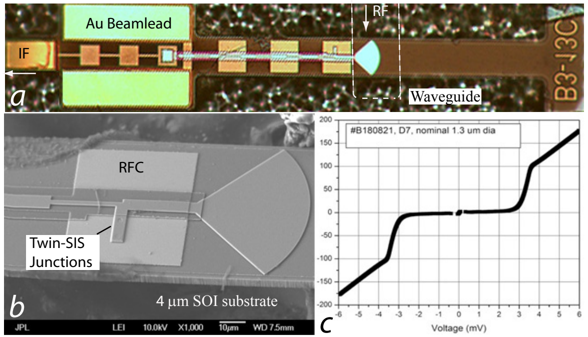

Figure 1: a) 1100-1250 GHz SIS junction, b) SEM photograph of the junction area, c) promising I/V curve from a test device on the wafer.

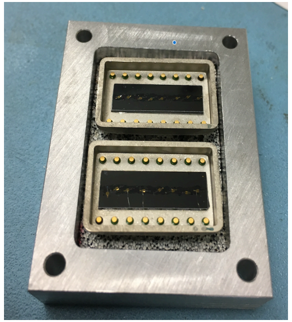

Figure 2: Chip Carrier, allowing eight I/V curves at a time to be obtained.

Results

a) Accomplishments versus goals: All existing MDL NbTiN SIS wafers were carefully investigated with wafer B190821 having both 900 GHz and 1.1 THz devices.

b) Devices from this wafer were mounted and LHe dipped. One of the important finding was that device handling was difficult. As a result considerable effort has gone into better handling methods, which includes a fundamental understanding of more optimal device geometry for future wafer runs. Hence the RTD was very valuable to identify good devices and show us the path to the future.

c) Write a Picasso to obtain follow-on funding.

Publications and References

[1] van Dishoeck, E. F. et al. Water: From clouds to planets. In Protostars and Planets VI, p. 835 (2014).

[2] Lis, D. C., et al. Herschel/HIFI measurements of the ortho/para ratio in water towards Sagittarius B2(M) and W31C. *A&A.* **521**, L26 (2010).

[3] Jacob W., Kooi, "Quantum Limited SIS Receiver Technology for the Detection of Water Isotopologue Emission From Comets," IEEE TRANSACTIONS ON TERAHERTZ SCIENCE AND TECHNOLOGY, doi: 10.1109/TTHZ.2020.3010123.