

APPLICATION NOTE

# Adhesives for Dielectric Resonator Assemblies

## Adhesive Evaluation Criteria

### Unloaded Quality Factor (Qu) Degradation

Generally, a simple figure for loss tangent is not sufficient enough to judge an adhesive, and data is seldom available at the microwave frequency of use. The adhesive's dielectric loss and Unloaded Quality Factor (Qu) of the resonator/support assembly is sensitive to the RF mode, which might be important if the adhesive is in a strong Electric field (E-field) where dielectric losses matter.

Most critical are high-Qu applications such as narrowband filters, where the DR Qu is kept high with low-loss supports and substantial distance to metal cavity walls. In this case for modes such as TE<sub>018</sub>, the dielectric loss of the adhesive between the DR and its support is very critical and dependent upon the volume of adhesive used. The interface between the support and the metal floor (if adhesive is used there) is much less influential for RF losses, because the E-field at that boundary is very low for this mode.

In less critical lower-Qu applications such as Dielectric Resonator (DR) oscillators (DROs) where only a thin substrate intervenes between the DR and RF ground, the dielectric loss of the adhesive may be inconsequential, because the DR is generally spaced fairly close to the cavity floor. In this case, the current losses in the cavity floor may dominate and result in an observed Qu that is substantially below the catalog-specified DR value. The adhesive will have minimal effect in this low-Qu case.

### Effect on Dielectric Resonator (DR) Frequency

Adhesives pull the DR frequency. It is possible for the frequency to go up or down depending upon the mode, the adhesives' dielectric constant, and how the adhesive interacts with the E-fields. The adhesive behaves as a thin spacer, with a bond line that must be process-controlled between the resonator and the support. This space is filled with a dielectric constant lower than the ceramic, and that effect must be verified experimentally.



### Differential Expansion Rates at the Bond Interface

The adhesive must accommodate the effective thermal expansion mismatch, which is a combination of the:

- Material linear expansion coefficient
- Thermal conductivity of the resonator and support materials
- Mass of the DR and support
- Heating/cooling rate

Simply matching temperature coefficients is not enough. Thermal mass is often overlooked. A thin-wall, tubular alumina support may actually expand faster in time than a more massive DR attached to it, even if the linear expansion coefficients are nearly matched. This is particularly true with large DRs used for 850 MHz to 950 MHz. Do pay attention to linear thermal expansion mismatches between the surfaces to be bonded.

The Trans-Tech, Inc. (TTI) DRs are typically in the 8 ppm/°C to 10 ppm/°C expansion coefficient range, while alumina is approximately 6 ppm/°C. An aluminum chassis expands much more at a 24 ppm/°C rate, and probably at a faster rate than the ceramic support fixed to it.

### Useful Operating (Service) Temperature Range

What is the heat resistant rating of the adhesive? Does the bond hold its mechanical strength through repeated temperature cycles? Qualification testing should be considered, including accelerated life-cycle thermal swings.

### Sensitivity to Solvents

Do surface preparation cleaning solvents leave a residue that affects bond strength? Is the adhesive bond affected by cleaning later in the manufacturing cycle? Do not assume that a cleaning step does not leave a residue.

### Cure Time

Do the parts to be joined have to be fixtured during the cure to prevent movement or to ensure bond line thickness? Parts that shift position during curing might cause electrical performance problems later, especially if concentricity of the assembly is important.

### Storage Life

Is the adhesive consumed before the shelf life expires? Are special storage temperatures required? Ensure proper storage facilities exist before the adhesive arrives on the loading dock.

### Requirements for Surface Preparation

Do the surfaces to be bonded require roughening or chemical treatment to ensure the preferred bond strength? Find out what effect this might have on the resonator's Qu. Roughened surfaces can be a disaster where RF currents flow on a metal surface and high-conductivity plating may actually aggravate the problem by accentuating the surface imperfections.

### Strength

Does the bond hold through temperature cycling and mechanical stress? TTI recommends performing tests such as shear or pull strength, and temperature cycling.

### Safety and Handling Precautions

Are ventilated hoods required? Is the adhesive or its vapors a skin or eye irritant? Are there any potentially toxic products from curing and/or excess temperature exposure? Ensure to avoid disposal ordinance problems by properly handling the empty containers.

### Bonding Small DRs

In this category, TTI includes parts that might be used at about 5 GHz and above or DR diameters 0.400 inches (10 mm) or smaller.

Loctite 499 is a popular fast-setting, which is one-part a Cyano-Acrylic (CA) type adhesive used by many commercial satellite Low-Noise Block (LNB) receiver manufacturers. TTI finds DRs are bonded directly to soft substrates such as the Rogers, Taconic, or Arlon products. In many cases, an alumina support

is bonded to the substrate, and the DR is bonded to the support with CA adhesives.

Loctite 4212 is another choice with a slightly wider temperature range. Products intended for outdoor use are typically shielded from weather with O-ring sealed construction. To locate the properties of these adhesives, contact Loctite's technical support (1-800-LOCTITE) or go to Loctite's website (<http://www.loctite.com>).

TTI recommends the Araldite General Purpose Adhesive (AW-106/HV-953) from the Huntsman Corporation, as it is much stronger than the Loctite CA series. TTI has seen araldite used to bond DRs to fosterite or alumina supports, and not even high heat breaks down the bond strength. When high heat is intentionally used for disassembly, the ceramic often cracks before the bond, possibly due to excessive mismatch in effective expansion rates.

