Super Durable Cover Lens Film
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Scratch Resistance and Stress Strain Curves

Scratch Resistance is related to $G_{sr}$ (storage modulus) and $S_{pls}$ (Plastic Strain).

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Automotive Scratch Damage Occurrence

1. Mar - 75%
2. Rough Trough - 15%
3. Crack - 6%
4. Delamination - 3%
5. Chipping - 1%

Increasing Z Axis Force or speed
Sand Abrasion - Low z axis force

Taber Linear Abraser - Medium z axis force

A Taber Abrader - Medium z axis force

Pencil hardness - Very high z axis force
Different hard coat formulations give different rankings in tests with different z axis force. This is due to varying failure modes. High z axis forces can lead to cracking and chipping of brittle coatings. Since they have such a high modulus these same coatings can do well in a low z axis force test.

Sand Abrasion (delta haze) and Pencil Hardness (scratch width, microns)
Super Durable Hard Coat

Goal is to replace glass cover lens with a hard coated plastic lens. This will enable thinner, lighter, more durable displays.
Cover Lens Film Requirements

Needs to be glass-like in terms of
1. Abrasion Resistance
2. Appearance
3. Touch- Friction- “haptics”
4. Stiffness

But also:
1. Flexible
2. Light weight
3. Shatterproof
4. Thin
Requirement: Glass-Like Appearance

11μm Hard Coat (RI = 1.5)

3-10 mil Primed PET
Requirement: Abrasion and Flexibility

Hard Coats with improved technology can be abrasion resistant and flexible

Trends are constant however improved hard coat technology (red arrows) can shift curves
Issues with Pencil Hardness Test
1. Variability
2. Substrate Affect
3. Backside Scratches
4. Unrealistic Force Used
5. Single Pass Test
6. Doesn’t relate to Display Damage
Variability of Pencils

Fig. 14.12. Nanoindentation hardness of the whole series of pencil leads.
(Fig. 4 In “Scratch resistance of brittle thin films on compliant substrates”, Materials Science and Engineering A 493 (2008) 292–298)
Glass (and other brittle materials) dramatically lose strength when they are scratched multiple times vs. just one scratch.
The final issue is that this test is not relevant to real display damage. Despite even std. glass doing very well in the pencil hardness test in real life it gets scratched. Real damage is caused by either some type of abrasive grit (like under a cleaning cloth) or a metal object. We are investigating scratch tests that either use ScotchBright (abrasive grit) or steel (metal)
Alternative Abrasion Methods provide Practical “Real Life” Tests

**ABRASIVE PARTICLES**
(3M™ Scotch-Brite™ Heavy Duty Scour Pad, 0.25cm²)

- 4 passes – 1kg

**DULL METAL (keys, coins)**
(uses a 1.6mm steel rod)

- 20 passes - 2000 grams
Abrasion Test Comparison

Choice of Test Makes a Difference
Need a test that relates to “real life”

3M™ Scour Pad (scratches)

SiC 800 Grit (scratches)

Steel Wool (cuts)

Delta Haze

Steel wool 2000 rubs 1000 g/cm²

3M™ Scotch-Brite™ Heavy Duty Scour Pad - 100 rubs 126 g/cm²

SiC 800 grit 10 rubs 38 g/cm²
3M Hard Coat Technology Platform

3M invented the first nanocomposite hard coat over 20 years ago. Since that time we have continued to advance this technology with over 50 patents in a variety of areas. Applications include: Displays, Electronics, Graphics, Dental, Window Films, Energy, etc.

- Properties include: abrasion resistance
- Anti-smudge (Easy Clean)
- Anti-Fingerprint, Fingerprint Fading
- IR reflection
- UV absorption
- Anti-stat (controlling conductivity)
- Anti-lint (dust repellant)
- Low Reflection
- Anti-glare
- **And Now: Super Abrasion Resistance!**