### Bonding Large DRs

Because the DR assemblies intended for 800 MHz to ~2 GHz are massive, the CA-type adhesives may not be appropriate. Araldite, mentioned previously, is fine for ceramic-to-ceramic joints, but is not very flexible to accommodate differential thermal expansion rates, such as alumina to aluminum. If plastics are used for supports, the thermal expansion coefficient of the plastic is almost certainly many times that of the ceramic resonator.

The designer is cautioned to evaluate the bond with thermal cycling and pull/shear tests. Almost any epoxy degrades the assembly Qu and the effect is volume-related. The bond line has to be carefully process-controlled to minimize the RF losses while still preserving mechanical strength.

### Proprietary Assemblies

TTI provides assemblies of DRs bonded to supports as a service to its customers. TTI is equipped for high-volume assembly of small DRs (0.400 inches in diameter or less) to plastic or ceramic supports.

Specifically, TTI has shipped hundreds of thousands of bonded cellular radio base station DR assemblies operating in the 850 MHz through the 2 GHz range. TTI has a heavy investment in the required processes, including:

- Adhesive storage and handling
- Surface preparations
- Adhesive dispensing
- Alignment fixturing
- Curing
- Electrical and mechanical testing, including qualification tests

Generic versions of qualification test reports are available for qualified customers. TTI is keenly aware of the process control required to minimize the DR Qu degradation, while still ensuring a high-strength bond, mechanical alignment, and accuracy of the assembly's resonant frequency. The specific adhesives and processes TTI uses are proprietary to TTI.

### Disclaimer

TTI is frequently asked for recommendations regarding adhesives to bond DRs to substrates, metal cavity floors, ceramic supports, or other materials. TTI does not assume the role of adhesive consultants (except where our proprietary assemblies are concerned), but can offer a few suggestions based upon industry trends. TTI does not profess broad knowledge of adhesives technology, nor of vendors for qualified adhesives, but we do indeed have specific experience in bonding our DRs to our alumina, fosterite, and cordierite supports. Ultimately, the suitability of any specific bond must be determined for the user's particular applications.

Copyright © 2013, Trans-Tech Inc., Inc. All Rights Reserved.

Information in this document is provided in connection with Trans-Tech, Inc. ("Trans-Tech"), a wholly-owned subsidiary of Skyworks Solutions, Inc. These materials, including the information contained herein, are provided by Trans-Tech as a service to its customers and may be used for informational purposes only by the customer. Trans-Tech assumes no responsibility for errors or omissions in these materials or the information contained herein. Trans-Tech may change its documentation, products, services, specifications or product descriptions at any time, without notice. Trans-Tech makes no commitment to update the materials or information and shall have no responsibility whatsoever for conflicts, incompatibilities, or other difficulties arising from any future changes.

No license, whether express, implied, by estoppel or otherwise, is granted to any intellectual property rights by this document. Trans-Tech assumes no liability for any materials, products or information provided hereunder, including the sale, distribution, reproduction or use of Trans-Tech products, information or materials, except as may be provided in Trans-Tech Terms and Conditions of Sale.

THE MATERIALS, PRODUCTS, AND INFORMATION ARE PROVIDED "AS IS" WITHOUT WARRANTY OF ANY KIND, WHETHER EXPRESS, IMPLIED, STATUTORY, OR OTHERWISE, INCLUDING FITNESS FOR A PARTICULAR PURPOSE OR USE, MERCHANTABILITY, PERFORMANCE, QUALITY, OR NON-INFRINGEMENT OF ANY INTELLECTUAL PROPERTY RIGHT; ALL SUCH WARRANTIES ARE HEREBY EXPRESSLY DISCLAIMED. TRANS-TECH DOES NOT WARRANT THE ACCURACY OR COMPLETENESS OF THE INFORMATION, TEXT, GRAPHICS, OR OTHER ITEMS CONTAINED WITHIN THESE MATERIALS. TRANS-TECH SHALL NOT BE LIABLE FOR ANY DAMAGES, INCLUDING BUT NOT LIMITED TO ANY SPECIAL, INDIRECT, INCIDENTAL, STATUTORY, OR CONSEQUENTIAL DAMAGES, INCLUDING WITHOUT LIMITATION, LOST REVENUES OR LOST PROFITS THAT MAY RESULT FROM THE USE OF THE MATERIALS OR INFORMATION, WHETHER OR NOT THE RECIPIENT OF MATERIALS HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.

Trans-Tech products are not intended for use in medical, lifesaving, or life-sustaining applications, or other equipment in which the failure of the Trans-Tech products could lead to personal injury, death, or physical or environmental damage. Trans-Tech customers using or selling Trans-Tech products for use in such applications do so at their own risk and agree to fully indemnify Trans-Tech for any damages resulting from such improper use or sale.

Customers are responsible for their products and applications using Trans-Tech products, which may deviate from published specifications as a result of design defects, errors, or operation of products outside of published parameters or design specifications. Customers should include design and operating safeguards to minimize these and other risks. Trans-Tech assumes no liability for applications assistance, customer product design, or damage to any equipment resulting from the use of Trans-Tech products outside of stated published specifications or parameters.